The Process of Thinking and Making in the Beginning Design Studio

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ABSTRACT

Shabnam Kavousi

Based on the results of numerous studies, researchers have found that metacognition, or the ability to “think about thinking,” plays a significant role in students’ design education. Educators are increasingly focused on metacognition in design education, not only with the subject matter, but also with the development of metacognitive skills for self-regulated and lifelong learning. Since the early 2000s, there have been an increasing number of studies on the role of metacognition in education. However, there is a lack of research on the nature of metacognitive processing in design education and how metacognitive strategies develop in design students. This study focuses on the process of learning, in terms of design thinking, and specifically on the role of metacognitive learning. The purpose of the inquiry is to extend metacognitive theory to design learning and uncover the factors and influences of metacognitive thinking and learning during a student’s first year in the Design Lab. In this study, the researcher probed the students’ metacognitive ability in different design learning-tasks. The research frames metacognitive aspects of students’ learning based on evidence obtained from students while they were working in the Design Lab. The evidence is as follows: verbal description (oral or written), experiential (videos or notes about people in action) and artifactual objects of the learning process (sketches and models). The field studies utilized a constructivist paradigm to examine the various forms of thinking in action, and the actions that occur during a learning-task.

Verbal protocol analysis of video recordings of students engaged in selected learning design tasks was used to uncover the metacognitive thinking that develops during the execution of the learning-task. The researcher used a thematic data analysis process to develop an understanding of the data and identify common themes that arose from the investigation. Themes were generated through the interpretation of the data in light of the literature reviewed, the research questions, and the researcher's personal knowledge and intuition.

The cyclical process of metacognitive thinking for design students was examined based on three main categories: *Reflective process knowledge*, *reflective process monitoring*, and *reflective process control*. The research reveals that metacognitive thinking plays an important role in design idea generation and development, and is an important part of the creative process in design. As one would expect, based on metacognitive theory, the differences between high-performing and low-performing students are well explained. High-performing students focused more on metacognitive thinking, especially monitoring their design process, while low-performance students were more concerned with cognition, or doing the task.

The findings have added new knowledge to the fields of metacognition and self-regulated learning by identifying the conscious thinking process that occurs when students engage in design learning in the first year Design Lab. This knowledge will be helpful to design educators in formulating design learning-tasks for students in their labs in tandem with fully utilizing the environment of their school.

ABSTRACT (General)

Researchers have indicated that metacognition or the ability to “think about thinking” plays a significant role in the education of design students. Educators are focusing on metacognition in design education not only to improve students’ performance in design education but also to improve students’ metacognitive skills that can be utilized for self-regulated and lifelong learning. Although there have been increasing number of studies on metacognition in the past decade, there is still a need to further investigate metacognition in design education and also how to develop metacognitive strategies in design students.

This study focuses on the influence of metacognition on designers thinking and learning process. The purpose of this research is to extend the current metacognition theories to design environment and uncover the factors and influences of metacognitive thinking and learning during a student’s first year in the Design Lab. In this study the researcher used different design learning-tasks to better understand students’ metacognitive abilities, which is done by analyzing the data acquired from students while they were engaged in the Design Lab. The following types if data was acquired: verbal description (oral or written), experiential (videos or notes about people in action) and artifactual objects of the learning process (sketches and models.

To better understand students’ metacognitive thinking, they were video/audio taped as they worked on the design learning-tasks. The researcher used a thematic data analysis process to extract the common themes that existed in the data. Themes were generated by interpreting

students' actions in light of the reviewed literature, the research questions, and the personal knowledge and intuition of the researcher.

Metacognitive thinking is divided in to three main subcategories: *Reflective process knowledge*, *reflective process monitoring*, and *reflective process control.* Results indicated that the metacognitive thinking plays an important role in the generation and development of design ideas and is an important part of the creative process in design. The metacognitive theory was able to clearly explain the differences between High-performance and Low-performance students. High-performing students focused more on metacognitive thinking, especially monitoring their design process, while low-performance students were more concerned with cognition, or doing the task.

The findings have added new knowledge to the fields of metacognition and self-regulated learning by identifying the conscious thinking process that occurs when students engage in design learning in the first year Design Lab. This knowledge will be helpful to design educators in formulating design learning-tasks for students in their labs in tandem with fully utilizing the environment of their school.

DEDICATION

“It is my honor to dedicate the results of my Ph.D. study to my parents

Sohrab Kavousi & Farzaneh Pourtaghi

Whom without their support and assistance, I wouldn’t be standing here”

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As a female student who grew up in a culture where families play a big role in an individual's life, one of my biggest challenges in leaving my country to continue my education in the United States was to leave my family behind and start my life in a new environment. In life, there are many paths you can take and many people who share the journey with you but it is the special people who help you along the way, and they are the most important people who care enough to give you their unconditional love and support. I want to tell them that your love has planted a little garden in my heart and my path. You've touched my life and warmed my heart in so many ways.

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In loving memory of my uncle, Mohammd Pourtaghi Tehrani and my sister, Elaheh Jamalifard, their memory will always be with me.

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List of Abbreviations

Abbreviation	Definition
Co	Cognition
CSK	Cognitive Strategies Knowledge
CE	Control of Environment:
CPA	Control of Personal Feelings
CSA	Control of Situational Actions
HP	High-Performance
LP	Low-Performance
MC	Metacognitive Control
ME	Metacognitive Experiences
MK	Metacognitive Knowledge
MS	Metacognitive Skills
PFM	Personal Feeling Monitoring
PHY	Physical Processing
C	Reflective Process Control
K	Reflective Process Knowledge
M	Reflective Process Monitoring
SA	Self-Awareness
SAM	Situational Actions Monitoring
TA	Task-Awareness
UB	Unrelated Behavior

Preface

There is no such thing as a neutral education process. Education either functions as an instrument which is used to facilitate the integration of generations into the logic of the present system and bring about conformity to it, or it becomes the 'practice of freedom,' the means by which men and women deal critically with reality and discover how to participate in the transformation of their world (Freire, 2000, p.5).

1. Chapter: Introduction

1.1. Introduction to the Design Process of Thinking and Making

1.1.1. **Architectural design**

Design is a means of decision-making aimed at satisfying human needs (Simon, 1969) or creating novelty and future possibilities in order to bring change to human society (Reswick, 1965). The decision-making processes in other disciplines, such as engineering, or accounting, do not necessarily require creative thinking or innovative ideas. Seeking innovations and novelty is fundamental in design practice (Kung & Pui-yuen, 2008). There is no fixed, correct solution in art and design. The creative acts are open to diverse interpretations and applications. Because of the importance of the creative component, architectural design should be taught differently. Design problems are usually ill-defined and require a higher level of creativity in comparison with other problem-solving activities. Architectural design has multiple dimensions, which involves a variety of skills and thought processes like analytic reasoning, intuition, and creative expression (Powers, 2017). One dimension of architectural design is metacognition,[1] which is the main focus of this study.

1.1.2. **Teaching architectural design**

The architectural design programs at Virginia Tech have established a somewhat unique pedagogy for freshman students that in some instances goes against accepted beliefs and

[1]. In its simplest form metacognitions is defined as "thinking about thinking" (Flavell, 1976; Lawanto et al., 2013)

practices (normative theories)[2] about teaching and learning found at many other universities. For instance, students are purposely not told "*what to do.*" Questions are often answered with questions and individual exercises are not graded. The Foundation Design Lab or first year studio is the first step in the journey to becoming a designer, and has an undeniable importance in learning the principals of designing at Virginia Tech. In order to teach students to design, educators set up situations or projects that help students develop their metacognitive thinking. This starts first with the Foundation Design Lab where educators create a field in and around students as a fertile territory for learning. In comparison to other years, the design learning-tasks used in Foundation Design are purposefully more ambiguous and less pragmatic. There are fewer limitations and defined frameworks that affect the students' thinking process; thus, it is less complex and enables the student to engage in, and become better at, metacognitive thinking. Therefore, this research is concerned with understanding metacognition in the process of learning and its interaction with other forms of conscious thought-processing within the setting of the Foundation Design Lab.

People usually engage in metacognitive thinking without being aware of it. It is often done in a subconscious manner. Thus, making students aware of their metacognition can help improve their use of it in their design thinking. The purpose of this research is to better understand the role of metacognition in the learning experience of foundation design students. This was done by analyzing design behaviors and comparing high-performing and low-performing students.

[2]. *"Normative theories, as its name, are implies theories that explain and describe practices that are normally accepted and have become conventional* (Groat & Wang, 2013, p.115)".

The need for further metacognitive study is frequently identified in the research; for example, Rahman and Masrur (2011) highlighted that "*there is a need to explore the nature of metacognition through further research*" (p. 135). As Motloch (2001) highlighted, design is a versatile, nonlinear, and complex problem-solving process and as noted by Tarricone (2011), there is a lack of [metacognition] research in the context of complex problem-solving. This leads one to conclude that there is a lack of metacognition research in the area of design.

Few researchers have comprehensively evaluated metacognition in the context of design; some research has occurred related to engineering design activities (Lawanto, Butler, Cartier, Santoso, & Goodridge, 2013), instructional design and training (Clark, 1988, 2002; Reingold, Rimor, & Kalay, 2008) and architectural design (Hargrove, 2008, 2013; (Ku & Morgan, 2006)). Overall, the results from these studies suggest that metacognition improves learning and enables learners to control their thinking (Flavell, 1976; Lawanto, 2010). In this study, the researcher examines the different thought processes of design problem-solving/engagement, as it occurs in the Foundation Design Lab students.

1.1.3. **Metacognition and self-regulated learning**

Metacognition is important to self-regulated learning[3], particularly because of its interaction with other main factors in student learning, such as the acquisition of cognitive skills and the provision of an open educational environment. Self-regulated learning places a greater responsibility on the learner to become more metacognitive in the process of learning (Carson,

[3]. Self-regulated learning is a mode of learning in which students are in control of planning, monitoring and evaluating their own learning activities (Meyer et al., 2008).

2012), which empowers designers to succeed by making them more aware of their learning processes. Metacognitive skills can be used to facilitate self-regulated learning.

Carson emphasizes the importance of assisting learners not only with subject content, but through developing metacognitive skills for self-regulated learning and lifelong learning. It is a significant goal of educational systems to provide students with a learning environment and learning experiences that help them to develop the abilities for lifelong learning (Carson, 2012). Metacognition is an essential first step in developing lifelong learning, which further emphasizes the importance of this research. In this way, learners are required to be capable of controlling their own learning through the control of their cognition[4], motivation, and actions, for successful, and effective learning. In this study, the researcher demonstrates how different metacognitive processes in design problem-solving can lead to different results, and what the conditions are that will lead to successful designs.

1.1.4. **Creativity and metacognition**

Daniel Pesut[5] (1984) emphasizes the importance of developing creative-cognitive thinking skills in students, especially design students, in order to give them an understanding of their creative thought processes and enabling them to self-regulate their creative thoughts. He has conceptualized creativity "*as a self–regulatory metacognitive process.*" He defines creative thinking as "*a synthetic metacognitive process—of generating novel and useful associations, attributes, elements, images, abstract relations or sets of operations—that better solves a*

[4]. Cognitive processing or cognition is as an action that will lead to learning; thus, engaging in activities such as "making models," or "sketching" can be described as an act of cognition (Carson, 2012).

[5]. Daniel Pesut is the Director of Katharine J. Densford International Center for Nursing Leadership and a Professor of Nursing at the University of Minnesota.

problem, a plan, or results in a pattern, structure, or product not clearly present before (p.15)." The role of metacognitive thinking in design has been identified as an essential ingredient of creative thinking (Sternberg & Williams, 1996). A designer can improve creativity by focusing on metacognitive thinking. Metacognitive research (Brown, 1978 and Flavell, 1979) has a significant role in psychology in the area of teaching creativity (Lawson, 1979), and in the analysis of problem-solving and thinking. Teaching design students to think about their own cognitive processes in a systematic way may help them manage creative thought processes. This way of thinking may provide designers with an understanding of when, where, and why to use specific thinking strategies or cognitive approaches. Although there have been numerous research studies, the area is still not completely understood. There is a clear lack of research, especially in the area of metacognition in learner-centered environments. Thus, there is a need for educationally situated, applied research to further our understanding of the role of metacognition and resulting the self-regulated activities in design student learning.

This study is focused on the interaction between the personal reflections of students, their corresponding actions, and the rationale for those actions that occur during design decision-making. Accordingly, the role of metacognition and self-regulated learning in fields that require creative problem-solving will be addressed in this study. This dissertation will provide a practical theory that can help educators enhance student metacognition, and thus learning.

1.2. Background

Little has changed since the 1950s in regard to the model of education in many disciplines such as engineering, math, and biology. This model of education supports large classes and single-discipline delivery through lectures; which is different than the model used in architectural design. These two models of education can be categorized into "teacher centered" and "learner centered" models of education. The latter model encourages students to develop their own knowledge and understanding within the limits set by the teacher, using planned activities and some guidelines to break students' prescriptive habits. "Learner centered" education changes the role of students from passive recipients of knowledge to active participants in the process by which they acquire knowledge.

Learning as an interactive process is an important issue in architectural design education. In architectural design education, the curriculum is structured to facilitate student learning. In this sense, the program provides courses that are interrelated and reinforced throughout the architectural design curriculum.

Learning how to design can be a frustrating and confusing process that may be difficult for students to understand. In spite of employing a range of strategies for teaching design, the failure to grasp the process of designing can challenge a student's willingness/ability to stay motivated and actively engaged in design projects (Powers, 2017). Research has revealed that students who are unaware of their metacognition do not achieve their full potential, which in turn will result in less than optimal learning. John Dunlosky[6] and Janet Metcalfe[7], (2009) in their book "*Metacognition*" state that metacognition can significantly improve students' problem-solving success by addressing many of the fundamental issues associated with poor student performance in the lab (goal setting, motivation, monitoring) (Matanzo & Harris, 1999).

[6]. John Dunlosky is an author and an Associate Professor of Psychology at Kent State University with a special interest in self-regulated learning

[7] Janet Metcalfe is Professor of Psychology and Neurobiology and Behavior at Columbia University with a special interest in human learning

Although in the last three decades, design theoreticians and educators such as Dorst, 1997; Lawson, 1994, 2006; Schön, 1984 have become interested in the teaching methodology used in design and identifying the best educational methods in order to achieve the desired learning outcomes, but little research has been done to study the effectiveness of metacognition in Design Lab settings. This study focuses on metacognitive thinking of students while engaged in design learning-tasks. In the Foundation Design Lab in the School of Architecture + Design, at Virginia Tech; the intent of the education process is to teach students to think critically and freely about their design learning-tasks, which makes it an ideal setting to acquire the data used in this research.

1.3. Purpose of the Study

Design is a complex activity, and there is no single universally agreed upon method of learning design and creativity. In this study, the researcher focuses on the "process of learning," both in terms of design making and design thinking, specified as metacognitive learning. The research examines metacognitive thinking while engaged in design to help better understand students' learning, which can potentially lead to improved pedagogy, which would benefit both students and educators. In this study the researcher utilized substantive[8] and procedural theories[9] to better understand students' thought processes while engaged with design tasks. The body of knowledge which resulted from this study, can enhance design education and practice.

[8]. Substantive theory explains the nature of the phenomena with which designers have to deal with while working (Lang, 1987).

[9]. Procedural theory is concerned with the nature of praxis in the design fields (Lang, 1987).

1.3.1. Research objectives

The objectives of this study are to understand metacognitive thinking, which takes place during architectural design learning (reflective practice) in typical Foundation Design Lab assignments, and the condition that leads to the development or change in student metacognition thinking in Design Labs. This research will also develop the fundamental components and the configuration of a coherent model of metacognition in the domain of reflective practices while engaged in design tasks in the Foundation Design Lab (first year). This will result in a hierarchical model of metacognitive activities for "reflection in action" practices in design domains. The researcher intends to merge theories and concepts from design education, educational psychology, and other fields to develop practical theories that can serve as an interactive model about individual differences leading to the successful process of metacognition and learning. Understanding metacognitive process in Foundation Design activities has merit because the information gained should provide a valuable result for professors regarding confusion and agonizing obstacles that students experience during their problem-solving, and thus benefiting students, faculty, and curriculum developers.

1.3.2. Research questions

To achieve the above, the study examines students' metacognitive ability in defined design learning-tasks. To do this, a set of research questions related to metacognition, and students' learning and performance on Lab projects were used to guide the research and maintain the focus of the study:

- What metacognition activities take place during architectural design learning (reflective practice)[10] in typical Foundation Design Lab exercises?
    - What are the metacognitive thinking processes that design students use to engage a design learning-task?
    - What are the effective conditions in metacognitive design problem-solving?
    - How do metacognitive thinking and actions influence students' design learning?

1.4. Foundation Design Lab in the School of Architecture + Design at Virginia Tech

To familiarize the readers with the settings in which this study took place, in this section a brief description of the Foundation Design Lab is provided. The Foundation Design Lab in School of Architecture + Design at Virginia Tech plays a very important role in helping students become members of the architecture profession. As potential design students progress through their pre-university education, they become very good at following recipes, "*tell me what to do and I will do it well*" (Kavousi & Miller, 2014, p. 2550). However, learning design is not prescriptive; when it comes to learning design, there is no recipe. Hence, the Foundation Design Lab employs a prospective approach in which the requirements of the final design are indicated but students are not constrained in the techniques they use, or the order in which tasks are completed. In other words, design is performed in a result-oriented environment by not limiting the designer on how to solve the problem, rather by what the solution should be; designers are usually free to use whatever approach they desire. By focusing on finding a solution, the prospective approach emphasizes the role of students in the learning process. The design learners actively

[10]. Reflective practice is a method of approaching design where each problem is considered a unique problem that requires a unique solution (Schön, 1984).

and constructively engage in a process of generating meanings, and in order to affect their learning and motivation they are constantly adapting their thoughts, feelings, and actions as needed.

The Foundation Design Lab is considered beyond a classroom, but rather a learning community made up of faculty and students. The Foundation Design Lab in the School of Architecture + Design at Virginia Tech had about 206 students and 10 professors during the Fall of 2016. All first year architecture, industrial design, interior design, and landscape architecture majors study together in the Foundation Design Lab. The focus of the Foundation Design Lab is not on any of the professional disciplines. Rather the focus is on basic elements of design. They are addressed visually and conceptually in two and three dimensions through the application of different materials and tools. Students cultivate artistic judgment and a means of self-evaluation through a variety of design exercises with the objective of developing the essential design skills necessary to the four disciplines. The Foundation Design Lab is the first step of a long process of becoming a professional designer (Kavousi & Miller, 2014). The students are taught at levels of gradually increasing difficulty (spiral curriculum). The concept of the spiral curriculum involves information being structured so that for some complex activity like design, ideas can be taught at a simplified level first, and then re-visited at more complex levels later on. In the Lab, students start with the simplest form of exercises and move along the spiral constantly repeating same process in different and more complex situations (Kavousi & Miller, 2014; Takaya, 2008). Ideally teaching this way should lead students to be able to solve problems by themselves (Takaya, 2008). Instead of defining a traditional approach with its specific boundaries and limitations, the Foundation Design Lab helps students to think critically, choose and develop their own framework without questioning commonly accepted frameworks, and it encourages them to explore in different ways and based on a variety of different resources, not simply relying on their professors. As a result, each individual in the Foundation Design Lab will gain their own identity, which is both further integrated and further defines their course of engagement in practice (Kavousi & Miller, 2014). This learner-centered method encourages students to take responsibility for (i.e. construct and defend) their own knowledge and understandings, although usually within the context of planned activities and some degree of teacher guidance. Bruner (1996, P.87), referred to this process as "*taking control of your own mental activity*". There are also some tenets followed by professors in the Foundation Design Lab, such as answering questions with questions and not simply telling students what is wrong with mediocre design work, but praising good design work.

1.5. Limitations of the Study

This study has two limitations. First, participants were selected from a top-ranked architecture school[11] where students with high GPA and SAT scores from around the country apply and are admitted (relatively homogeneous population). Second, the architecture program employs a unique pedagogy, therefore transferability of the results beyond this sample should be made with caution. The learning-tasks used in this study were developed with the help of experienced Foundation Design instructors. The pedagogical requirements of the program necessitate learning-tasks for the first year students to be purposefully more ambiguous and

[11]. According to Design Intelligence's annual report on "*Best Architecture & Design Schools 2016*," Virginia Tech's undergraduate Architecture program is ranked 3rd nationwide (DesignIntelligence, 2016).

less pragmatic, and thus the results cannot be generalized to all learning-tasks in all design disciplines.

1.6. Structure of the Thesis

This study is structured in six chapters. This section intends to provide readers with an overview of the structure of this dissertation. Chapter 1 discusses the purpose of the study, including the background of architectural education, and research questions and objectives. In Chapter 2, a review of the literature needed to understand this research is provided. The literature review chapter has been divided into three sections. The first section summarizes the important literature regarding architecture education, the second part discusses literature regarding metacognition and related topics, and the third section provides the literature related to the methodology that was used in this research. Chapter 3 is divided into three main parts and provides a detailed description of the design tasks given to the students, the data collection method, and the reasons why the Foundation Design Lab was selected for the study. In Chapter 4, the process that resulted in the development of the theoretical framework is described. In Chapter 5, the results of the study are provided, along with discussions regarding the outcomes. In Chapter 6, a detailed discussion regarding the results is provided, and discussions is provided in terms of answers to the research questions posed for this study. Chapter 6, also provides the researcher's suggestions regarding the implementation of the results and future studies in relevant fields.

2. Chapter: Literature Review

2.1. Introduction

The focus of this dissertation is metacognitive thinking and learning within the field of architectural design. An understanding of the present literature, as well as trending research in the area of architecture lab learning and teaching is necessary to conduct this study. The reviewed literature can be divided into three categories:

1) Two examples of architecture education and how they are different from education in other disciplines

2) Theoretical definitions of metacognition and the importance of metacognition in education

In this regard, relevant constructs in the literature are described. After studying each topic in separate sections, their relationships are discussed with a focus on the impact of metacognition on students' problem-solving abilities.

3) General theoretical context of grounded theory and qualitative method to justify the methods used for the collection and analysis of the data (Figure 1)

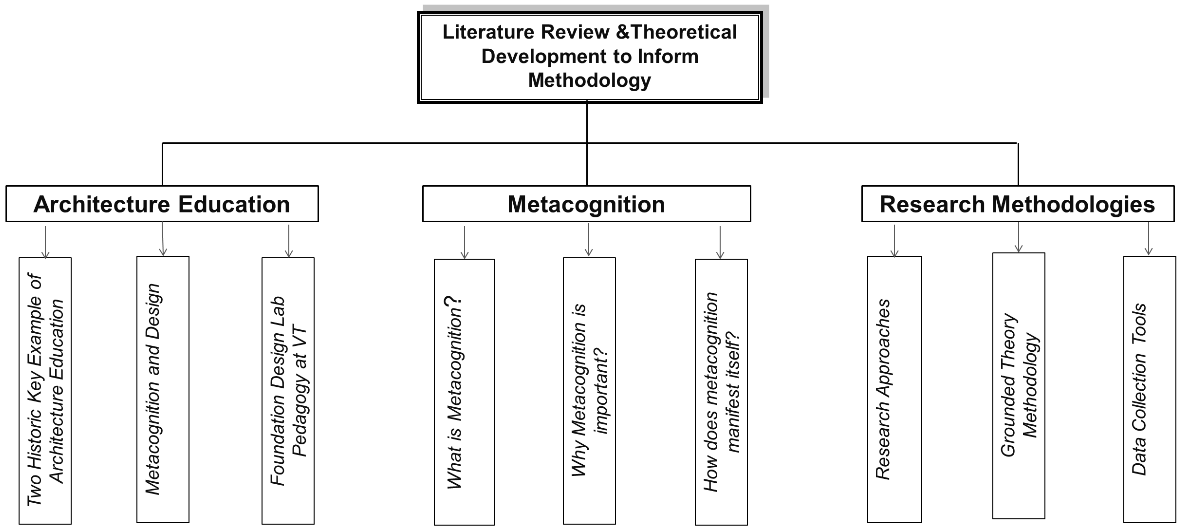

Figure 1. Conceptual background of the research

2.2. Architecture Education

One objective of architecture education is to provide a foundation that enables students to think comprehensively in order to contribute effectively through design in the complex, post-industrial world. Educational leaders recognize that understanding the way individuals learn is key to educational improvement (Demirbas & Demirkan, 2003). Design educator Nigel Cross (2011) states that, *"Education is not only development of knowledge but also about developing ways of thinking and acting"* (p.140). Moreover, educational experts Boyer and Mitgang (1996) emphasize that for design education to function effectively, students must become active participants in their own learning. The researcher asserts that this can be achieved through metacognition.

The first step in investigating architecture education is to review its history. Therefore, in this section, a limited, yet cross-cutting historical context of architecture education is examined. Then, since Virginia Tech's Foundation Design Lab constitutes the introductory phase of architecture education, it is also the focus of this research. Thus, the educational approach of the Foundation Design Lab is described. In the final part of this section, the influence of metacognition in design is explained.

2.2.1. The historic key context of architecture education

Although, architecture education can be traced back to Plato in the 4th century, this is not the focus of this research. Only the schools of thought that are relevant to the current practices in architecture education are discussed in this section. In the United States, architecture and its education have been greatly influenced by that of Europe (Mahmoodi, 2001). Because of this influence, the researcher will first describe two key primary architecture education practices in Europe and then indicate how these educational approaches were used to inform current architecture education systems in the United States.

To understand Virginia Tech's School of Architecture + Design's educational model, it is important to understand its historical roots. In this section the educational practices of two historically important European Architecture schools are provided, Ecole des Beaux-Arts in Paris as reorganized in 1863 and the Bauhaus school in Germany established in 1911. The selection of these schools is based on two reasons. First, according to Powers (2017), these two schools influenced the architecture education system of the United States more than others. The second reason is that these two schools represent two different approaches to architecture education, which are regarded as key precedents to architecture education in the United States.

The Bauhaus can be regarded as an institution with a more open-ended design focus, while the Ecole des Beaux-Arts had a more master-centered, composition oriented pedagogy. Similar to Virginia Tech's pedagogy, the Bauhaus was also influenced by the child development theories of educational reformers and thinkers, Montessori and Pestalozzi, who put the student at the center of the educational process (Cross, 1983). The researcher believes that the underlying idea of the School of Architecture + Design at Virginia Tech is based on nurturing and supporting metacognitive thinking. This could be because the professors that teach students at Virginia Tech or because the pedagogy has been built based on the ideas of Montessori and Pestalozzi. This dissertation is not going through a lengthy review of the program's educational history and reforms, yet a brief discussion is necessary because of their importance to Virginia Tech's pedagogy.

Johann Pestalozzi (1746-1827) implemented his education theory at a school that he founded in Yverdon, Switzerland in 1805. Pestalozzi's educational theory was based on Rousseau's ideas that learning should be done through activity, free from the constraints of traditional education systems, and learning by discovering instead of being instructed (Smith & Knapp, 2011, p.29). Maria Montessori (1870-1952) developed her educational theory by combining the ideas of educational thinkers Friedrich Froebel[12], Jean Marc Gaspard Itard[13], Dr. Edouard Seguin[14], and Giuseppe Sergi[15] (Smith & Knapp, 2011). Montessori emphasized the

[12]. Friedrich Wilhelm August Fröbel (1782 – 1852) was born in Germany. He was Pestalozzi's student and a pedagogue and laid the foundation of modern education. His most prominent work is the establishment of Kindergarten as a place to nurture children's education.

[13]. Jean Marc Gaspard Itard (1785 – 1838) was a French physician, he developed theories for the education of children with special needs.

[14]. Edouard Seguin (1812 – 1880) was a French physician and educationalist who worked under Itard and is most famous for his theories on the education of students with cognitive disabilities.

importance of the learning environment, and creating learning communities in the classroom. She believed that the learning environment is as important as the learning itself. Montessori's method is based on multiple principals: 1) the teacher should pay attention to the learner and not the other way around, 2) the pace of learning should be controlled by the learner, 3) educators are responsible for the learning environment, and 4) learners should be allowed to make mistakes and learn from their mistakes, "*teach by teaching, not by correcting*" (Smith & Knapp, 2011, p.201).

2.2.1.1. ***École des Beaux-Arts***

The École des Beaux-Arts, or the school of fine arts, was established in 1648 in Paris. The School was reorganized in 1863 to a campus-based architecture education system. Prior to the mid-19th century, architecture education was based on the apprenticeship model in which students of architecture were trained by working alongside practicing architects in their studios (Boyer & Mitgang, 1996).

The emphasis in the Beaux-Arts education philosophy was on the traditional aspect of architecture. Students' architecture education training was based on students' interaction with an architect, the atelier-master. The student had the role of an apprentice working in the office of the architect, the master, which gave the central role to the teacher (teacher-centered education system) (Powers, 2017). Beaux-Arts' architecture education system also emphasized the compositional aspects of many architectural designs rather than the technical aspects of making architecture by prioritizing precedence rather than student creativity. An example of

[15]. Giuseppe Sergi (1841 – 1936) was an Italian anthropologist and Professor at the University of Rome

this in the Beaux-Arts is that a significant part of learning was drawing classical orders and ornaments (Cho, 2011).

The essence of the Beaux-Arts' education system can be represented by prescription, competition, and fixed repetitive assignments (Carlhian, 1979). In Beaux-Arts, architecture students did not have control over the course type and content, or the number and kind of assignments, but they were free in selecting their studio master, and the order and sequence of courses. Also, the school did not require any academic prerequisites for entrance eligibility. The atelier master was a practicing architect with his own practice and visited the studio once a week. Thus, students generally sought help from more senior students in the studio (Carlhian, 1979). In the Beaux-Arts' method of teaching, students first learned by constructive criticism of their designs, and then by observing and taking inspiration from the suggested solution to the problem that the master had created as an example (Weatherhead, 1941). As well, the Beaux-Arts' system promoted competition between students as a means to compare students, which emphasized final productions rather than processes (Powers 2017).

2.2.1.2. ***The Bauhaus***

The Bauhaus school was developed in 1911 in Weimar, Germany by Walter Gropius who was an architect. Bau in German language means to build or building. The name can also be traced back to the Medieval term 'Bauhütten' (Whitford, 1984). The name Bauhaus was coined by Gropius to be, a "house for building, growing, nurturing" (Dempsey, 2002). Bauhaus belongs to the modern period and has greatly influenced architecture education in the United States, and Virginia Tech's Design Lab culture (Power, 2017). The great impact of Bauhaus in the U.S. is mainly because many of the school's professors fled Nazi Germany and became professors in prominent U.S universities. Gropius and Marcel Breuer landed in Harvard's architecture school; Mies van der Rohe would lead the Illinois Institute of Technology, and Joseph Albers at Black Mountain College in North Carolina and Yale University (Cho, 2011). Gropius's pedagogy and emphasis on modern technology and mass production dominated the Bauhaus education system (Anthony, 1991). Gropius believed that the underlying fundamental of all design disciplines was the same, and teaching history of architecture did not nurture students' aesthetic abilities, so he refused to include it in the Bauhaus's curriculum. The Bauhaus's education system was based on an art-technology axis so Instead of teaching the history of architecture, the education system focused on teaching color, composition, and Gestalt theories[16] (Cross, 1983; Salama, 1995).

Unlike Beaux-Arts, Bauhaus's objective was to teach art and crafts. Media-based workshops were a significant part of the curriculum in the Bauhaus. Gropius believed that the "craft" (using industrial machines) should be engaged before the architecture courses (Broadbent, 1995). According to architectural educator Ji Young Cho (2011), the most significant differences between Bauhaus and Beaux-Arts in teaching architecture were that, the Bauhaus had:

- An education system where students had a larger role in their own education
- Students were evaluated based on their process and not the product

[16] . Gestalt theorists challenged the fact that the new concepts are not simply recombining old ideas; instead, they possess a larger relative value as compared to the old ideas (a whole that is greater than the sum of its parts) (Schön, 1963).

The objective of a Bauhaus education was to emphasize the importance of craft in architecture as much as the art. The slogan coined by Gropius was *"art and technique as a new unity"* (Weatherhead, 1941, p.179).

Bauhaus's education system was divided into three stages. The first stage was the preparatory classes, such as form and composition, and practical workshops. The main focus in the second stage was on technical courses like model building, training, and building construction lectures. The final stage focused on architecture and construction through courses like design studio, and lectures on steel and reinforced concrete (Weatherhead, 1941). Figure 2 shows a schematic view of Bauhaus's education model. These three stages can also be recognized at Virginia Tech's School of Architecture + Design. In the first year students have the foundation labs and workshops on new materials and preliminary courses like the study of color, which is similar to the first stage at Bauhaus. In the second and third years, students take classes on subjects focused on materials and construction technologies, which is a combination of the second and third stages at the Bauhaus. The final stage at Virginia Tech is the synthesis of everything that students learn through the five-year professional degree curriculum, which is somewhat different from the final stage of the Bauhaus.

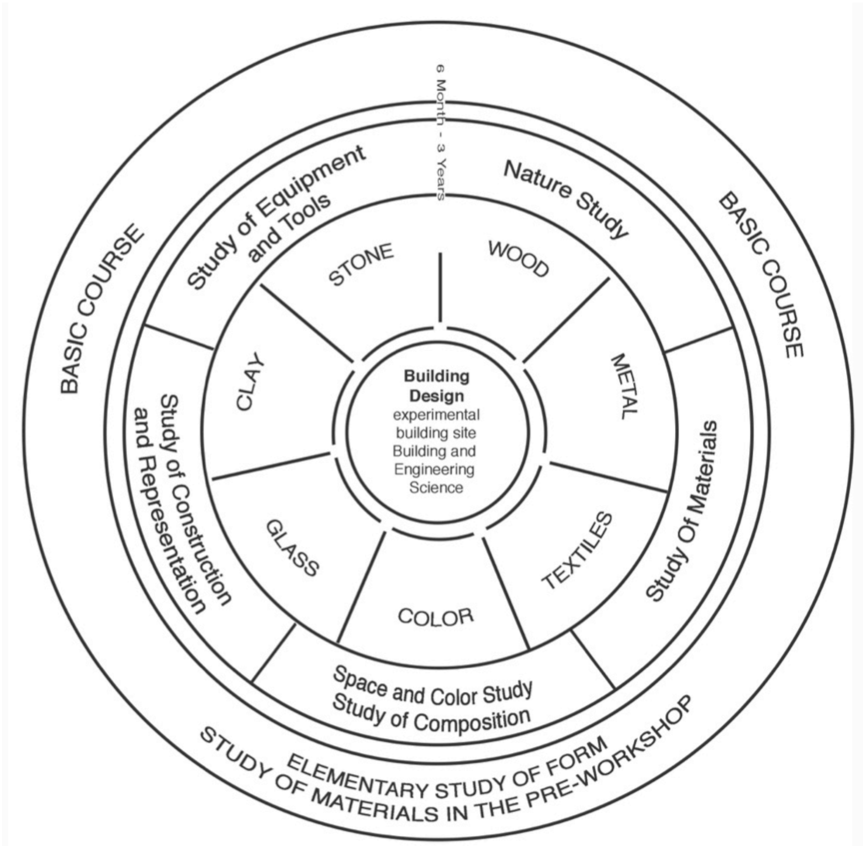

Figure 2. Gropius, 1923 Bauhaus Curriculum. Adopted from Design and Form: The Basic Course at the Bauhaus and Later (p. 8), by J. Itten, 1967, New York City, NY: Wiley. Copyright 1975 by Otto Maier Verlag.

Eight years after the Bauhaus established itself in Weimar, politics forced its relocation to Dessau, and after that to Berlin. The school was forced to close in 1933. The closing of the school was a major factor that contributed to the immigration of many of its educators to the United States.

2.2.2. **Current architecture education practices in the United States**

The Bauhaus ideas of "*craftsmanship, aesthetic logic, appreciation of the properties of materials, and an aesthetic that derived from the exploration of geometric forms,*" formed a foundation of U.S. architectural education (Boyer & Mitgang, 1996, p.16-17). Although the architecture education system in the United States was originally influenced by the European schools (Bauhaus and Beaux-Arts), as time passed it deviated from the European schools and developed its own character (Mahmoodi, 2001).

According to design educator, Kees Dorst, the deviation from the European education system can be attributed to the work of Herbert Simon (1916 – 2001)[17] and Donald Schön (1930 – 1997), who were the major forces behind identifying two distinct methods of design thinking. Simon promoted the rational problem-solving method, and Schön was the proponent of reflective practices in design education (Dorst, 1997).

2.2.2.1. ***Rational problem-solving***

At the beginning of the 1970s, Simon published his influential book "*The Sciences of the Artificial*" introducing the idea in which design was perceived as a process of rational problem-solving. This paradigm considers design as a process of rational search (Simon, 1969). In the rational problem-solving process, the problem space, which is to be surveyed in search for a 'satisficing'[18] design solution, is defined by the design problem. Adopting natural sciences, like physics, as the model for the science of design as well as the adoption of a positivistic dimension of science are the ways through which design can be seen as a process of rational problem-solving. The rigor of design research is being emphasized; it should be objective with the logical analysis and observation leading to formal and general models of the design process (Dorst, 1997, p.204).

[17]. Herbert A. Simon was an American political scientist, economist (winner of the 1978 Nobel Prize in Economics), sociologist, psychologist, and computer scientist at Carnegie Mellon University.

[18]. The word 'satisficing' is a combination of the words satisfying and suffice; in terms of design decision-making it refers to a decision that is not the best possible decision but it satisfies the design problem, it is "good enough" (Simon, 1969).

2.2.2.2. ***Reflective practices***

More than fifteen years after the Simon paradigm, Schön's book, "*The Reflective Practitioner*," proposed a fundamentally different paradigm in which he proposed design as an reflective activity. This radically different constructionist theory was propounded as a reaction to the problem-solving approach with the aim of dealing with the perceived limitations of conventional design methodology (Schön, 1984). Schön's approach is against design training programs that generalize the processes of design. He notes that every problem is unique and therefore should be approached accordingly, rather than using general design processes. Thus, it is important for a designer to understand every problem and how it should be approached. In his view, creating a problem from a problematic situation is the first step in finding the solution. Schön identifies the ability to determine how a design task should be approached as a core skill that designers should possess. Schön calls this "the artistry of design practice"; he identified the failure of the previous analytical framework to describe this as one of its limitations. He believes that the systematic approach to design only works if the problem is ill-defined. A description of design as a "*reflective conversation with the situation*" was therefore provided by Schön as an alternative epistemology of design practice serving as a means of dealing with unique problems (Dorst, 1997; Schön, 1984).

The constructionist view of human perception and thought processes is the guiding principle of Schön's theory. Here designers construct their own worldview according to their experiences, which is gained by the implementation of "move-testing experiments" (involving action and reflection) (Schön, 1983, p.146). The major constituents of design activities in this paradigm are actions and the ability to make informed choices alongside intelligent decisions.

In this paradigm the most important thing is to be able to make intelligent decisions about the actions. The designer should also be able to evaluate the outcome(s) of the experimental actions as well as react to the outcome(s). The important factors related to the situation are named by the designers in this "*reflective conversation with the situation*" in order to frame a problem in a specific way while making efforts to come up with a solution; the designer must also evaluate the actions taken towards solving the problem (Dorst, 1997).

Schön argued that this new paradigm is the foundation of a typical design methodology while criticizing the technical rationality of the previous paradigm. He posits that the design methodologists that adopt this paradigm limit themselves to general principles of design processes. He said in this paradigm, little emphasis is placed on the design structure, an important task of linking process and task in a real life design situation. In Schön's opinion, all design tasks are unique. To him, the framework for analysis of the first paradigm fails to give a detailed explanation of the practice of design. With this, he regrets that professional institutions don't teach solving unique design problems and the artistry of design practice (Schön, 1984).

2.2.3. **Architecture education at VT**

A quick review of the history of Virginia Tech's School of Architecture shows how it was influenced by the education system of the Bauhaus. In 1928, Architecture was taught at Virginia Tech as Architectural Engineering by Clinton Cowgill. Leonard Currie became the head of the architecture department in 1956. Currie, who graduated from Harvard, came from the architecture office of the Architects Collaborative (TAC), established by Walter Gropius. Both

Gropius and Marcel Breuer, who was his protégé, moved to Cambridge, Massachusetts, to teach at the Harvard Graduate School of Design. Currie was a student of both and later worked alongside Walter Gropius at TAC. Charles Burchard who is known as the founding dean of Virginia Tech's College of Architecture was also Walter Gropius' student at Harvard University (Kavousi & Miller, 2014). Charles Burchard brought new faculty to the school. Among those was Olivio Ferrari. Ferrari had been both a student and faculty at Ulm with Max Bill who devised the school and the educational program. Bill was a graduate of the Bauhaus. Burchard and Ferrari collaborated on this shows the path that connects the School of Architecture + Design at Virginia Tech to the Bauhaus and indicate how it could be influenced by many educational tenets of the Bauhaus.

The student-centered education system of the Bauhaus strongly influenced the education system of Virginia Tech, however one sees the student taking a differentiated role. Today, students are more in control of their education, which also means that they are more responsible for their education. In this method of education students, are perceived as reflective practitioners.

This study is therefore guided by the perspective, which describes design as a reflective practice whereby the problem-solving decisions made by the designer are based on his/her ability to understand the design task and being able to find a solution that will solve the problem of the given situation, rather than just employing general design guidelines. Against this backdrop, four important issues (designer, task, design process, and design knowledge) are discussed in the refection in action process.

2.2.3.1. *The designer in reflective practice*

The widely known paradigm of constructionism forms the basis of design as reflective practice (Schön, 1987). In the epistemology of constructionism, perception is described as a process that involves the active construction of a worldview. The world of the subject is affected by the reality of the existence of an objective only to a limited extent. Based on his analysis of Schön's work, Dorst asserts that in a constructivist paradigm[19] the world being constructed is affected by the way the subject perceives the world. This involves the situation at hand as well as the goals that the subject intends to achieve while constructing this personal world. A valid understanding of human behavior is only possible when this personal constructed worldview is considered (Dorst, 1997).

2.2.3.2. *The tasks in reflective practice*

The theory of technical rationality is developed based on the assumption that the design problem is clearly established. Schön(1983) states that:

> *'…Although Simon proposes to fill the gap between natural sciences and design practice with a science of design, his science can only be applied to well-formed problems already extracted from situations of practice…' (p.47).*

On the other hand, Schön makes no assumption regarding the design problem, but rather emphasizes design as a reflective conversation, which is greatly influenced by the designer's structuring role, and his/her ability to develop tasks alongside possible solutions; this is done in one framing action. In reflective practice, there is no standard method of determining what

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[19]. Constructivist paradigm, which is a learning philosophy, should not be mistaken with Constructivist architecture which was form of modern architecture.

technique is more suitable for a design task because design tasks can be sub-divided and analyzed in several ways. Thus, the design task and solution go hand-in-hand and must be developed together (Dorst, 1997; Schön, 1983).

2.2.3.3. ***Design process in reflective practice***

The rational behavior of designers is reflected in the way they assign names to the design task and the design solution, and afterwards frame the design task together with the solution. This process is influenced by how the designer perceives the design task and design situation. The description of design as being locally controlled is the metaphor of "reflective conversation'" whereby people take actions and evaluate their actions while considering other factors with the immediate problem-solving value (Schön, 1992, p.4).

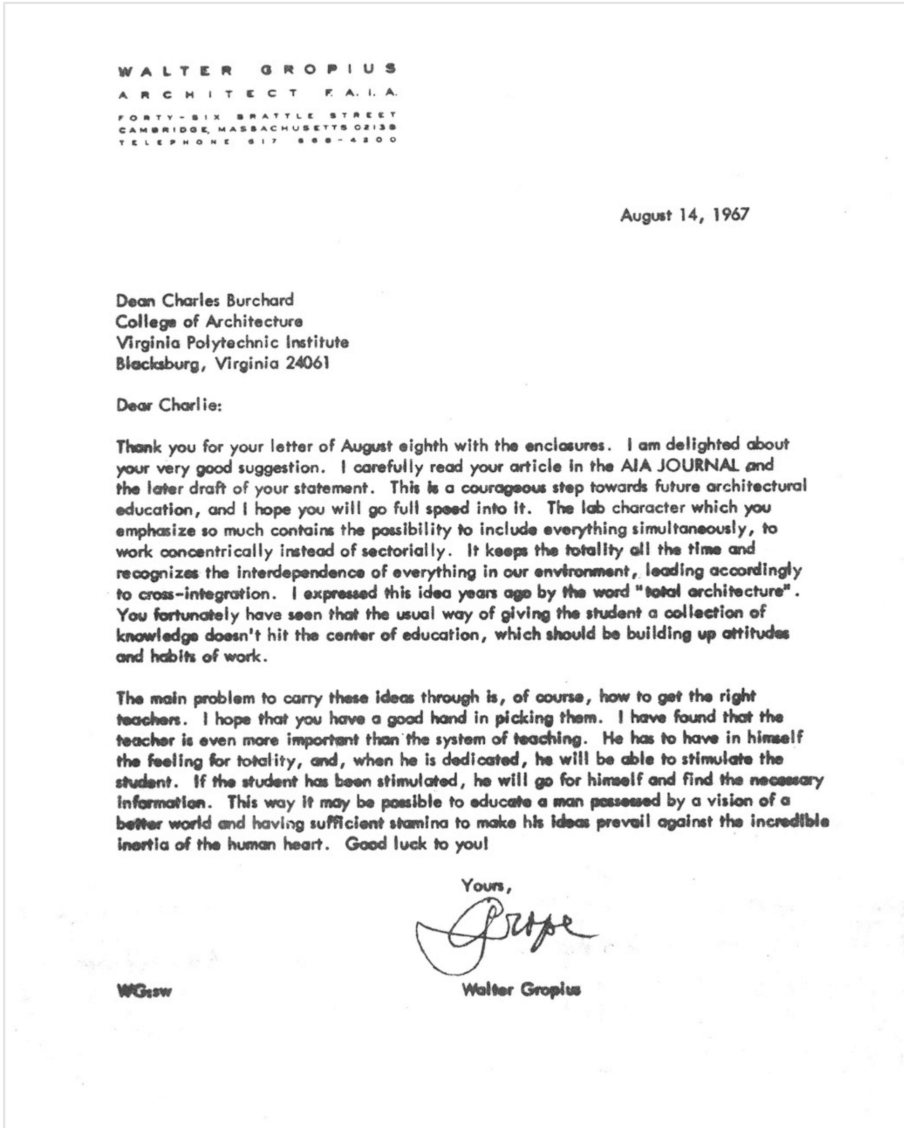
Even though the theory of reflective practice can be extended to contain higher-level strategies, it does not majorly deal with such strategies when compared with the stages involved in rational problem-solving. Here, a single strategy can be viewed as multiple moves, which should be framed and assessed similar to single moves. Dorst conveys that the essence of Schön's (1983) "refection in action" mechanism posits that designers do not make evaluations of concepts, but they make an evaluation of the actions which they take when framing and solving a design task. The major unit of design, which is evaluated and manipulated by the designer, is not a static descriptive concept as given in rational problem-solving, but rather it is dynamic (Dorst, 1997).

2.2.3.4. *Design knowledge in reflective practice*

According to Schön (1983), design practice does not heavily rely on general scientific knowledge about strategies and techniques of design. The “essence’ or ‘artistry” of design is seen in the designer’s ability to do what is required in a given situation, what methods and strategies to employ because every situation is unique and should be treated as such by the designer (Schön, 1987, p.13). According to Dorst (1997), Schön describes design as a major activity in professional training schools. In this regard the generalities of the processes of design as well as declarative knowledge, which is required for solving design-related problems are referred to as design knowledge (Dorst, 1997).

2.2.4. **Foundation Design Lab pedagogy at VT**

The pedagogy for architecture education at Virginia Tech is different relative to many other universities; in some instances it can even go against common practices. Charles Burchard laid the foundation for this pedagogy, based on his experience from working under Walter Gropius. This influence can best be seen in a letter from Gropius to Burchard (Figure 3) regarding the new pedagogy that (Burchard, 1972) was implementing at Virginia Tech:



WALTER GROPIUS
ARCHITECT F.A.I.A.
FORTY-SIX BRATTLE STREET
CAMBRIDGE, MASSACHUSETTS 02138
TELEPHONE 617 868-4200

August 14, 1967

Dean Charles Burchard
College of Architecture
Virginia Polytechnic Institute
Blacksburg, Virginia 24061

Dear Charlie:

Thank you for your letter of August eighth with the enclosures. I am delighted about your very good suggestion. I carefully read your article in the AIA JOURNAL and the later draft of your statement. This is a courageous step towards future architectural education, and I hope you will go full speed into it. The lab character which you emphasize so much contains the possibility to include everything simultaneously, to work concentrically instead of sectorially. It keeps the totality all the time and recognizes the interdependence of everything in our environment, leading accordingly to cross-integration. I expressed this idea years ago by the word "total architecture". You fortunately have seen that the usual way of giving the student a collection of knowledge doesn't hit the center of education, which should be building up attitudes and habits of work.

The main problem to carry these ideas through is, of course, how to get the right teachers. I hope that you have a good hand in picking them. I have found that the teacher is even more important than the system of teaching. He has to have in himself the feeling for totality, and, when he is dedicated, he will be able to stimulate the student. If the student has been stimulated, he will go for himself and find the necessary information. This way it may be possible to educate a man possessed by a vision of a better world and having sufficient stamina to make his ideas prevail against the incredible inertia of the human heart. Good luck to you!

Yours,

Walter Gropius

WG:sw

Figure 3. Letter by Walter Gropius to Charles Burchard, August 1967. Reprinted from Gropius, W. (1967, August 14) Correspondence from Walter Gropius to Charles Burchard. Walter Gropius/G. Preston Frazer Papers, Ms1992-052, Special Collections, Virginia Tech, Blacksburg, Va.

As the Dean, Burchard, revolutionized the education system by replacing the teacher-centered design studios with student-centered Design Laboratories. In the context of architecture education, the terms design studio and design lab are often used interchangeably but in reality, they present two distinct approaches. Studios have a studio master who is an expert and gives information to the students, e.g. Frank Lloyd Wright was a studio master. On the other hand, a design laboratory is a place where experiments happen and the instructor is, to some extent, a co-creator. In Section 2.2.1 the researcher provides examples of famous Design schools that follow each of these schools of thought. The idea behind this new pedagogy was to give students a holistic, total view of architecture education. This was done by increasing the sophistication of the content as students moved from one year to the next, instead of changing the content itself. The change in the pedagogy also resulted in the change in the environment in which learning was happening. The learning environment must enable students to utilize the resources of the school as a total person. The environment must also allow for interactions providing a continuous flow of information, increasing students' competencies. (Burchard, 1972)

Another influential character in developing the current education system is Charles Steger. He became the dean in 1980 at the age of 34 after completing his entire education at Virginia Tech. He created the "*Educational Tenets of the College*" document, which emphasized principles like: student self-activation, freedom to determine assignments, self-pacing, self-criticism, and self-correction (Stubbs and Gordon, 1989).

Cowgill Hall (the building where the Foundation Design Labs are located) is a vast space with no dividing walls or doors; ceiling height is relatively high to promote openness (Figure 4). Each student has their own desk in this area. Students are socially inseparable from each other in the lab. The openness of this space enables students to be aware of what is going on in the lab, allowing them to walk around and interact freely with other people.

Figure 4. Cowgill Hall, built in 1968 (Left) and Burchard Hall addition built in 1998 (Right) [20]

The space also promotes interaction between students from different years by placing their desks near each other.

> *You get collaboration of people without having a typical wall in front of you or you can walk around just see people's works and no will one stop you. [Foundation student] (Kavousi & Miller, 2014, p.2554)*

The Lab is often situated in a location that allows students easy access to facilities like a pottery lab, library, or wood shop (Kavousi & Miller, 2014), where they can easily see and access these workshops. The nature of the Lab transforms the academic space into a place of communal interaction among students and professors; through those interactions, students are able to gain new insights on design learning-tasks.

It is expected that in the School of Architecture + Design, the students and faculty become learners that interact at various respective levels of experience while seeking the same thing, which is an inner attitude that is necessary for creative discovery (Burchard, 1969). Charles Burchard, the founding dean, explained that, this inner attitude gives "learners" the means and methods that will result in the identification of related problems in the environment, which will lead to translating complex content into a qualitative reality through a holistic experience

[20]. Burchard Hall photo courtesy of Shelley Martin

(Burchard, 1969). Continuous dialogue between students and the educator is what characterizes the Design Lab; therefore it can be said that a significant portion of learning in Design Lab happens through collective interaction (Kavousi & Miller, 2014).

The new pedagogy that was implemented by Charles Burchard and Olivio Ferrari revolutionized the Design Lab, unlike before where design was a studio course where about 15 students relied on a master for instruction; now the Design Lab[21] is more flexible, allowing students to explore and identify new information for the learning-task at hand; this makes the students more responsible (Burchard, 1967; Burchard, 1972) Here the student has the opportunity to study the learning-task, examine theory against observation, identify the need to set new goals, question ideas and schools of thought, as well as produce design in two and three dimensions. In this kind of learning environment, students learn not to be threatened by their mistakes but rather, they are motivated to experiment with different techniques and approaches according to their own reasoning, and accept failure as an important aspect of learning. Students are motivated and believe that they could be successful in the design course by seeing their learning as a process, not just in their projects but across projects over time. The way students handle their learning- tasks and various design situations is of great importance to professors and vice versa. In the Design Lab information is shared bi-directionally between faculty and students. In this kind of learning, students learn from the experiences of either their course-mates or professors (Kavousi & Miller, 2014).

[21]. Burchard (1965) used the word "Experimental Laboratory" instead of the "Design Studio" to differentiate the new pedagogy of Architecture Education at Virginia Tech. It was called experimental because it focused on the search process and not the end solution, the intention was for students to discover the nature of the problem that architecture was concerned with. It was called a laboratory because of its concentric structure, which meant students were exposed to everything simultaneously (Burchard, 1972).

The Design Lab is a place where students both individually work and communally pin up their designs regularly. The presented work provides students with the opportunity to share their designs and engage with other students regarding the objects being displayed. During these presentations, the work is used to focus a ranged of shared experiences, while the professors highlight the strengths of certain designs more so than weaknesses. Through the discourse between and among students and professors, students are able to improve their designs on their own.

One of the major features of the Design Lab is that it gives room for student- professor interaction; because the professors often walk around to challenge the students while they are performing various tasks. This support given to the students by the professors increases their motivation and confidence, knowing that their professor is always there for them (Kavousi & Miller, 2014).

Furthermore, the process of designing in a Design Lab is time and effort consuming; the repetitive approach of designing and redesigning is a vital part of working in the Design Lab. The comprehensive engagement of students in Lab work allows the student to build relationships beyond academic work (Kavousi & Miller, 2014). Therefore, such an interactive environment is beyond the conventional classroom in which students' interaction with each other plays a substantial role in their learning.

In this regard, *"in the Foundation Design Lab, the constructivist approach and positioned learning are important aspects of the Foundation Design Lab. Constructivism is a learning philosophy which holds that the idea of knowledge is structured by the knower based on* *personal experiences"* (Kavousi & Miller, 2014, p. 2548). Simply put, Foundation Design Lab is established within social processes whereby learning occurs, which is why the researcher used a social cognitive[22] dimension to explain the outcomes.

2.2.5. **Metacognition and design**

Design is a complicated process and is often presented in forms that are not well-defined. Similar to what has been a note by (Sheppard, Macatangay, Colby, & Sullivan, 2009) in engineering design, architecture design is also not a linear process. Learning how to design can be a frustrating and confusing process (Powers, 2017). Educators cannot simply teach students how to solve problems; identifying the problems constitutes an important part of the educational process as well (Demirbas, 2001).

For over two decades, the role of metacognition in improving academic performance has been promoted in many curriculum documents. According to Jeni Wilson[23] (1998) most educators regard metacognition as an important element necessary for several cognitive learning-tasks (Li & Munby, 1996). This further emphasizes the importance of studying students' thought processes, highlighting students' role in this kind of educational system. For this purpose, discoveries regarding cognition and metacognition can be utilized to develop pedagogical models. The results from such studies further recognize the importance of student-centered educational environments (Bransford, Brown, & Cocking, 2000).

[22]. Social cognitive theory states that individuals learn not only through their own experiences but also from observing others.

[23]. Jeni Wilson is an author and lecturer at the University of Melbourne's Institute of Education with a special interest in children's thinking and in assessment.

Compared to high school, students in college are often required to complete larger, longer-term projects and must do so with less guidance from the teacher. One purpose of the design pedagogy is educating students within a determined period of time. Through this process, novice designers become professional enough to influence the community through their designs. The importance of the projects that students work on in Design Lab comes from the fact that self-regulation and goal-directed behavior in the lab is directly associated with what a student is learning from the project and project-related tasks, which prepare students for positions in a future community. Therefore, the unique and different nature of Design Lab and architectural design pedagogy in comparison with typical classrooms and theoretical disciplines highlights the significance of self-regulated learning. Students who want to become self-directed learners must learn to analyze the requirements of the task, assess the level of their own knowledge and skills, strategize, monitor their performance, and adjust their strategies as needed.

The American institute of Architecture Students (AIAS) task force states that there is a lack of creativity in the present design education pedagogy. Per Olaf Fjeld in European Association for Architectural Education stated that *"[design educators] have a tendency to forget the difficulties of creation, and to take the creative act for granted in assuming that information and know-how alone can replace creativity"* ((Fjeld, 2005) in EAAE[24]. In reaction to this problem, AIAS notes that administrators of design education have the ability to improve educational experience by using design programs and syllabi that promote the awareness and

24 European Association for Architectural Education

understanding of the processes that relate to creative thinking. Consequently, this will help design program administrators to share and disseminate policies that will result in improved creative thinking. The association believes that the application of this improved educational approach by design schools is done on a small scale and more effort could be made in order to incorporate the approach into programs and curricula (AIAS, 2002). This research helps with this process by providing an in-depth understanding of how design students understand their metacognitive processes.

Metacognition plays a critical role in the effectiveness of designers, hence it is considered as an essential ingredient of creative thinking (Sternberg & Williams, 1996). Due to the contribution of metacognitive research to the psychology of teaching creative skills (Flavell, 1979; Flavell, 1981; Lawson, 2006), creative thinking can be defined as a metacognitive process. Pesut (1984b) also asserts that creative thinking enhancement is the result of exploiting the fundamental skills of creativity like brainstorming, and synectics[25], which are really action-oriented metacognitive guides.

According to findings of metacognitive research, individual differences in problem-solving are related to their metacognitive thinking. In other words, students approach a learning-task differently because of the differences in their metacognitive thinking process (Hargrove, 2008). Activities such as planning how to approach a creative problem-solving situation are metacognitive by nature. In this regard, basic metacognitive awareness and attention can significantly influence the problem-solving process. Therefore, as also supported by the

[25]. Synectics is a methodology in regards to problem-solving where thought processings that the subject may be unaware of are stimulated (Prince, 1970)

educational psychologist Dr. Norbert Jausovec (1994), the objective is manipulating metacognitive processes to explicitly help design students to plan their problem-solving efforts, set goals for their efforts, and monitor their progress toward their goals.

Based on research in the area of metacognitive skills, it is worthwhile to draw some conclusions about how metacognitive strategies or skills relate to creative problem-solving performance. From a theoretical viewpoint, metacognition is an important aspect of cognition, and can dramatically affect problem-solving performance (Doerner, 1974; Schoenfeld, 1983; Sternberg, 1982). Researchers have attributed individual differences in problem-solving to metacognition, and that basic metacognitive awareness and attention through instruction can significantly influence problem-solving (Hargrove, 2008; Jausovec, 1994).

It is important for administrators and design educators to carefully examine how educational projects and practices promote metacognitive processes as an integral part of learning. Doing so requires an in-depth understanding of students' metacognitive thought process, which is the main objective of this research. The AIAS has shown concern about how the present approach used by design education rewards students with the "best looking" projects with much focus on the appearance of the end project, rather than its quality and the processes used in the design work (AIAS, 2002).

2.2.5.1. *Relationship between metacognitive thinking and academic performance*

The concept of metacognition is helpful in the case of cognitive failures and difficulties students encounter upon dealing with information processing and problem-solving (Efklides & Sideridis, 2009; Flavell, 1976).

Better learning and achievement are obtained by students who are more metacognitively sophisticated (Lee & Shute, 2010; Ormrod, 2012). Successful students are aware of when they behave strategically and when they do not (Eggen & Kauchak, 2001; Ozsoy, 2011), emphasizing the fact that learning can be effective in cases where it occurs consciously. However, some students require explicit training and coaching to learn such skills since they do not spontaneously engage in metacognition (Cubukcu, 2009). In this regard, it has been proven that metacognitive training can considerably improve performance, even if administered for a short time (Cubukcu, 2009; Nietfeld & Schraw, 2002; Thiede, Anderson, & Therriault, 2003). Therefore, it is important for design students to be explicitly or implicitly trained to use metacognitive thinking in their problem-solving process.

From a theoretical perspective, metacognition, which is an element of cognition, can have a significant influence on problem-solving competency. According to Bransford et al. (1986), training in metacognition could assist people to improve their ability to think and learn. Thus, different approaches like incorporating techniques into the syllabus for metacognition training in problem-solving were proposed by (Davidson & Sternberg, 1998).

Activities such as planning how to approach a problem-solving situation, are metacognitive by nature. Because metacognition plays a critical role in successful problem-solving, it is important to study students' metacognitive activities and developments to determine how they can be taught to improve their control of the cognitive resources. Jausovec (1994) designed and executed a series of studies to better understand the influence that metacognition has on problem-solving performance. The results suggested that students' performance in regards to ill- and well defined problems can be improved by aiming the instructions at manipulating metacognitive processes. Taken together, the results indicate that metacognition is an important factor in problem-solving performance. Metacognition appears to be important for solving creative (open-ended) problems. In addition, it was also shown that high performing students have a better understanding of their general cognitive strategies – how and when to apply them – relative to less proficient learners (Jausovec, 1994).

Metacognitive research has revealed that metacognition could significantly predict academic performance. In line with the fundamental role of metacognition in successful learning (Caviola, Mammarella, Comoldi, & Lucangeli, 2009; Desoete & Ozsoy, 2009; Desoete, Roeyers, & De Clerq, 2001; Teong, 2002) and a reasonable relationship between students' academic success level and metacognitive skills is demonstrated by several studies (Case, Harris, & Graham, 1992; Desoeae & Roeyers, 2002; Kirby & Ashman, 1984). Design educator, Ryan Hargrove (2007) studied the influence of explicit metacognitive training on the performance of design students using a quantitative methodology and standardized tests in a controlled experimental setting. However, due to the deep and hidden layer of metacognitive learning, the researcher has taken upon herself to use qualitative analysis in students' natural setting (Foundation Design Lab) to further the understanding of student thinking process.

2.3. Metacognition

Conscious awareness or the "meta" phenomenon is what sets human beings apart from other animals (Samek, 1981). John H. Flavell is an American developmental psychologist focusing on the cognitive development of children. In his 1976 article "*Metacognitive aspects of problem-solving*" Flavell introduced the concept of metacognition from the combination of cognitive and behavioral research activities (Flavell, 1976; 1979). It is also considered by some professionals as the "control center" of the cognitive system because the dynamic processes involved in learning are controlled by metacognition. By enabling us to control these dynamic processes (such as cognitive and affective), metacognition plays a great role in problem-solving circumstances (Flavell, 1976; 1979).

Metacognitive activity can both precede and follow, cognitive activity (Lawanto et al., 2013). The literature on metacognition dates back to as early as 1933 (Dewey, 1933). Although the term "reflective self-awareness" was used rather than "metacognition". Reflective self-awareness was used to explain the importance of carefully, actively, and persistently considering one's knowledge and beliefs. The term metacognition emerged from information processing studies conducted in the 1970's. Flavell's (1976) description of metacognition as the individual's awareness, consideration, and control of his/her cognitive processes and strategies introduced him as the pioneer researcher in the field of metacognition. This definition of metacognition is now quoted regularly in the literature.

In research regarding metacognition, most of the time has been consumed by three main barriers. These issues are: (1) the conceptualization of the major areas of metacognition, (2) differentiating between cognition and metacognition and (3) ascertaining the relationship between the different aspects of metacognition (Wilson & Clarke, 2004). There are a number of questions that should be answered before conducting any research on the influence of metacognition on students' performance: "what is metacognition?", "why metacognition?", and "how does metacognition manifest itself?". The answers to these questions have been used to guide the researcher in developing her theoretical framework.

2.3.1. **What is metacognition?**

After more than 40 years, during which the concept of metacognition has been part of the education psychology discussions, there is not a uniformly accepted definition for metacognition, which has caused confusion in the field (Rahman & Masrur, 2011). Metacognition has been described in many ways throughout its history. To answer the question, the researcher has reviewed various definitions extracted from the literature on metacognition to identify the elements, features, components, or skills that are associated with Metacognition. Table 1 provides the definitions that have been used for this purpose.

Table 1. Definitions of metacognition

Researcher	**Definition**
(Flavell, 1976)	*"Metacognition refers to one's knowledge concerns one's own cognitive processes and products and anything related to them, e.g. the learning relevant properties of information or data.* *Metacognition refers, among other things, to the active monitoring and consequent regulation and orchestration of these processing in relation to the cognitive objects or data to which they bear, usually in the service of some concrete goal or objective."* (p. 232)
(Flavell, 1979)	*"Knowledge and cognition about cognitive phenomena."* (p. 906)
(Flavell, 1985)	*"Knowledge or cognitive activity that takes as its object, or regulates, any aspect of cognitive enterprise."* (p. 104)
(Brown, 1987)	*"Metacognition refers loosely to one's knowledge and control of one's own cognitive system."*(p.66)
(Metcalfe & Shimamura, 1994)	*"Knowing about knowing."*(p. 1)
(Child, 1995)	*"A person self-consciously examining his/her mental processes, becoming aware of problems and adjusting accordingly, in order to improve effectiveness."*(p.136)
(Schraw & Dennison, 1994)	*"Metacognition refers to the ability to reflect upon, understand and control one's learning."* (p. 460)
(Wilson & Clarke, 2004; Wilson, 1998, 2001)	*"Metacognition refers to the awareness individuals have of their own thinking and their ability to evaluate and regulate their own thinking."* (p.694)
(Shimamura, 2000)	"*Metacognition refers to evaluation and control of one's cognitive processes. In this way, metacognition often suggests conscious or volitional control of thoughts, memories, and actions*." (p.313)
(Lawanto, 2008)	*"Metacognition is higher level thinking that involves active control over the thinking processes involved in learning."* (p.ii)
(Zimmerman & Moylan, 2009)	*"Metacognition refers to knowledge, awareness and regulation of ones thinking."* (p. 299)
(Martinez, 2006)	*"Metacognition is the monitoring and control of thought."* (p.696)
(Santoso, Boyles, Lawanto, & Goodridge, 2011)	*"Metacognition is a conscious activity, dealing with human internal mental processes that are hard to observe compared to physical activity."*(p.3)

Flavell's (1976) definition focuses on what the individual knows about how she/he learns. On the other hand, his 1985 definition makes the role of regulation (monitoring and control) more central to the learning process within metacognition. Another definition of metacognition provided in (Table 1) is based on its philosophical origins or its ontological roots. In this sense metacognition *is defined as "cognition about cognition"* (Flavell, 1979) *or a "model of cognition"* (Nelson, 1996) (Cited in Efklides, 2011, p.6), *"Knowing about Knowing"*(Koriat, 2000, P.149 ; Metcalfe & Shimamura, 1994, P.1) *or " thinking about thinking"* (Flavell, 1976; Lawanto et al., 2013; Rahman & Masrur, 2011, P.135)*, or "monitoring and control of thought"* (Martinez , 2006, p.696) that focuses less on the epistemological or axiological perspectives of metacognition. The definition that has guided the researcher in this study is the one given by Flavell (1976), who defines metacognition as the knowledge that people possess about their own cognitive processes and outcomes as well as other information necessary for learning. Table 2 provides a summary of the skill and components that were extracted from the definitions listed in Table 1.

Table 2. Components of metacognition

Author	**Components**
Flavell's (1976)	Awareness, consideration and control of cognitive processes and strategies
Brown (1978)	Planning, monitoring and modifying thinking
Gall, Gall, Jacobsen, & Bullock (1990)	Knowing the process, selection of the appropriate strategies and monitoring the effectiveness of the strategies

The understanding of metacognition that has developed based on this study, defines metacognition as a form of meta-level process of the status of learning at the current stage and how it should proceed. A successful self-regulated learning process requires effective use and execution of the process mentioned above.

2.3.1.1. *Metacognition features and elements*

Based on the definitions given by different researchers from different fields to the term metacognition it can be concluded that the main elements of metacognition are self-regulation, awareness, meta-reasoning, auto-consciousness, and memory-monitoring. Despite this lack of clear definition, researchers in the field of metacognition have categorized it into two constructs: 1) metacognitive knowledge and 2) metacognitive regulation and control (Rahman & Masrur, 2011), or in simple terms knowledge of cognition and self-regulation of cognition (Brown, 1987). The first one refers to what an individual knows about cognition while the second one refers to how cognition is regulated. It can be said that the confusion regarding the definition of metacognition is a result of separating the concept into two distinct but related aspects (Garofalo & Lester, 1985; Schoenfeld, 1992).

Various researchers categorize the features and components of metacognition differently but there is still some overlap among categories identified by various researchers. Flavell (1979) stated that the main factors related to metacognition are person, task, and strategies. The factor referred to as the person include everything that learners believe about themselves or other people regarding cognitive processes. While the factors regarding tasks and strategies are considered as the available information, which results into learners understanding of the demands of a given task (goals and how they can be achieved). These three factors that influence the awareness and control of learner's cognitive tasks are successfully identified by Flavell in his definition of metacognition (Lawanto, 2008).

Professor Scott Paris[26] and Peter Winograd[27] (1990) in their article, "How metacognition can promote academic learning and instruction," view metacognition through two primary features: 1) Cognitive Self-Appraisal (CSA), and 2) Cognitive Self-Management (CSM). The judgment made by a person about his/her ability to achieve a goal is considered as cognitive self-appraisal while the maintenance of executive control, which shows "how metacognition helps to orchestrate cognitive aspects of problem-solving", is regarded as self-management (p. 18). The skills that are often used by learners to show the presence of self-management include the ability to plan, control, and assess the process of learning (Wilson & Clarke, 2004).

2.3.2. **Why metacognition**

The second question that we need to answer is "why metacognition?". Numerous research studies have shown that metacognition, or the ability to think about thinking, greatly influences learning. (Chambres et al., 2002; Chan & Moore, 2006; Graves, 1983; Jonassen, Strobel, & Lee, 2006; Lawanto, 2008; Ross, Green, Salisbury-Glennon, & Tollefson, 2006). The roles of metacognition have been acknowledged in various fields, including science (Gourgey, 1998), technology (Phelps, R., Graham, A., & Thornton, 2002; Phelps, Graham, & Thornton, 2006) engineering (Case, Gunstone, & Lewis, 2001; Lawanto et al., 2013; Lawanto & Johnson, 2009; Newell, Dahm, Harvey, & Newell, 2004), mathematics (Garofalo & Lester, 1985; Kaune, 2006;

[26]. Scott G. Paris is a Professor of Education and Psychology in University of Michigan with interest on the development of children's learning, motivation, reading, cognitive strategies, and metacognition.

[27]. Peter Winograd is an Emeritus Professor of Law and former Director of the Center for Education Policy (CEPR) at the University of New Mexico.

Schoenfeld, 1992, & Schoenfeld, 1988), reading (Mokhtari & Reichard, 2002; Paris & Oka, 1986), and areas of writing (Carr, 2002; Wong, 1999). Even though research has shown that metacognition plays an important role in learning, there is limited research on how students use metacognition to solve problems. Research in this area has been on-going for about 30 years, so it is not considered as a new field but the evaluation of metacognition is a new field (Wilson, 2001).

Although many researchers believe that metacognition is a set of knowledge that needs to be learned (Smith, 1994), it is useful even for those who are not conscious about it. Learners engage in some method of planning, monitoring, or regulating without knowing that they are using metacognition techniques. However, possessing such knowledge and awareness contributes to its facilitation and the enhancement of student thinking (Hartman, 2001; Schraw, G., & Moshman, 1995). One of the advantages of metacognitive learning is that students are able to improve their control over their learning process, which in turn enhances their new metacognitive knowledge acquisition and construction. Based on this factor, studio professors should use proper techniques to enhance students' metacognitive learning as an extension to their syllabus (Ku & Morgan, 2006).

According to Meyer et al. (2008) metacognition is considered as one of the main skills required for independent learning. Independent learning is a learning method "*in which a student acquires knowledge by his or her own efforts and develops the ability for enquiry and critical evaluation*" (Candy, 1991, p. 2). The importance of metacognition is due to the key role that independent learning skills play in students' success in higher education learning, especially in design disciplines, where the instruction of relevant skills should begin in the first year of higher education curriculum. The essential role of first year is critical as the mental capacity of freshman students in higher education can be increased through the development of independent learning skills (Field, Duffy, & Huggins, 2014). Thus, first year students should be taught the skills needed for independent learning. A review of literature on independent learning reveals that there are three main skills related to independent learning; metacognitive (how learning is or should proceed), cognitive (content of the learning), and affective (emotions, moods, motivational responses and states) (Meyer et al., 2008).

2.3.2.1. ***Metacognition and self-regulation***

Dinsmore et al. (2008) indicate that self-regulation and metacognition definitions have become diluted to the point where today basic questions that are raised in this regard show that the concepts are not fully understood. The terms metacognition and self-regulation are frequently and interchangeably used in the educational literature (Dinsmore et al., 2008). Interchangeable use of these terms has resulted from the absence of explicit guiding conceptual frameworks in research studies, which create confusion in terminology (Winters, Greene, & Costich, 2008). Thus, we end up asking whether metacognition is the same as self-regulation, instead of asking how metacognition is involved during self-regulation (Schunk, 2008).

The desire to make efforts geared towards the accomplishment of self-goals is known as self-regulation (Carver & Scheier, 1998). For individuals to be successful in self-regulating, it is important for them to take note of their goals, monitor the goals, regulate their emotions, behavior, cognition and their environment (Kuhl & Fuhrmann, 1998). The theories of self-regulated learning have shown that metacognition plays a vital role in the process of self-regulated learning (Boekaerts, 1999; Efklides, 2011).

Metacognition is often discussed together with self-regulation and self-regulated learning, indicating the complex set of abilities employed by individuals to control their behavior and their learning to reach desirable goals (Zimmerman & Schunk, 2011). According to Bandura's (1986) theory of reciprocal determination and the concept of agency, there is a mutual influence among people, their behavior, and the environment. Individuals' ability to exert agency presupposes their awareness of what they do and their ability to develop strategies to control and regulate it. As a key component of "agency," metacognition has been increasingly regarded as one of the facilitating factors of self-regulated learning whereby people transfer skills, knowledge, and strategies across contexts and situations (Negretti, 2012). Metacognition is a critical component of the self-regulation process because at the personal-awareness level it is part of self-awareness. Self-awareness is the experience of I as agent – acting, thinking, and feeling at a specific place and time, in unity with one's past (experiences, beliefs, and goals) and future goals (Efklides, 2011; Vogeley, Kurthen, Falkai, & Maier, 1999).

In contrast to Bandura (1977), who was especially focused on the person–environment–action dynamic in his articulation of self-regulation, Flavell and colleagues (e.g., Miller, Kessel, & Flavell, 1970) were most concerned with the relation of maturation and experience with individuals' awareness of their thoughts. Based on these different theoretical roots, metacognition is clearly concerned with cognitive orientation, where self-regulation emphasizes behavioral and emotional regulation (Dinsmore et al., 2008). However, these roots became increasingly entangled due to the growth of metacognitive strategies in relation to one's awareness of their cognition, and therefore metacognition began to venture into the realm of behavior more associated with self-regulation. On the other hand, the correspondence of self-regulation to metacognition has become increasingly pronounced when targeting the cognitive realm rather than the psychosocial or behavioral domains (Dinsmore et al., 2008). Many self-regulation researchers consider the reciprocal determinism of the environment on the individual, mediated through behavior, in contrast with metacognition research in which the mind of the individual is emphasized as the initiator or trigger for subsequent judgments or evaluations (Dinsmore et al., 2008). In simpler words, the derivation of knowledge from the environment (external) or individuals' minds (internal) could be regarded as the distinction between these two approaches.

The three foundational theorists (James, Piaget, and Vygotsky) provide an integrated and complementary perspective for metacognition, very simply viewed as knowledge or awareness of self as knower, and self-regulation, viewed as control of or acting upon self as actor (Fox & Riconscente, 2008). Across all these three theorists, Fox and Riconscente (2008) demonstrate that metacognition and self-regulation are parallel and intertwining constructs.

From another perspective, self-regulation is an autonomic process aiming at supporting operation for the purpose of achieving self-goals (Carver & Scheier, 1998). In successful self-regulation, individuals' awareness of their goals are necessary as well as monitoring and control of their cognition, emotions, behavior, and environment. Metacognition is regarded as instrumental in this process (Fox & Riconscente, 2008). What influences an individual's awareness towards his/her cognition and triggers control processes to serve the goal in the self-regulation process is metacognitive experience (Koriat, 2007).

The definition of self-regulation, which describes it as the extent to which "*individuals are metacognitively, motivationally, and behaviorally active participants in their own learning process*" (Zimmerman, 1995, p.3), reflects the close relationship between metacognition and self-regulation. More emphasis is laid by Zimmerman, (1995), on the fact that in addition to metacognitive skill and knowledge, motivational and behavioral processes are part of the elements of self-regulation that results in acting on one's beliefs. Zimmerman's framework of metacognition considers metacognition as the predecessor and precursor of self-regulation that triggers mental and physical behavior, which puts the thoughts into action. By defining metacognition as a process in which "*an individual exerts self-regulatory control over his or her cognitions,*"(Ford, Smith, Weissbein, Gully, & Salas, 1998, p.220), the reciprocal relationship between metacognition and self-regulation is validated (Fincham & Cain, 1986). Even though the relationship between metacognition and self-regulation is reciprocal, there is a difference between both; metacognition is mainly concerned with the process of thinking, while self-regulation is concerned with thought and action. Hence, the researcher has utilized the use of metacognition for the purpose of this study, where the focus is on understanding students' design problem-solving thought process.

2.3.3. **Metacognition and its manifestations**

The third question that we need to answer is "how does metacognition manifest itself?". To answer this question, first we need to have a clear understanding of the existing metacognition perspectives and frameworks. In the following section each concept is defined and the relevant literature is provided.

2.3.3.1. ***Metacognition perspectives***

Based on the literature reviewed it can be concluded that there is no universally agreed upon framework for metacognition but there are three commonly used but distinct perspectives of metacognition, which attempt to explain the relationship between various forms of thought processing that occurs during problem-solving. The first perspective is based on Dunlosky and Metcalfe (2009) and Pintrich[28], Wolters[29], and Baxter (2000) framework where metacognition is considered to have three general components; the difference between these two frameworks is in their definitions and sub-elements, and not the main categories: 1) metacognitive knowledge, 2) metacognitive judgments and monitoring, and 3) self-regulation and control of cognition. The second perspective is from Paris and Winograd, 1990, where metacognition has two major elements: 1) cognitive self-appraisal and 2) cognitive self-management. The third perspective is based on Flavell's (1979) framework. Similar to the first perspective, Flavell's framework considers three components for metacognition: 1) Metacognitive knowledge, 2) Metacognitive experience, and 3) Metacognitive skills.

[28]. Paul R. Pintrich (1953–2003) was a professor of education and psychology at the University of Michigan who made significant contributions to the fields of motivation, epistemological beliefs, and self-regulated learning. Pintrich published over 140 articles, book chapters, and books on topics related to educational psychology.

[29]. Christopher A. Wolters is a professor and Director of the Walter E. Dennis Learning Center at Ohio State University.

In order to develop a framework that describes the behavior of design students, it is important to understand various components of each of the perspectives. Thus, this section provides a detailed description for each of the elements.

The definitions for the three components of metacognition for the first framework (Dunlosky and Metcalfe (2009) and Pintrich, Wolters, and Baxter (2000)) are provided below; a detailed schematic is provided in Figure 5.

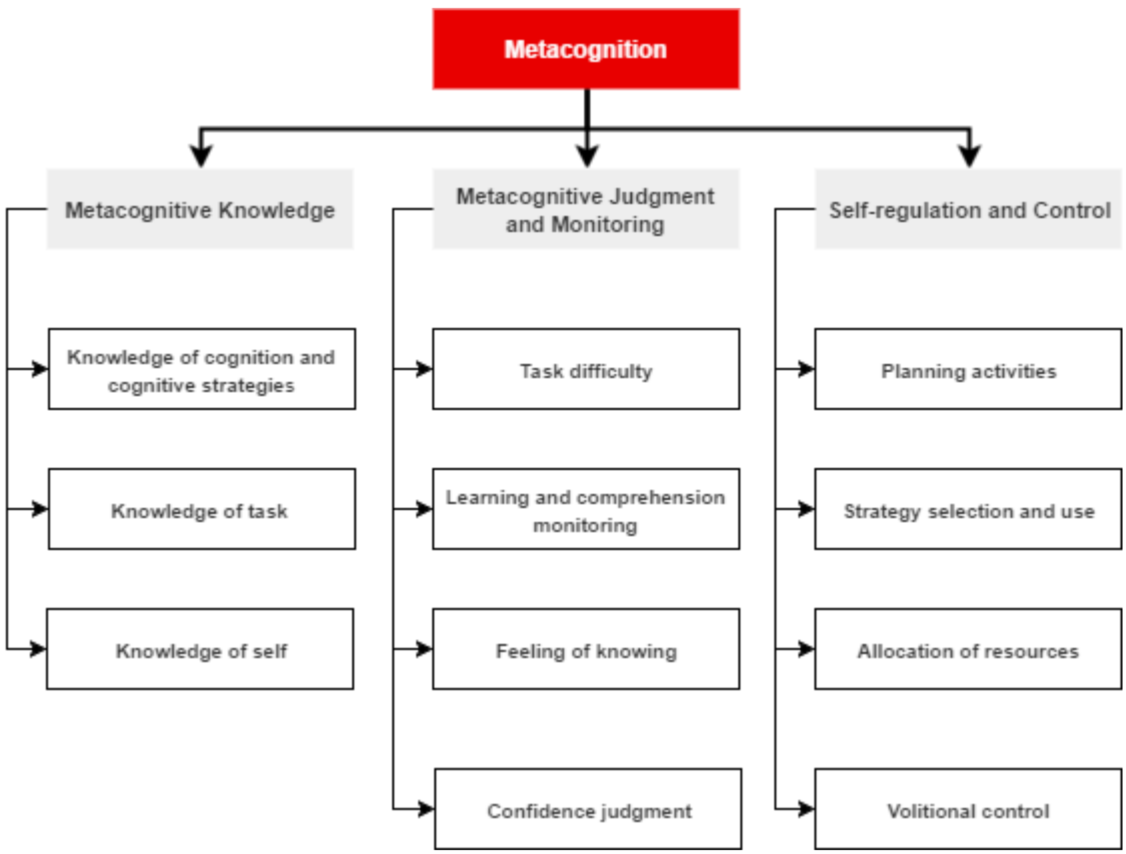


Figure 5." Three general components of metacognition and self-regulated learning" Adapted from Issues in the measurement of metacognition (p. 47) by P.R. Pintrich et al., 2000, Lincoln, NE: Buros Institute. Copyright 2012 by the Buros Center for Testing.

According to Cotterall and Murray (2009) since metacognition knowledge "*represents the knowledge-base that students draw on as they make decisions about their learning*" (p.34) it is an irreplaceable part of independent learning. It is essential for curriculum designers, teachers, students, and anyone else involved in education to make this clarification.

Although metacognition knowledge is stable for the most part (Wenden, 1999), cognitive maturing, socialization, implicit and explicit learning and experiencing, gradually change it. The complexity of metacognition and the difficulties of understanding metacognition clearly, become apparent when researchers like Pintrich et al., 2000 use a definition of metacognition knowledge to conceptualize and delimit issues. A more detailed description of MK is provided in section 2.2.3.2.

1) Metacognitive judgments and monitoring

Metacognitive judgments and monitoring refer to the ongoing metacognitive activities from four general metacognitive processes: (a) task difficulty or ease of learning judgments (EOL), (b) learning and comprehension monitoring or judgments of learning (JOL), (c) feeling of knowing (FOK), and (d) confidence judgments that individuals may engage in as they execute a task. Contrary to the static nature of metacognitive knowledge, metacognitive judgment and monitoring reflect metacognitive awareness and are more process-related (Pintrich et al., 2000).

Ease of Learning (EOL) as defined by Nelson & Narens (1990) refers to individuals' ability to determine the difficulty level of a task, i.e. how hard it will be to learn or remember the material. Ease of learning judgments use metacognitive knowledge of the task and metacognitive knowledge of the self, relative to previous experiences regarding the task. Since

EOL judgments occur before the learner starts the task, in the acquisition phase they should be treated independent of judgments of learning or readiness for a test (e.g., Hunter-Blanks, Ghatala, Pressley, & Levin, 1990) cited in (Pintrich et al., 2000).

Judgment of learning (JOL) is another type of metacognitive judgment or monitoring. JOLs happen during or after the new information has been acquired and predict test performance in the future regarding the information that is currently recallable (Nelson & Narens, 1990). In Pintrich's et al., 2000, model of memory, JOLs are present during the acquisition and retention phases. JOLs become visible in a variety of student activities, such as individuals realizing that they did not understand the material they just studied. JOLs can also be made while students monitor their learning by asking themselves questions.

Feeling-of-knowing (FOK) is the third type of metacognitive awareness process (Koriat, 1993; Nelson & Narens, 1990). Feeling-of-knowing (FOK) judgment is similar to the JOL in the sense that it is a prediction regarding future performance, but they are judgments regarding if currently non-recallable information is known and/or if it will be recalled later (Pintrich et al., 2000).

The fourth type of metacognitive judgment is about an individual’s confidence level in what they recall, basically how sure they are regarding the correctness of their answer. What makes this different from the previously mentioned judgments is that the assumption here is that the judgment follows the retrieval of information (Nelson & Narens, 1990). Judgment of confidence is also present in error detection or debugging activities where it is assumed to produce some metacognitive awareness regarding the accuracy of performance. An important aspect of metacognitive judgment and monitoring is to calibrate these confidence judgments to actual performance (Pintrich et al., 2000).

2) Self-regulation and control

Self-regulation and control is the collection of activities that individuals engage in to adapt and change their cognition or behavior. Many researchers have attempted to define metacognitive control (MC). The definition of metacognitive control provided by Dunlosky and Metcalfe (2009) is "*regulating some aspect of a cognitive activity*" (p.3). Son and Schwartz (2002) define MC as "*the ability to use those [metacognitive monitoring] judgments to alter behavior*" (p.15). Pintrich et al. (2000) form the conceptual discussion of MC around four general categories: 1) planning, 2) strategy selection and use, 3) resource allocation, and 4) volitional control.

Planning, which involves setting the goals to guide cognition and monitoring, is a key aspect of cognition and behavior regulation (Pintrich et al., 2000). Another key aspect of control and regulation of cognition is the decision to select from various strategies for learning, memory, reasoning, and problem-solving. Multiple studies have emphasized the importance of the selection of appropriate cognitive strategies on learning and performance (Pintrich et al., 2000).

Allocation of resources is the third aspect of self-regulation and control that has been included in this framework. Although resources like time, overall effort, and pace of learning are not strictly cognitive, the regulation and control of these resources is an essential aspect of metacognition (Pintrich et al., 2000).

Volitional control or control of emotion, motivation, and the general environment is the fourth aspect of self-regulation and control. Some theorists use the term volitional control to refer to all of metacognitive control and regulation activities (Corno, 1993; Kuhl, 1985, 1992). Learners activate their cognition, emotions, and motivational beliefs, which can play a significant role in their learning(Pressley & Afflerbach, 1995). Volitional control in combination with metacognitive judgment and monitoring form the "on-line" process orientation of metacognition and self-regulated learning. Metacognitive knowledge (the "static" component of metacognition) is an important resource that learners use to monitor and control their learning.

The second framework divides metacognition into two subcategories; the following sections provide the definition for each of the subcategories:

1) Cognitive Self-Appraisal

Paris and Winograd (1990) define self-appraisal as ''*judgments about one's personal cognitive abilities, task factors that influence cognitive difficulty or cognitive strategies that may facilitate or impede performance*'' (p. 17). In other words, it is the perception that an individual has regarding his/her ability to accomplish a task or achieve a goal through the use of motivational components like self-efficacy, goal orientation, task value, as well as learning the beliefs that enhance self-directed learning (Lawanto, 2008). Pintrich, Smith, Garcia, and McKeachie (1991) define intrinsic goal orientation as the degree to which factors such as challenge, curiosity, and mastery motivate the student to participate in a task. Pintrich et al. (1991), argued that task value is different from goal orientation in the sense that goal orientation is the reason for a student's participation in a task, while task value is how the student evaluates a task based on how interesting it is, and the relevance and usefulness of the task. The student's belief and confidence in his/her ability to perform a task, according to Lawanto (2008), is referred to as self-efficacy. Bandura, (1986) further argued that ''*people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances*,'' (p. 391) are referred to as self-efficacy. The individual's willingness to start up challenging tasks is positively affected by anticipation of getting a desired result. In contrast to self-efficacy, learning belief is described as a student's understanding that the outcomes he/she expect are dependent on the efforts, which he/she puts in (Corno & Mandinach, 1983; Pintrich et al., 1991).

It is not uncommon for students to doubt if they have sufficient knowledge (procedural, conditional and declarative knowledge) to solve a task when given one. In this study the judgment about the ability of students to accomplish a task and the confidence in the skills, which they have to accomplish the task is referred to as self-knowledge. Also, in this study students' performance expectation is referred to as self- reliance. Task value in this study is defined as the perceptions that the students have about issues related to the design learning-task, such as importance, and interest. The personal reflections regarding the abilities and knowledge states of the students are known as the three motivational factors perceived to drive the actions of students (Paris & Winograd, 1990). Students are likely not to put much effort in completing a task if they know that the knowledge which they have and their expectation to be successful in solving a problem is low, as well as having little value for the problems which they have to solve (Lawanto, 2008).

2) Cognitive Self-Management

The self-management skill, which is also known as executive control of behavior (Paris, S., Lipson, M., Wixson, 1983), refers to a student's plan prior to the start of a given task and making the required modifications and adjustments while performing a task. Students' self-management ability is reflected through the presence of three skills, which are planning, regulation, and evaluation (Lawanto, 2008). Planning is mainly concerned with activities like goal setting, task analysis, and selection of strategies that enhance the achievement of certain goals. The continuous adjustment and fine-tuning of cognitive activities by learners is known as regulating. The process through which learners make an assessment of the current state of knowledge is referred to as monitoring and evaluating. Such evaluation activities include but are not limited to self-testing, self-questioning and tracking of attention and progress during and after executing a task. Paris and Winograd (1990) suggest that the subsequent instruction and the performance of students are directly influenced by cognitive self-management.

The third framework divides metacognition into three subcategories of metacognitive knowledge, metacognitive experience, and metacognitive skill. The following sections provide the definition for each of the subcategories.

Metacognitive knowledge (MK)

As concluded by Flavell (1976), metacognitive knowledge (MK) is knowledge and comprehensive understanding of cognitive processes and outcomes, and is about a person knowing the strategies that might be effective. According to Efklides, (2001) metacognitive knowledge is the "*knowledge we retrieve from memory and regard what the person knows or believe about him/herself and others as cognitive beings, their relations with various cognitive tasks, goals, actions or strategies as well as the experiences s/he has had in relation to them*" (p. 299). MK contains information regarding both one's self and others, as well as information about tasks, strategies, and goals (Flavell, 1979). In addition to task categories and their related features, metacognitive task-knowledge also involves relations among tasks and the methods by which they are processed. Furthermore, knowledge of varied strategies and the conditions such as when, why, and how to rationalize their use are embraced by metacognitive strategy-knowledge. Finally, knowledge regarding the goals people pursue if faced with particular tasks or situations is included in metacognitive goal-knowledge (Efklides, 2008).

Metacognitive knowledge can be divided into three areas, namely declarative, procedural, and conditional knowledge (Paris, Cross & Lipson, 1984). The knowledge about one's general processing abilities is called declarative knowledge, where procedural knowledge refers to the knowledge about how to successfully solve problems, and conditional knowledge is defined as knowledge about when to employ specific strategies (Sperling, Howard, Staley, & DuBois, 2004).

Metacognitive knowledge is continuously enriched and updated through integrating new information resulting from monitoring of cognition at a conscious level. This occurs through communication and interaction with others (Ruffman, Slade, & Crowe, 2002) or observation of peoples' behavior/actions and their outcomes in specific tasks within various contexts (Efklides, 2008; Fabricius & Schwanenflugel, 1994).

Metacognitive Experiences (ME)

Metacognitive experiences (ME) have been considered as the awareness and feelings, which arise in relation to dealing with a task while processing the related information (Efklides, 2001, 2006, 2008). Flavell (1979) provides a somewhat similar definition for ME as "*any conscious cognitive or affective experience that accompanies and pertains to any intellectual enterprise*" (p.906). They are the interface between the person and the task, the knowledge regarding features of a specific task, the smoothness of cognitive processing, the progress toward the task objectives, the effort made in cognitive processing, and the result of processing (Efklides, Kourkoulou, Mitsiou, & Ziliaskopoulou, 2006; Efklides, 2002, 2008). They are represented in the form of metacognitive feelings, metacognitive judgments/estimates, and online task-specific knowledge (Efklides, 2001, 2006, 2008). Online task-specific knowledge is analytic in nature, which distinguishes it from metacognitive judgments, which can be products of both analytic and nonanalytic processes (Efklides, 2008; Kahneman, 2003; Koriat & Levy-Sadot, 1999; Koriat, 2007) as well as metacognitive feelings, which are nonanalytic in nature (Efklides, 2008; Koriat & Levy-Sadot, 1999; Koriat, 2007).

Metacognitive feelings have been extensively studied in the context of meta-memory research through feelings of knowing, familiarity, and confidence (Efklides, 2008), as well as the feeling of difficulty (such as the lack of processing fluency) and error detection (as in discrepancy from the goal), which are studied in the context of problem-solving (Efklides, 2006).

Metacognitive feelings are affective and cognitive. The affective character can be best explained with feedback loops[30](Desoete & Ozsoy, 2009; Ozsoy, 2011).

Metacognitive judgments/estimates include judgment about learning, estimation of the work required and the time needed or spent. Individuals make a judgment about their confidence relying on two sources of information: their feeling of difficulty (Koriat, 2007) and their estimate of solution/response correctness (Efklides, 2008). Thus, metacognitive feelings as products of nonconscious and nonanalytic inferential processes can provide a database for analytic judgments/estimates or control decisions (Koriat & Levy-Sadot, 1999). In this regard, appropriate control decisions could be endangered when the person feels highly confident about the incorrect outcome of cognitive processing due to processing fluency (Efklides, 2008; Kruger & Dunning, 2009).

Online task-specific knowledge includes task information, as well as ideas or thoughts that we are aware of in dealing with a task. It also comprises metacognitive knowledge that we retrieve from memory in order to process the task. For example, the knowledge about previously used procedures, and comparisons of their similarities or differences with the current task (Efklides, 2008).

Metacognitive Skills (MS)

Metacognitive skills (MS) can be defined as the ability to use metacognitive knowledge strategically to achieve cognitive objectives (Desoete, 2008; Ozsoy, 2011). In other words,

[30]. Constantly comparing the current situation with the goals (see Carver, 2003; Carver & Scheier, 1998)

metacognitive skills refer to the voluntary control individuals have over their own cognitive processes (Efklides, 2008). According to Azevedo and Aleven (2013); metacognitive skill is the ability to coordinate the application of metacognitive knowledge in the context of one's metacognitive experience, and applying the knowledge in a situation in which it will be effective. It has been also regarded as employing particular strategies deliberately in order to control cognition. Executive control of cognition is identified by (Brown, 1987), which involves selective attention and working memory, planning, conflict resolution, error detection, and inhibitory control (Shimamura, 2000).

The literature focuses on four metacognitive control skills: prediction, planning, monitoring and evaluation (Desoeae & Roeyers, 2002; Desoete, Roeyers, & De Clerq, 2001; Ozsoy, 2011). Prediction skill refers to the ability of students to predict the difficulty level of a task through which they regulate their engagement related to outcome and efficacy expectations. Prediction skill also includes selection of appropriate strategies and resource allocation (Desoete, 2008). Prediction skills give students the ability to think about the learning objectives, proper learning characteristics, and the amount of time available. Planning skills enable students to think in advance of how, when, and why to act in order to obtain their purpose through a sequence of sub-goals leading to the main problem goal. In a classroom context, planning involves analyzing exercises, retrieving relevant domain-specific knowledge and skills, and sequencing problem-solving steps (Desoete, 2008).

On-line awareness of comprehension and task performance is regarded as monitoring. Monitoring skills can be described as the ability to have self-regulated control over the cognitive skills used during the actual performance. Monitoring skills are used to recognize problems and to adjust the plans (Desoete, 2008). Proficient students are assumed to have the ability to choose the appropriate skills and modify their behavior with a change in task demands, consciously using previously acquired knowledge and selecting appropriate study behavior (Montague, 1998). A good example of monitoring skill is periodic self-testing ability while learning. The evaluation skill enables students to assess the products and regulatory processes of their learning, whereby their goals and conclusions can be re-evaluated. Evaluation enables students to assess their performance on the task; their performance can be compared with each other and the results of comparison can be used to locate errors in the solution process (Desoete, Roeyers, & Buysse, 2001; Ozsoy, 2011).

The person is aware of the outcome of the monitoring process – for example, through metacognitive experiences, such as a feeling of knowing, a feeling of confidence, a feeling of satisfaction, an awareness of not understanding, and so forth. Also, the person is aware of the beliefs or ideas she or he has about cognition (metacognitive knowledge) and can report them or reflect on them (Flavell, 1979; Koriat, 2007). Moreover, the person constantly and consciously controls the monitoring of cognition (Flavell, 1979; Nelson & Narens, 1994).

The knowledge that an individual possesses regarding his or her cognitive processes and products or anything of that nature is referred to as Metacognition. Goos and Galbraith (1996) refer to active monitoring and consequent regulation and organization of the previously mentioned cognitive processes in relation to cognitive objects, which is usually used to achieve a goal or objective as metacognition.

Scholars do not unanimously agree on the classification of metacognition features. However, there are some agreements among them. According to Flavell (1979) metacognitive knowledge primarily consists of person, task, and strategy elements. The person factor includes everything that learners know regarding their own or other learners, as cognitive processors. Task and strategy elements respectively refer to the available information that will clarify the demands of the task for the learner, and the strategies that will help them achieve these goals (Lawanto, 2010).

A review of the existing literature indicates that frameworks that use three categories to describe metacognition are generally more promoted, and since it will be shown in the data analysis chapter, the data acquired in this research can be better explained using a framework with three subcomponents. The framework developed for the purpose of this research is based on the framework of Nelson and Narens's (1990), Dunlosky and Metcalfe (2009) and Pintrich, Wolters, and Baxter (2000), which considers metacognition to have three subcomponents. This framework provides a comprehensive definition for the vital aspects of metacognition, such as the processes of reflecting, analyzing, drawing conclusions, and applying the findings accordingly. The framework used for the purpose of this research includes all of the essential components of metacognition models offered by the previously mentioned researchers.

Based on the reviewed literature, it can be concluded that metacognition manifests itself in individuals' knowledge regarding their own mental process, their ability to monitor the learning process and make accurate judgments, and their ability to utilize the two previous facets to make decisions that enhance their learning.

2.3.4. **Metacognition and other forms of thought processing**

Although the main focus of this research is metacognition, the researcher needs to have sufficient information regarding other types of thought processing (i.e. cognition, affective) to be able to identify and differentiate them from metacognition. In the following sections, these types of thought processes are defined and their relationship with metacognition is investigated.

2.3.4.1. ***Metacognition and cognition***

In the context of cognition, the acquisition and processing of information produces knowledge. Thus, metacognition "*takes over*" whenever cognition "*ends*." The process of metacognition involves improvement or "*accommodation*" of current mental plans (Hergenhahn & Olson, 2001; Ku & Morgan, 2006). Since the relationship between metacognition and cognition has a symbiotic nature, to understand metacognition, first we need to have a general understanding of cognition. Miller's Information Processing Theory (IPT), provides an explanation of the way humans learn cognitively (Miller, 1956). In this theory, learning is described as a sequence of mental processes in terms of encoding, perception, attention, and storage, as well as knowledge retrieval from long term memory (Schunk, 2004). Learning is described as an active process that involves the construction of mental schemata in the long-term memory, rather than the process of verbatim remembrance of information (Metcalfe & Shimamura, 1994).

Long-term memory has a complex structure that allows learners to identify, think, and solve problems. The ability to identify problems and think of appropriate actions that can be used in solving those problems is known as skilled intellectual performance (Ku & Morgan, 2006).

According to Carson (2012), because of the interdependence of metacognition and cognition, it is important to understand the meaning of cognition before seeking to know what metacognition is and what it is not. Cognition includes knowledge, thinking, intelligence and classifying. However, the complexity and span of the term cognition will increase as it is fully explained. Flavell, Miller, and Miller (2002) note that, the act of symbolizing and fantasizing could also be referred to as cognitions. Organized bodily movements and perception are also categorized as cognition (Carson, 2012; Flavell et al., 2002).

Metacognition describes and explains people's control over their learning and thinking process. The difference between metacognitive tasks and cognitive tasks is that metacognitive tasks includes tasks like monitoring and regulation of the problem-solving process, while cognitive process include tasks such as the remembrance of things that were earlier learned and using them to solve current tasks. Therefore, it can be said that the major difference between metacognition and cognition is that the former is basically concerned with the process of problem-solving, while the latter is mainly concerned with the problem-solving itself (Marchant, 1989). Metacognition lies within the broad concept of cognition. Therefore, metacognition cannot be separated from cognition (Nelson, 1999).

For over two decades research has been going on in the field of metacognition, and there is an agreement among most of the researchers that skills of cognition are needed to carry out a task, while the skills of metacognition are needed for understanding the way the task was carried out (Garner, 1988; Schraw, 1998).

Even though metacognition is sometimes considered as a vague concept due to the difficulty in differentiating it from cognition, Garofalo and Lester (1985) draw a conclusion, which describes metacognition as “*second-order cognition*” that consists of monitoring, awareness, knowledge and the regulation of information flow during cognitive processing. Some researchers (Carson, 2012; Garner, 1988) differentiate between the processes of metacognition and cognition by using the definition given by Flavell. According to these researchers metacognition is mainly associated with the mental evaluation of the progress of a task, while the main focus of cognitive process is the progress towards the completion of a task without the use of monitoring and control. Brown (1987) notes that "*the processes that have recently earned the title metacognitive are central to learning and development and lie at the very roots of the learning process*" (Brown, 1987, p.68).

Metacognitive control is linked to the metacognitive actions that help to control individuals’ thinking or learning (Ozsoy, 2008). Therefore, it is related to metacognitive regulation through both monitoring and control. In this regard, metacognition is introduced by scholars Efklides[31] (2001, 2008) and Nelson and Narens (1994) as a model of cognition (object-level) that functions at a meta-level due to the two main functions served by metacognition, namely monitoring and control of cognition (Flavell, 1979). In a bilateral relationship, metacognition is informed by cognition through the monitoring function, and informs cognition through the control function

[31]. Dr. Efklides is a Greek psychology professor with special interest in educational and cognitive psychology

(Figure 6). Metacognitive monitoring describes how object-level information becomes linked to meta-level information. The monitoring operation describes the relationship between the informational inputs and outputs using a comparison operator. Metacognitive control is how information at the meta-level shapes behavior (Winne, 1996). Such a connection between metacognition and cognition through the monitoring and control functions underscores the functioning of metacognition at a meta level (Efklides, 2008).

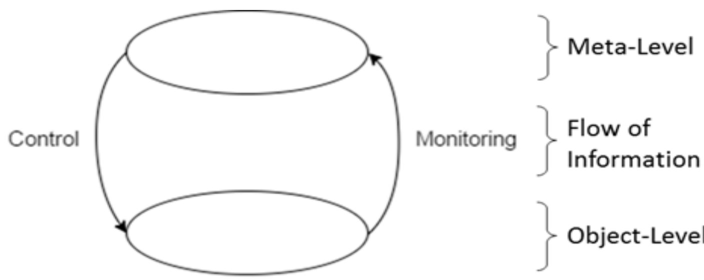


Figure 6. "A framework relating metacognition (meta-level) and cognition (object-level)" Adapted from The psychology of learning and motivation (p.126) T. O. Nelson and L.Narens (1990), New York: Academic Press. Copyright 1990 by Academic Press.

There is a complicated interplay between cognition and metacognition when it comes to the case of student problem-solving (Artzt & Armour-Thomas, 1992; Dunlosky, 1998; Lester, Garofalo & Kroll, 1989; Schoenfeld, 1992). Nothing is always at the meta-level, rather "*one aspect is metacognition in relation to the later aspect*" (Nelson, 1999, p.625).

2.3.4.2. ***Metacognition and affect***

The main concerns of affective states and activities are emotions, attitudes, and the beliefs of an individual and their response to situations. There are some aspects of metacognition that possess affective character (i.e. metacognitive experience) (Efklides, 2006). Thus, there is a theoretical basis for the connection of metacognition to motivation and affect.

According to the MASRL (metacognitive and affective model of self-regulated learning) model[32] developed by Efklides (2011), affect implies attitudes like affective, cognitive, or behavioral dispositions as well as emotions like fear, anxiety or shame in connection to learning. These emotions may be the outcome of the monitoring of a cognitive processing for example, if monitoring results in identification of errors that leads to anxiety (negative affect), and if it leads to liking the task (positive affect) the task is completed successfully (Dina & Efklides, 2009).

The role of affective processing in metacognitive experience can be clarified with an example. Students might experience negative affect whenever they detect an error or encounter challenges without being able to point to the source of their feeling; these negative feelings could be due to inefficiency or lack of required knowledge, demands of the task or contradictions with past knowledge.

Micro-level and macro-level are two levels that can be used to describe the relationship between motivation, metacognition and affect while an individual is performing a task. It is important to know the level of functioning of a self-regulated learning process because at a macro-level metacognition, motivation, and affect are represented by the learners' characteristics like metacognitive knowledge, self-efficacy beliefs, and achievement goal orientations (Pintrich, 2000a; Schunk & Zimmerman, 1998) that are not influenced by the task or the situation. When a person is carrying out a task, the online processing of the task, along with the respective monitoring and control processes, happen in the task-specific micro-level.

[32]. A model which explains the interactions between motivation, affect, and metacognition

This level of self-regulated learning is the most important to researchers in the field of metacognition; this may be the reason behind the communication gap between metacognition research and research about self-regulated learning. The micro-level of functioning is reflected in self-regulated learning activities (Greene & Azevedo, 2007; Winne, 2004). The mundane perspective of human experience, which is reflected in the micro-level measures, is emphasized by Efklides (2006), in contrast to macro-level measures that deal with human characteristics that are more general and stable. While metacognitive knowledge functions in this general macro-level, metacognitive experience functions at the micro-level.

In the case of feeling difficulty, task features (Metallidou & Efklides, 2001) as well as self-concept of ability (Efklides & Tsiora, 2002), are considered the main reasons. Efklides (2008) states that metacognitive feelings, which is one of the components of Metacognitive Experience (ME), operate solely at the personal level of awareness and not on the social level of metacognition.

2.3.5. **Summary of Metacognition**

To summarize the concept of metacognition, we will refer back to the three questions posed at the beginning of this section: “what is metacognition?,” “why metacognition?,” and “how does metacognition manifest itself?” In this research, metacognition is defined as the knowledge people possess about their own cognitive processes and outcomes, as well as other information necessary for learning.

The researcher has focused her study on metacognition for two main reasons: 1) previous research, as cited in this chapter, highlights the positive influence of metacognition on learning and problem-solving abilities, and, 2) the researcher, based on her extensive review of architecture education theories from Europe and the US, believes that the underlying idea of the school of Architecture + Design is to nurture and support metacognitive thinking. Since metacognition is a "meta" phenomenon, it is challenging to identify its manifestation, hence, there is not a universally agreed manifestation for metacognition, especially in the context of architecture education. The researcher has developed a new framework to explain, "how does metacognition manifest itself?" based on the framework of Dunlosky and Metcalfe (2009) and Pintrich, Wolters, and Baxter (2000).

Based on the reviewed literature on Metacognitions, the researcher recognizes the need to:

- Further explore the process of metacognitive thinking in design
- Develop a detailed theory of metacognition
- Link the theoretical concepts of metacognition with the practices in design
- Enhance the educational system/curriculum based on nurturing the metacognitive thinking of students

2.4. Research Methodologies

> *"Methodology refers to the choices we make about appropriate models, cases to study, methods of data gathering, forms of data analysis etc. in planning and executing a research study"* (Silverman, 2010, p.110).

The objective of this research is to understand the metacognitive thinking that takes place during architectural design learning which can be used to further the understanding of design students' thought-processes, and to enhance future educational practices in architecture. This research is being conducted at the Foundation Design Lab in the School of Architecture + Design at Virginia Tech.

In this chapter the theoretical background of this study is presented, starting with a discussion covering the paradigm of constructivism, which is the main philosophical underpinning of the study. The chapter further explains the grounded theory methodological approach guiding this study, as well as providing justification for the researcher's choice of methods for data collection and the process of data analysis.

2.5. Research Paradigm

A research paradigm can be defined as *"the basic belief system or world view that guides an investigation"* (Guba & Lincoln, 1994, p.105). This study is based on the Constructivism and Social Cognitive worldviews. The main objective of this study is to understand metacognition as well as the interaction that goes on between metacognition and other kinds of conscious thought-processing that is present in first-year Design Lab students. Based on the Constructivism and Social Cognitive paradigms, this study aims at exploring the multi-reality of different experiences of students in a social context (i.e. design lab). By doing so, the researcher is able to develop patterns that can result in theory generation (Creswell & Plano Clark 2007). In other words, the research does not intend to test or even prove hypotheses in this study, but to explore the process of metacognitive thinking, which results in patterns and/or theories that explain the experiences of multiple learners in a design learning-task.

Student-centered and student-directed forms of learning, which are the forms of learning under investigation in this study, are often driven by Constructivism (Jonassen & Easter, 2012;

Jonassen, 1991, 1998; Land, Hannafin, & Oliver, 2012; Sawyer, 2006) and Social Cognition (Ormrod, 2012).

Constructivism is the "*philosophical belief that people construct their own understanding of reality*"(Oxford, 1997, p.36). This philosophical belief does not support the notion that there is an external body of knowledge that is simply transferred, but supports the idea that the knowledge possessed by individuals is constructed by their real life experiences. Constructivism gained strong ground in the 20th century - "*constructivism has multiple roots in the psychology and philosophy of this century*" (Perkins, 1992, p.20). The social cognitive paradigm was developed in the 1960s and 1970s, and emphasizes the idea that a great deal of human learning happens in social contexts; people can gain knowledge, beliefs, skills, and strategies by observing and interacting with each other (Ormrod, 2012).

The only way through which a researcher can have knowledge of phenomena is through epistemology (Walker & Evers, 1988). Hitchcock & Hughes (1995), state that epistemology can significantly influence the choice of data collection and research methodology. In relation to the constructivist paradigm for the current study, the epistemological belief is that *"meanings are constructed by human beings as they engage with the world they are interpreting"* (Crotty, 2003, p.43). In this research, meaning is given 1) by the students, and 2) through the researcher's interpretation as an observer immersed in the research setting. The process through which we acquire knowledge about the world is referred to as methodology, or described as "*an articulated, theoretically informed approach to the production of data*" (Ellen, 1984, p.9). Methodology is the special way in which research in approached; it helps provide a better understanding of the data, the focus of the study, data analysis and the association between data and what is being reference (Guba & Lincoln, 1994).

2.6. Research Approaches

Worldviews such as constructivism have an influence on strategies and methods used in research. A detailed breakdown of philosophical approaches, methods of data collection for the three research approaches (quantitative, qualitative and mixed methods) and suitable methods of enquiry for the three approaches has been given by Creswell (2009) and presented in Table 3.

Table 3. "Qualitative, quantitative, and mixed-method approaches" Adopted from Research design: qualitative, quantitative, and mixed methods approaches (p.18) , by J. W. Creswell, 2014, Thousand Oaks, CA: Sage. Copyright 2014 by Sage.

Tend to	Qualitative	Quantitative	Mixed Methods
Use these philosophical assumptions	Constructivist / advocacy/participatory knowledge claims	Post-positivist knowledge claims	Pragmatic knowledge claims
Employ these strategies of enquiry	Phenomenology, Grounded theory, Ethnography, Case Study, And Narrative	Surveys and Experiments	Sequential, Concurrent and Transformative
Employ these methods	Open-ended questions, emerging approaches, text or image data	Closed-ended questions, predetermined approaches, numeric data	Both open- and closed-ended questions Both predetermined approaches, and quantitative and qualitative data and analysis

Tend to	Qualitative	Quantitative	Mixed Methods
Use these practices of research as the researcher	Positions him- or herself Collects participant meanings. Focuses on a single concept or phenomenon. Brings personal values into the study. Studies the context or setting of participants. Validates the accuracy of findings. Makes interpretations of the data. Creates an agenda for change or reform. Collaborates with the participants.	Tests or verifies theories or explanations. Identifies variables to study. Relates variables in questions or hypotheses. Uses standards of validity and reliability. Observes and measures information numerically. Uses unbiased approaches Employs statistical procedures.	Collects both quantitative and qualitative data. Develops a rationale for mixing Integrates the data at different stages in the inquiry. Presents visual pictures of the procedures in the study. Employs the practices of both qualitative and quantitative research.

Qualitative and quantitative research designs are the two major and commonly used research approaches that require different ways of thinking because they serve different research purposes. The difference between these two research approaches is so clear, that researchers using these different approaches rarely cross their boundaries; they only do so if they are using a mixed method.

The main characteristics of qualitative research are that they are inductive, context specific (interpreted in natural settings), and subjective (concerned with interpretations and meanings). Therefore, compared with a quantitative approach, a qualitative approach is more suitable for purpose of this research. The major differences in the two approaches are discussed subsequently.

2.6.1. **Deductive and inductive**

One of the ways of differentiating between the two approaches is through the inductive-deductive dichotomy categorization, which is also known as exploratory vs. confirmatory.

In particular, a qualitative research strategy is characterized as inductive, which involves the development of a theory through the observations of empirical data (Saunders, Lewis, & Thornhill, 2007). In this approach, the research typically starts with observations and collecting data from students, which are used to create themes, and then are developed into broad patterns, theories, or generalizations (Morgan, 2013). In the last step of qualitative research the result is compared with existing literature (Bahari, 2010). The main objective of the inductive approach is to understand an issue within its context. Thus, this approach aims to explore and arrived at new discoveries and theories (Bahari, 2010; Morgan, 2013).

In contrast, a quantitative research strategy is characterized by a deductive approach in which theory is used deductively and as the start of a study. Quantitative research is often guided by an existing theory; through this theory a model for the study is generated. The process of data collection is then guided by the model, which has been generated from the theoretical framework (Creswell, 2014). In simple terms, quantitative research is mainly concerned with theory testing and verification through the examination of research questions or hypotheses, which have been carved out from the theory. In this research approach, the process includes identification of variables, instrument development, and data collection through the use of the designed instrument; this process results in the acceptance or rejection of hypotheses, or confirming or rejecting a theory (Bahari, 2010). Thus, the use of this research design is employed in extensive research where the deductive approach is used in evaluating a theory (Bahari, 2010; Bryman, 2004; Morgan, 2013).

In qualitative studies, there are no prescribed categories, which limit the researcher (Denzin, 1971; Eisner, 1981; Smith, 1983a, 1983b), while the reverse is the case for quantitative research where a set of categories from an existing theory guides the research (Firestone, 1987; Smith, 1983a, 1983b). In simple terms, before a quantitative study is carried out, there are already existing categories and the researcher only needs to ascertain the relationships among them (McCracken, 1988; Smith, 1983a, 1983b).

In summary, it can be said that quantitative research is majorly concerned with theory-testing and verification through a deductive approach; it is a research design that is guided by theory. On the other hand, qualitative research majorly focuses on theory development through an inductive process. Therefore, an inductive approach used in qualitative research aims at creating theory and new discoveries through a research design that is flexible and emergent, while the aim of the deductive approach used in quantitative studies is to test a theory through a well-structured and explicit research design.

2.6.2. **Context and generality**

Another difference between the two approaches is the objective of the inquiry. While quantitative research aims at generating a set of theoretical statements, which can be generalized at the end of the study (Firestone, 1987; McCracken, 1988; Smith, 1983a, 1983b), qualitative research design aims at providing a detailed and rich description of the researched phenomenon within its context; the objective of qualitative research is not to generalize

(McCracken, 1988). The findings of qualitative research are theoretically and practically important because they help provide solutions to practical problems (Jacob, 1988; McCracken, 1988), while serving as guide for hypotheses development for quantitative research (Miles & Huberman, 1984). The knowledge obtained from qualitative research can only be applied within a particular social context, and any attempt to apply it outside its social context will alter its meaning (Guba & Lincoln, 1981; Guba, 1987; McCracken, 1988; Smith, 1983a, 1983b). On the other hand, the findings of quantitative research is context-free and can be generalized and applied outside its context (Hathaway, 1995). In this regard, findings are factual if they are applicable to all similar situations and settings with same meaning (Firestone, 1987; Smith, 1983a, 1983b).

Therefore, the difference between the two approaches is that qualitative research is context-oriented while quantitative is characterized by its generalizability. In qualitative research, a detailed investigation is conducted on a particular group of people or a certain situation, while quantitative research is concerned with generalizing on a greater context (Morgan, 2013). Therefore, the idea of context in qualitative studies results in the holistic understanding of systems through a small number of cases, while that of quantitative research follows a process, which is well-structured with larger cases.

2.6.3. **Subjectivity and objectivity**

Qualitative research is mainly concerned with interpretations and meanings, which can be referred to as subjectivity. This emphasis on subjectivity applies to both what is studied and how research is conducted; acknowledging researchers' own interpretations as well as the significance of meanings in the lives of the people under study. In contrast, a set of purposes, which is adopted by quantitative research, is associated with objectivity. Detached measurement and minimizing the researchers' impact on the study are the effects of the emphasis on objectivity in the quantitative paradigm (Morgan, 2013).

The procedural dimension aspect is what often distinguishes subjectivity from objectivity. Through the use of personal contact, subjectivity makes the researcher the "*instrument"* in a qualitative study, while in quantitative study, objectivity most of the time emphasizes the use of standard measurement so as to ensure that the findings are reliable (Morgan, 2013). Here the experiences, background, and beliefs of the researcher usually have minimal effect on the data collection process, but in qualitative research the data collection process and the conclusions made from the gathered data could be affected by the background, beliefs and experiences of the researcher. In quantitative research it is possible for another researcher who uses the same procedure to get the same result. Therefore, it is expected that in quantitative research, the researcher should be detached from the measurement and the group being studied (Morgan, 2013).

Thus, often the objective purposes that characterize quantitative research are about measurement and detachment, in which researchers and the people they study should be separated. In comparison, the purposes that characterize qualitative research are usually associated with meaning and interpretation, through an interactive relation between researchers and the group under study (Morgan, 2013).

2.6.4. **Researcher's role**

The role of the researcher can also be a differentiating factor between quantitative and qualitative research designs. In quantitative research, often the researcher's role is minimized by his/her detachment from the setting and context being studied (Eisner, 1981; Smith, 1983a, 1983b) because of the assumption that the researcher is independent of the object under study (Eisner, 1981; Smith, 1983a, 1983b). As a result, "*there are social facts with an objective reality apart from the beliefs of individuals*" (Firestone, 1987, p.16).

Conversely, in qualitative research, usually the assumption is that the phenomena under study could best be understood by a researcher through immersion in the situation. This is the only way through which the researcher can obtain rich information about the phenomena from people who have experienced it or are experiencing it (Firestone, 1987; Jacob, 1988; Smith, 1984). Thus, Jacob (1988), posits that the major concern of a qualitative study is to carry out the research in its natural setting, while comprehending the students' views in a subjective and empathic manner.

The basic assumption of qualitative study is that knowledge is generated from human experience(s) (Firestone, 1987; Jacob, 1988; Smith, 1984). Therefore, it can be said that the qualitative researcher is guided by an understanding of the reality that has been experienced by the students in the study. In this research approach, reality, which is governed by rules is not applicable, because reality is differently constructed and understood by each person (Taylor, 1987).

In summary, the main reason why quantitative researchers are detached from the data collection process and the situation itself, is to avoid being biased so that the description of reality will not be affected by their personal judgments, which may or may not be the experienced reality (Firestone, 1987). In contrast, the researcher in qualitative research is the main player and is involved in the whole process of what is happening (Denzin, 1971; Smith, 1984). In this study, the researcher has minimized the influence of her bias on the results, by selecting multiple methods of data collection and analysis and peer examination.

2.6.5. **Qualitative approach for metacognition research**

It has been challenging for researchers who study the cognitive/metacognitive process to determine the way explicit knowledge and information are processed for the formulation of designed artifacts, because seeing what is in the black box of the designer's mind is impossible. According to Pressley (2000), qualitative analysis can enhance the understanding of cognition and metacognitive regulation because it is possible to make sense out of qualitative analyzes of complicated cognitive and metacognition process prior to using quantitative processes. Based on the differences between qualitative and quantitative research approaches mentioned in previous sections, in this study the use of qualitative research design, which is based on constructivist philosophy, is employed by means of grounded theory methodology. The methods and approaches selected for this study provide the necessary tools to accomplish its specific objectives, which are to comprehend and map metacognition in the Foundation Design learning.

It is of great importance to understand that there are three major issues in conducting research on metacognition. First of all, interpretation, comprehension and definitions of what metacognition comprise. Any disagreement or misunderstanding of what metacognition is made up of, can lead to varying data interpretations. Secondly, it is challenging to collect data on a meta-physical unit like one's thought process, which also depends on the abilities of the participants to express their thoughts in an articulate manner while conducting a learning-task. Thirdly, the analysis of this data is very subjective because the identification and measurement of metacognition heavily depends on the subjective interpretation of the researcher in the evaluation of what is cognitive and metacognitive (Georghiades, 2004).

Even though a large body of research on metacognition has been conducted using a quantitative research approach, a greater body of research has been carried out at a level that examines the components of metacognition in clinical settings. An attempt to examine metacognitive learning in a comprehensive manner will require the explorative possibilities provided by qualitative research (Pressley et al., 1998; Schraw, 2000). The best research approach to use when examining complex phenomena is the qualitative approach, which is more appropriate for open-ended and exploratory research that is inconclusive. Efklides & Misailidi (2010) support the notion that qualitative methodologies are the most appropriate for metacognitive research; *"these developments promise a bright future for metacognition research, owing particularly to the development of new methodologies [exploratory qualitative methodologies] which will allow a deeper insight into the nature of metacognitive phenomena"* (p. 1). One of the main advantages of qualitative approach is that it gives room for an in-depth examination of metacognition in practical context. In the context of this research, the researcher's ability to remain reflexive while applying the constructivist approach has resulted in a significant understanding of metacognition.

Although a large volume of research in the area of metacognition has been conducted using a quantitative approach, a number of reasons exist why a qualitative approach should be also be applied in metacognition research. One of the those reasons as given by Schraw & Impala's (2000), is that qualitative research provides a process of detailed assessment of questions related to the evaluation of metacognition; there is "*a large discrepancy between metacognitive theory and measurement practice*" (p. 299). There is often a difference between the theory of what metacognition is and the manner in which it occurs, and the results obtained from quantitative examination of the phenomenon. This is not to say that the use of a quantitative research approach in metacognition is inappropriate, but it implies that a quantitative research approach is more appropriate for re-examination of synchronized metacognition from a different perspective using different methods. Pressley (2000) has advocated using qualitative analysis of metacognition – *"Qualitative analysis of complex cognitive and metacognitive processes makes a great deal of sense before even attempting quantitative analyses of these processes* (p. 261*)".* More recent research similarly expounds the possible benefits to qualitative exploration of metacognition (Nuckles, Hubner, & Renkl, 2009).

Secondly, if the use of a qualitative approach can be employed in enhancing the comprehension of metacognition, then future improvements in quantitative research and measurement tools can be facilitated by this (qualitative) approach. Lastly, talking about state of art in the field of metacognition, Schraw (2000) concludes that measurements, which indicates that problems in the field of metacognition strengthen the need for the use of qualitative approach in metacognition research. After a qualitative and quantitative examination of all the measurements of metacognition, these six conclusions were reached:

1. A unified and detailed theory of metacognition is needed.
2. A wide gap exists between the metacognitive theory and measurement practice.
3. The different pros and cons of the various methods of assessment still remain unclear.
4. The psychometric properties of metacognition measurement instruments are unknown.
5. There is ambiguity about the domain- generality of metacognition.
6. Challenges in correlating metacognitive theory and educational practice (Schraw, 2000, p. 298-303).

Even though the case for qualitative research is strengthened by three of the conclusions above (points 1, 2, 6), a qualitative assessment alongside the use of grounded theory in comparing the way metacognition theoretical frameworks are related to the practical experience of learners is *"perceived by some outsiders as too theoretically disparate"* (Schraw, 2000). The use of qualitative analysis can be employed in examining learner metacognition, even though the findings cannot be generalized; the main aim is to have an in-depth understanding of the concept and the complexities surrounding it. Stern (1995), states that apart from enhancing an in-depth understanding, grounded theory helps the researcher to have a new perspective of common concepts. *“Grounded theory serves as a way to learn about* *the worlds we study and a method for developing theories to understand them"*(Charmaz, 2006, p.10), making it an ideal method for what the researcher is trying to achieve in this study.

According to Creswell (2003), when choosing a research approach it is important for the researcher to select an approach that is appropriate for the research problem "*if a concept or phenomenon needs to be understood because little research has been done on it, then it merits a qualitative approach. Qualitative research is exploratory and is useful when the researcher does not know the important variables to examine" (p. 22).* Although metacognition is a relatively new field, it will not be appropriate to say that insufficient research has been conducted in this area. However, the lack of a comprehensive and unified theory alongside the gap that exists between the theory and practice of metacognition makes it challenging to understand the significant variables in metacognition and how they are related to each other, thereby resulting in the conclusion that a qualitative research design could be more appropriate in this area.

The use of a qualitative research approach is employed in this study for the development of a theoretical framework for the exploration, explanation, and characterization of the process of metacognitive thinking among students in the Design Lab setting. The use of this approach will enhance the understanding of how the design process is influenced by the interaction of the components of metacognition. This research design is relevant to this study because the only way the researcher can gain a deep insight of the process of design is by observing and talking to the students and teachers while they work in the Design Labs. This is because observation is one of the main methods of gaining understanding of a phenomenon. An inductive research approach will be used for this study because the objective of the study is to understand the process of metacognition in students in order to develop a theoretical model, which provides an explanation of learning and achievement in the Design Labs.

2.7. Grounded Theory Methodology

In this section the researcher discusses the rationale behind the use of grounded theory in this study. Also, the coding and other procedures involved will be discussed in this section, alongside the issues related to the adoption of an approach that is based on the post-positivist background in a paradigm of constructivism.

Grounded theory was developed as a method for analyzing qualitative data by Strauss and Glazer in the 1960's and has been defined as "*a qualitative research method that uses a systematized set of procedures to develop and inductively derive grounded theory about a phenomenon*" (Strauss & Corbin, 1990, p.24), the goal of which is "*to generate a theory that accounts for a pattern of behavior, which is relevant to those involved*" (Glaser, 1978, p.3). Grounded theory when combined with the right tools enhances effective data generation and analysis. It is inductive in that, by prioritizing the data rather than looking at existing theories, the research reveals itself and theories are generated. "*Grounded theory can give you flexible guidelines rather than rigid prescriptions. With flexible guidelines, you direct your study but let your imagination flow"* (Charmaz, 2006, p.15).

In a discussion of the issues related to metacognition, Schraw (2000) stated that *"Grounded theories seem especially important at this juncture given the lack of a unified theory of metacognition"* (p. 314). Despite the fact that there is so much ambiguity about metacognition, the components of metacognition upon which pedagogical approaches developed, the validity of existing theoretical frameworks of metacognition is still debated. A research model that lacks a hypothesis that can be proven or disproven is appropriate for the investigation of a concept, which is ambiguous. The case with metacognition as identified in the literature.

It is inappropriate for a constructivist to make interpretations about a phenomenon or concept even before exploring and understanding the concept or phenomenon, because this direction could lead to a misconception of systems, processing and functional associations. Thus, when using grounded theory, a concept can be explored without any prescribed boundaries. The direction of the research is determined by the data analysis, which makes every developed proposition genuinely grounded in the collected data.

2.7.1. **Grounded theory methods**

There are two major paths taken by the originators (Barney G. Glaser and Anselm L. Strauss) of grounded theory, which created the differences between the two paths (Onions 2006). Over the years there have been some changes and variations in the discussion of grounded theory Methodology, which has resulted into the adoption of GTM by new researchers in a way that is opposed by Glaser (Strauss is now deceased). One of those researchers is Kathy Charmaz, who has developed a model of grounded theory from a constructivist perspective. Similarly, the researcher used a grounded theory methodology (GTM), based on a constructivist paradigm, to explore the multiple realities of students' metacognitive processing that occur during the Foundation Design Lab learning. The researcher believes that since she has also immersed herself in the environment she has been able to construct the reality of the situation. Even though Glaser (2012) claimed that the pairing of constructivism and GTM is "*not true*" GTM, the author believes otherwise. It is a justifiable pairing that is often used by researchers today who did not come from the positivistic research era (or philosophical stance) when GTM was created (Carson, 2012).

> *"Grounded theory methods consist of systematic, yet flexible guidelines for collecting and analyzing qualitative data to construct theories 'grounded' in the data themselves. The guidelines offer a set of general principals and heuristic devices rather than formulaic rules (Charmaz, 2006, p.2)".*

Just as the work of Glazer and Strauss changed from the era when quantitative research was controlled by positivistic research, so is their own original theory evolving in a direction that is different from what they initially developed; new researchers are adopting the theory and modifying it through new thoughts. Even as new researchers that have varying epistemological and ontological beliefs are drifting away from post-positivism, they continue to adopt grounded theory. Methodological and theoretical developments that have occurred since the 1960's have created an atmosphere for researchers who have taken the theory in new directions.

Although different researchers (Bryant, 2002, 2003; Charmaz, 2002, 2006; Clarke, 2003, 2005; Mills, Bonner, & Francis, 2006) have argued that a constructivist grounded theory is a research model that is valid, there is a need for the model to give an account for its theoretical and practical foundations. The process of constructivist research requires a strong relationship between the researcher and the research subjects. In this approach, it is required of the researcher to also be reflexive and not let his/her prior knowledge or belief affect the research. Furthermore, it is impossible or inappropriate to detach the researcher from the research process. The most important thing is to consider the researcher as an actor playing a role in the social process while making an attempt to *“study how - and sometimes why - participants construct meanings and actions in specific situations* (Charmaz, 2006, p.131).*”* It is also important for the researcher to understand and acknowledge the interpretivist aspect of the process, knowing fully well that his/her interpretations are not just about the reality experienced by the subjects, but should also be applied to the theory, which is finally developed by the researcher, unlike Glaser, who only provided a data dictum where the data and the data analysis are social constructions that present an interpretation on both sides, thereby making the development of a theory based on this model different from the objectivist perspective.

2.7.2. **The grounded theory process**

Despite the philosophical differences that exist between two paths in grounded theory, the main processes and methods are the same even though the terminologies are different. The use of constant comparative analysis through categorization and coding toward the development of theory is applied in all grounded theory models.

Constant Comparative Analysis

According to Glaser and Strauss (1967), "*The constant comparative method consists of four stages: (1) comparing incidents applicable to each theme that emerges from the data; (2) integrating themes and their properties; (3) delimiting the theory; and (4) writing the theory*” (p.193). Constant comparative analysis is carried out in the process of coding, categorization, and data analysis. It is a simultaneous process whereby data analysis is done alongside data collection, so the data analysis may determine the direction of subsequent data collection, and analysis.

In the first step of coding, conceptual codes are generated alongside further questions. A line-by-line coding of the transcribed data is often the first step of data analysis (Glaser, 1978). It is important that the researcher take a close look at every part of the data in order to find emerging codes rather than apply categories that already exist to the data. During the coding process a comparison between new data and existing data is carried out, after which, new information or knowledge is brought to light. Also, through coding the grouping of certain labels is made possible and the relationships among these labels are made visible. If at the coding stage the researcher is does not locate (devise) a theory, then this indicates that the research questions can be further developed.

The creation of action and process is the major emphasis of classic grounded theory (Glaser & Strauss, 1967; Glaser, 1978). Even though the objects of scrutiny in grounded theory are mental or social processes, the data must be coded *as "actions*" (Charmaz, 2006, p.48). Gerunds can also be used in the illustration of what is happening in the data. The researcher has followed this method in her coding process. See Section 4.1.

After the first step of coding, then comes the more focused coding whereby the most significant codes are selected from the large quantity of data (Charmaz, 2006). The researcher will have different results depending on the kind of processes he/she is looking at. For instance, *reading the task* in this study means students are engaging with the content of the task, which falls under the higher focused category of cognition, while in some other study it may mean *task-awareness,* which could be categorized as metacognition.

Lastly, the stage of theoretical coding takes place at the time that the researchers try to comprehend the associations between and within the different categories that have been found in the initial coding stages; this is to transform the understanding of concepts to theory development. According to Charmaz, (2006) the need for focused coding is precluded by these codes. Even at the last stage of focused coding, the researcher may need more data or even go back to re-examine the open and focused coding to detect obvious discrepancies. In simple terms, the researcher is constantly looking at the data to discover any part of it that is against the direction of theoretical development. The major categories are formulated at this stage.

The researcher is forced by the systematic nature of the research process to constantly check the data until every category and concept is consistent in the data. This is referred to as the saturation point. The process of data collection comes to an end when the researcher gets to the saturation point; here there is no more data that stand against other data. Also, at the saturation point, the addition of more data will not reveal any new knowledge. Therefore, there is a saturation of data in the categories and the researcher can go on to develop the emerging theory about the concept(s).

The diagram below (Figure 7) describes the process of constant comparison, which ends at the point of saturation. It is important to note that there is no specified number of times that the researcher should revisit the data; the emerging categories and concepts is determined by the manner in which the researcher handles the data.

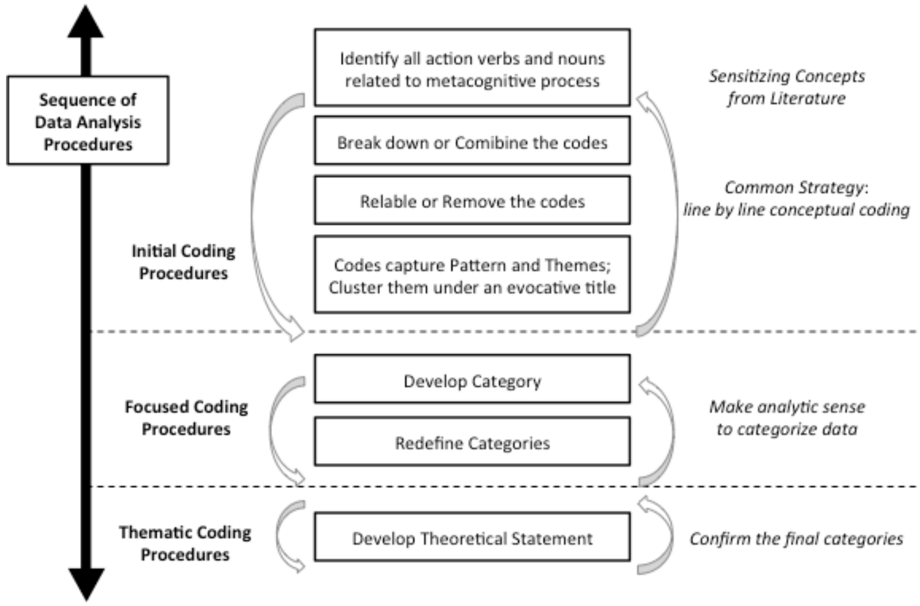


Figure 7. Data analysis steps

Theory Development and Generation

The theory development process occurs at the stage, where the researcher thinks he/she has gotten to the point of saturation. At this stage, the researcher puts into use all the ideas that result in the generation of theory about the concept being studied. Charmaz (2006), suggests that the process should be undertaken in the following manner (p. 117):

"Compare categories.

Use your categories carefully.

Consider how their order reflects the studied experience.

Now think how their order fits the logic of the categories."

Here the studied experience should be well linked with the theoretical statements which are made about them. "

At this phase, a number of researchers make an attempt to provide a visual representation and integration of their written memos by means of diagramming and mind maps. These diagrams and mind maps help to reveal the associations among the categories. This theory, which is formulated from the data, is referred to as the result of grounded theory. Creswell (1998) states that a grounded theory *"is articulated toward the end of a study and can assume the form of a narrative statement, a visual picture, or a series of hypotheses or propositions* (p.56)*."*

In summary, grounded theory consist of three main components, concepts, categories, and propositions (Pandit, 1996). Concepts are developed through a thorough examination of data; these concepts become the units of analysis. The development of wider units, which are transformed into categories made up of a collection of related concepts is made possible through the examination of data, which is done alongside data collection. Emergent theories about the phenomena are generated from these concepts and categories. In the case of this research, the concept is the action verbs and nouns which are narrowed down to only include a specific action and includes all the thought process in that unit, e.g. sketching, drawing, making a model. The category is main thought processing in metacognitive thinking, reflective process knowledge, reflective process monitoring, and reflective process control which emerged from grouping similar and related concepts. The proposition is the metacognitive thought processing framework that was developed by the researcher (see Figure 30).

2.8. Data Collection Methods

Different methods of data collection have been used in research focused on metacognition, such as the analysis of thinking-aloud protocols (Afflerbach, 2000), questionnaires (Pintrich & DeGroot, 1990), stimulated recall, online computer-log file registration, interviews (Zimmerman & Martinez-Pons, 1990), (Veenman, Wilhelm, & Beishuizen, 2004), eye-movement registration (Kinnunen & Vauras, 1995), and self-report inventory, which includes, retrospective verbalization and concurrent verbalization (e.g. Pintrich, Smith, Garcia, & McKeachie, 1991). It is important to note that all these methods share the strengths and weaknesses that are a function of the research paradigm they lie in (Veenman & Van Hout Wolters, & Afflerbach, 2006). It is impossible to see into the black box of the designer's mind; it has been difficult for those studying metacognitive processes to ascertain how one actually processes information and knowledge to formulate the designed artifact, but the literature supports the use of verbal data and protocol analysis as a technique to capture metacognitive processes (Goos & Galbraith, 1996).

2.8.1. **Verbalization methods**

One of the main methods of understanding the human thought process in complicated cognitive tasks is the analysis of think-aloud protocols (Ericsson & Simon, 1993; Suwa & Tversky, 1997). This method has been extensively used in design studies. It is important to develop indirect forms of measurement for those behaviors that cannot be directly observed. Therefore, verbal protocol analysis (retrospective and concurrent verbalization) is often used in metacognition studies (Panaoura, 2004).

The process where students are asked to verbally express what they are doing and thinking while handling a task, or what they have previously done, is referred to as, Verbal Protocol Analysis (VPA). According to some researchers, this method "*offers a much more direct window on processing than other forms of comprehension measurement*" (Pressley, 2000, p.291). Concurrent and retrospective verbalization are the most common types of VPA. Figure 8 provides a schematic view of the setting for the two verbalization methods.

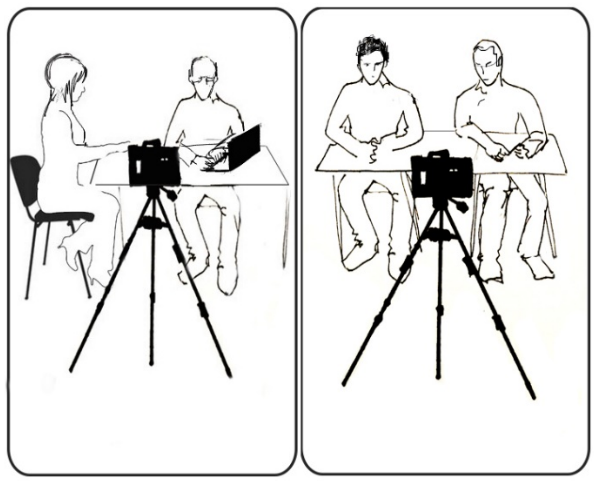


Figure 8. Session setting, concurrent verbalization(left) and retrospective verbalization(right)

Concurrent verbalization refers to the process where students describe their thought process while they're engaged with the learning exercise (Goos & Galbraith, 1996). The main shortcoming of this method is that describing the action may interfere with student's thought process. Students' interactions within a group is also categorized as concurrent verbalization. If the thinking of the subject can be spontaneously changed by VPA, then it means that what is seen in the data is not the natural occurrence of the process. The data becomes a subject of double hermeneutic even before the researcher begins to analyze it.

Retrospective verbalization refers to the VPA process where participants are provided with the means to help recall information from their memory; an example is to video-record the participants while they are engaged with the task and later use the recording to enhance their recall while self-reporting (Ericsson & Simon, 1980). In retrospective verbalization students are not required to analyze their learning process or reflect on what they are doing and thinking while they perform a given task; this is to avoid any form of distraction, which may interfere with the natural flow of thoughts.

The use of the retrospective protocol method for the individual reflective practice was employed in this research because it has been suggested by past work that talking aloud interrupts the thinking process of participants during sketching (Ericsson & Simon, 1993; Lloyd, Lawson, & Scott, 1995; Suwa & Tversky, 1997). Because the researcher intended to uncover the perceptual relationships between a designer and his or her own design, the results would have been weakened by this effect.

2.8.2. **Semi-Structured interviews**

The best approach for data collection in constructivist research is to use interviews, because they give room to the interviewees to provide a detailed description of their own real life experiences. Here the researcher does not view the knowledge of the interviewees as data that can be easily extracted.

Based on the kind of questions used, interview methods can be divided into three categories, which are: unstructured, semi-structured, and structured interviews. Semi-structured interviews "*involves asking a series of structured questions and then probing more deeply with* *open-form questions to obtain additional information*"(Gall, Borg, & Gall, 2003, p.246). In comparison to unstructured and structured interviews, semi-structured has more advantages because it is more flexible and interviewers can use it to obtain answers to unanswered questions while getting very rich data according to the responses of the interviewee. This technique is appropriate for a context which is dynamic, such as the assessment of metacognition in design activity, because it is highly flexible thereby allowing interaction with the students through an interview framework that is consistent (Santoso et al., 2011). The unknown and known aspects of metacognition are better explored through the use of semi-structured interviews in the Design Lab, alongside investigating other unanticipated topics (Ku & Morgan, 2006). The researcher employed the semi-structured interviewing method in this study.

Resolving the shortcomings of semi-structured interviews can be relatively easy. One of the weaknesses of this method is that some details could be missing, but this problem could be solved if the interviewer is experienced and well prepared for the interview. Also having a checklist of the interview questions close by can enhance the smooth and natural flow of the interview. The interviewer can constantly revisit the interview checklist to see what questions have been answered and those that haven't; this is to avoid the case of omission.

2.8.3. **Elicited texts**

In the elicited text type of data collection, participants of a study are required to provide the data in written form. The most common sources of elicited text are the mailed questionnaire, and the internet survey, which usually contain open-ended questions. Additionally, interviewers and ethnographers may solicit responses from participants in written form. They could be asking the participants to give a record of their cultural background, write daily logs or even record their work history; all these generate elicited text. *"These texts, like published autobiographies, may elicit thoughts, feelings and concerns of the thinking, acting subject as well as give researcher ideas about what structures and cultural values influence the person* (Charmaz, 2006, p.36)."

Elicited texts such as journals and diaries have similar advantages and disadvantages relative to conventional interviews. One advantage is that participants may be willing to provide more honest responses to personal questions in anonymous elicited text as opposed to interviews. The disadvantage of this method is that it heavily relies on participants' writing or note-taking skills. According to Murphy and Dingwall (2003), data similar to interview data could be generated from elicited text.

2.8.4. **Card-sorting**

Card-sorting is a popular data collection technique used to acquire data in metacognition studies in which action cards are given to students to help them express their thinking. According to Wilson (2001), the "*don't know*" responses are eliminated by using action cards. One of the main concerns in this type of data collection is the danger of leading the students to conclusions other than their own. To improve the validity of the technique used for measurement, many statements are used (Fowler, 1984; Reid, 1990); blank cards are also made available (Wilson, 2001) for the participants to express any thought processes that they feel are not represented in pre-printed cards (Table 4). The reflections of students on the already constructed card sequence can be stimulated through videos, while the researcher examines the videos in search of insights into the behaviors of the student. The role of video as a stimulator of student's reconstructions of their thinking processes is one of its significant benefits (Wilson & Clarke, 2004).

Table 4. Classification of metacognitive action cards. Adopted from" Towards the modelling of mathematical metacognition,"by J. Wilson and D. Clarke, 2004, Mathematics Education Research Journal, 16(2), P.31
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Awareness: I thought about what I already know I tried to remember if I had ever done a problem like this before I thought about something I had done another time that had been helpful I thought 'I know what to do' I thought 'I know this sort of problem'
Evaluation: I thought about how I was going I thought about whether what I was doing was working I checked my work I thought 'Is this right?' I thought 'I can't do it'
Regulation: I made a plan to work it out I thought about a different way to solve the problem I thought about what I would do next I changed the way I was working

2.9. Conceptual Framework for Situating Research Platform

This study is about design learning, from a multidimensional activity involving scrutiny of the design and thought processes. Understanding and researching this phenomenon requires knowledge from various disciplines, including education, psychology, and design. The researcher has approached this journey through a pluralistic lens on the "*doctrine of multiplicity*," which enables the researcher to focus on how multiple disciplines, in this case education theory (general education), independent learning in psychology, and first-year design education, interact with each other. In education theory, the cognitive and developmental perspectives of Piaget and Bruner, the philosophy of Dewey, and the child development theory and practice of Montessori and Pestalozzi influenced the researcher. In this study the researcher focused on metacognition and the development of first-year design pedagogy over the past five decades, through the papers written by a former Dean of the School of Architecture and Design at Virginia Tech, Charles Burchard (Burchard, 1959, 1965, 1969, 1973) and a former faculty member, Olivio Ferrari.

The individual elements of this study are illustrated in a circular diagram (Figure 9). The three disciplines (independent learning in Psychology, first-year design education, education theory) have intertwined, the cyclical relationships, which resulted in the development of a pluralistic view.

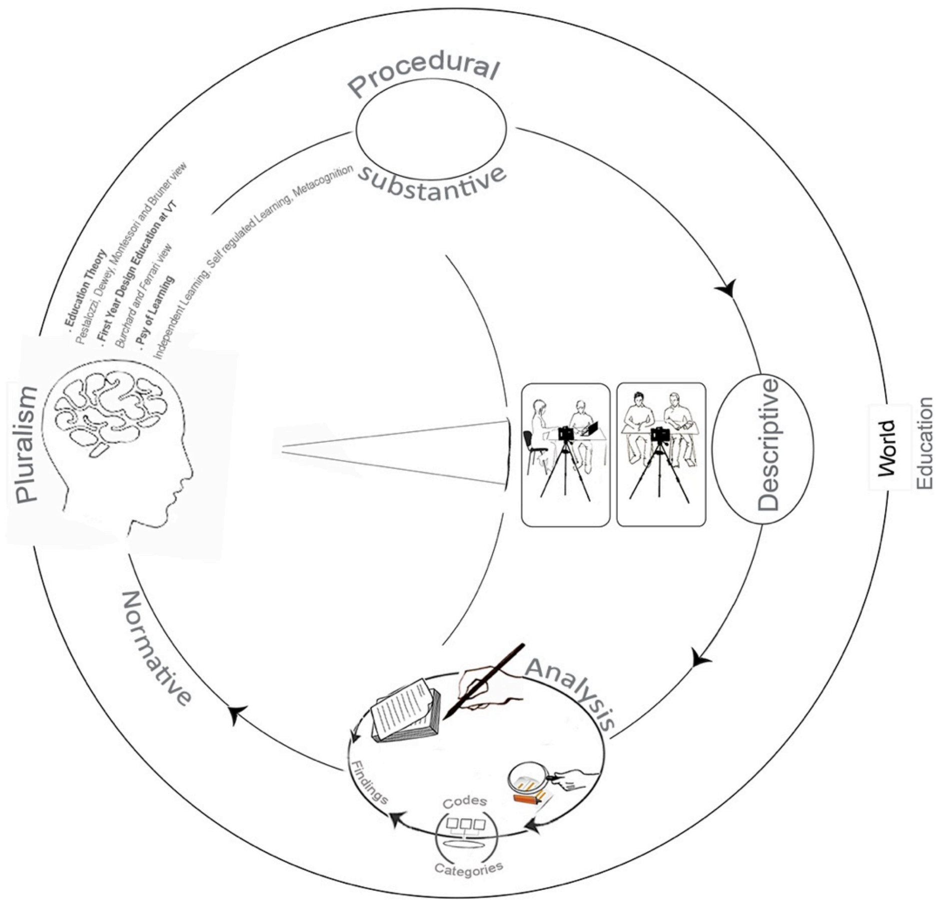

Figure 9. Conceptual framework for situating researcher platform

In this dissertation, pluralism theory[33] can work in tandem with substantive, procedural, and descriptive theories, where all three types of theory can inform and be informed by each other. Substantive theory explains the nature of the phenomena (i.e. environment) with which designers have to deal with while working. Substantive theory also deals with a designer's knowledge of the world and how they use it (Lang, 1987). With substantive theory the researcher explains how the studio does operate and how students' metacognitive thinking influences their designs. Procedural theory is concerned with knowledge about the processes of analysis, creation, and evaluation of design. Therefore, the researcher interprets students'

[33]. Pluralism refers to the fact that our understanding of the world is partial and cannot be represented in a single comprehensive and consistent manner (Horst, 2016).

(first-year) thought processes based on her perspectives through the defined disciplines (metacognitive process in Psychology, VT Foundation Design Lab education, architecture education, education theory). Procedural theory results in a body of knowledge that can enhance design education and practice. The researcher used these theories to understand the process of design, and investigate various forms of thought processes. In an attempt to provide a better perspective on the students' thought processes during the design process, the researcher also used cognitive psychology theories. This research is characterized by a personal perspective towards a reality, where it is believed that our understanding of communal environments (i.e. Foundation Design Lab) is created by individual interpretations (Borg & Gall, 2003). This is in agreement with the constructivist paradigm that the researcher has employed for this research.

The researcher in the descriptive section (data collection) starts to describe the data, gathered by using concurrent verbalization and retrospective verbalization methods. In the analysis part of the loop process (Figure 9), the research starts with close observations and interviews with students, to describe the metacognitive thinking process of students while engaged with the learning-task. Then, through the collected data, the researcher creates themes, which are then developed into broad patterns, or theories.

The researcher comes to a new perspective that may contribute to understanding of "how to teach or improve the teaching through the metacognitive process." Observation permits the researcher to enter into and understand the situation described. This procedure allows the researcher to view the study as process-oriented[34] rather than event-oriented[35]; in other words, all research choices are considered as interrelated rather than as a set of sequential steps (Hesse-Biber & Leavy, 2011). The outcome of such a process is a new and more detailed framework that explains metacognitive thinking in the Foundation Design Lab.

[34]. The outcome of each step is evaluated before moving to the next step and may influence the course of the research.

[35]. The research process is divided into a series of events that happen consecutively

3. Chapter: Methodology

The objectives of this study as explained in chapter one, are to understand the metacognitive thinking that takes place during architectural design learning (the reflective process) in the typical Foundation Design Lab exercises, and the conditions that lead to the development or change in student metacognition thinking in Design Labs. In order to achieve the objectives, the researcher designed three learning-tasks (see section 3.2 for more detail), recruited a number of first-year design students (see section 3.4), and employed a set of data collection methods (see section 3.3) and used grounded theory to develop an understanding of students' thought processes during design learning-tasks. Chapter 3 provides information regarding the research design, the learning-tasks, the methods used for data collection, the setting of the research, the participants, the data analysis, and the methods used to ensure the validity of the findings.

3.1. Research Design

Grounded theory when used in conjunction with a constructivist paradigm provides the necessary theoretical framework for the research to understand students' thought processes that occur during the learning-tasks in the Foundation Design Lab. The focus of this research is on "what metacognition activities take place during architecture design learning in the Foundation Design Lab? and, how do metacognitive thinking and actions influence students' design learning?" The exploratory nature of this subject requires rich and in-depth data that can be best achieved through a qualitative research approach (Merriam, 2009). As mentioned in section 2.7, this study follows the data analysis process of Charmaz, (2006) to accomplish the objectives.

In this research we will use Charmez's process to develop the fundamental components and the configuration of a coherent model of metacognition in the domain of reflective practices in design tasks in the Foundation Design Lab (first-year). This study will also develop a hierarchical model of metacognitive activities for reflection in action practices in design domains by merging theories and concepts from design education and educational psychology to develop practical theories that can serve as an interactive model about individual differences leading to a successful process of metacognition and learning. Section 2.6.5 provides a detailed description regarding the rationale of using a qualitative research method for the purpose of this research.

The researcher conducted three data collection sessions for this research. Each of the data collection sessions were different in the nature of the design learning-task, the number of participants and the data collection methods. Figure 10, provides a schematic of the research design. The first learning-tasks were done individually, and had 23 participants[36]. The data were collected using retrospective verbalization, questionnaires, and card-sorting. The second learning-task was done in pairs, had 19 participants, and data were collected using concurrent verbalization, and questionnaires. The third learning-task was the first-year design competition where 206 students participated, and data was collected using questionnaires (see Appendix G). Each of these are explained in greater detail below in this chapter.

[36]. See Appendix F for participants' identifications

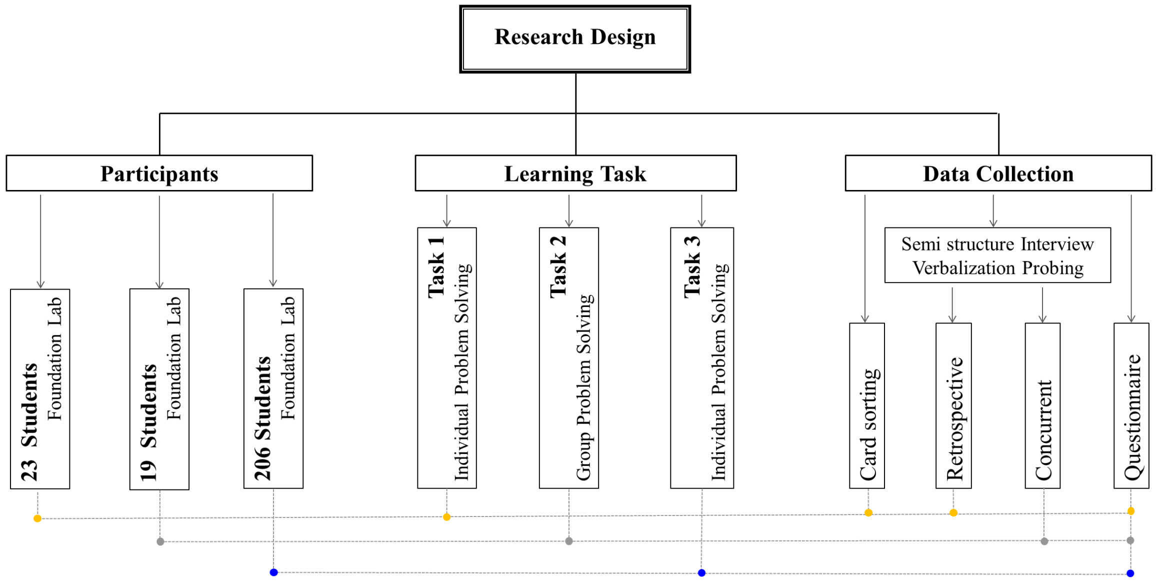

Figure 10. Research design depicting number of students, learning-task and data collection method

The data collected from the learning-tasks were analyzed, coded, and categorized to answer the research questions. In the following section, more details regarding these processes are provided.

3.2. Design learning-tasks and Foundation Design Lab

This section consists of two parts. First, a general typology of the learning-tasks and learning processes in Virginia Tech's Foundation Design Lab are provided. In the second part, details of the learning-tasks of this study and the rationale for their use are established.

Based on their characteristics, two major categories of learning methods emerged: learning-task typologies and learning processes. Learning-tasks have a period of duration in which something is developed, whereas learning processes increase students' intellectual capacities. In the following sections, the typology of each is explained.

3.2.1. **Learning-task typologies**

The design task that students work on has significant influence on the outcome of research regarding their thought processes. The researcher engaged in a multi-layered process to analyze and identify design tasks that indicated the potential for metacognitively rich data for the purpose of this research. The first step in this process was to study various learning-tasks that professors use in their labs.

It was suggested by faculty members to initiate this process by reviewing the existing and historic learning-tasks used by Foundation Design Lab faculties. Olivio Ferrari who was the first appointed Chair of the Foundation Program, contributed through lengthy discussion with Charles Burchard to the so-called "Blue Book,"[37] initiating many of these tasks in 1965. Over the years, the exercises and positions have evolved with other faculty members. The researcher collected additional information by interviewing Foundation faculty members, observing

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[37]. According to an Architecture workbook in 1965 written by a former dean of architecture at Virginia Tech, Charles Burchard, the first year of Foundation Design Lab (First Quarter - Design Laboratory Exercises) includes three different groups of tasks:

A. The intention of the first group of studies is to introduce the student to the language of design, by means of seminar discussions and design exercises. The first group of investigations is intended to help students discover a new way of looking at things which is necessary as they attempt to translate a program (verbal-abstract) into space or form (physical-conceptual).

B. The second group of exercises of the 1st quarter are intended to build upon the translation process, of which the student should now have gained a rudimentary grasp through his/her attempts to identify problems within the orbit of a written program and through his/her critical evaluation of the conceptualizations by which she/he arrives at a visual model-to extend, develop and clarify the program.

C. By this time the student should understand what can be done through the process of design. He/she has designer elements, has arranged elements in groups, questioned the solution of a contemporary object (street, bathroom, etc.), reprogrammed and redesigned such an object, has considered visual/structural organization in design, and explored order in design in terms of an understanding of form. He/she should now formulate his own problem and he should select the one he/she wishes. It can be an architectural problem, one in industrial design, a work of sculpture, or a research paper. Whatever the student thinks will enable him/her to sum up his/her understanding of the design process and his/her grasp of the language of design.

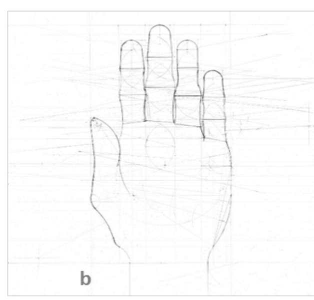
Foundation students in the Design Lab, and compiling a list of learning-tasks that were undertaken by second year students in their first-year. Once a comprehensive list of learning-tasks was aggregated, the researcher studied each learning-task and categorized them based on their characteristics, i.e. period of duration. The researcher established two categories with three typological sub-categories in each. The next step was to discuss the organization of tasks with faculty members to evaluate which task elements would be the most suitable for the purpose of this research.

Each specific task has its own unique specifications and limitations, but in terms of their content, context, and the way students work on them, the tasks can be broadly categorized into three different types. The three types of tasks identified by the researcher are: A) translational-transactional, B) material, tool, and form, and C) ordering condition. Each typological category will be described in more detail below.

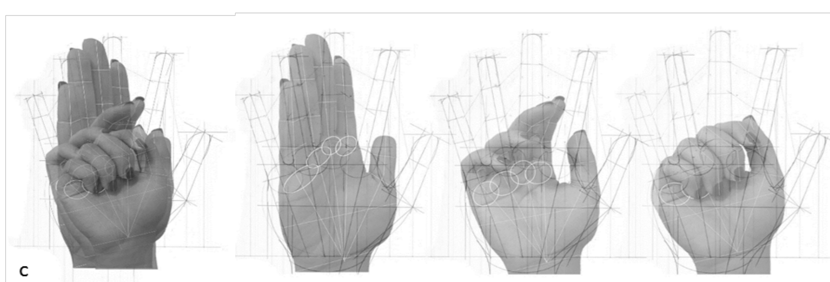
3.2.1.1. ***A - translational-transactional tasks***

In the translational-transactional type, the principles and qualities of a given, extant object are observed, studied, examined, analyzed, abstracted, and ordered as acts of translation, by the student. Discovered qualities or extracted principles are then extended transactionally to order something new (a designed thing). There are two different modes in which the translation occurs: two dimensional (graphic) and three dimensional (spatial). As an example, a "study of a hand" was assessed as being translational-transactional in that the study progresses through a process of analysis to a process of creation of a new "object of the hand." The initial step of this overall process entails the study and documentation of the hand, which can be done via sketching or photography. The next part of the study entails discovery of underlying systems of order or principles[38]. In this case, the study of the hand and its actions were engaged by drawings layered with photographs to probe the limits of movement (Figure 11). In the next step, learners removed specific details of the object and distilled its critical attributes by drawing a diagram of the underlying system. Then, in the final step, learners used the system to order a new object (Figure 12).

1a. Study and observation of the hand through photography



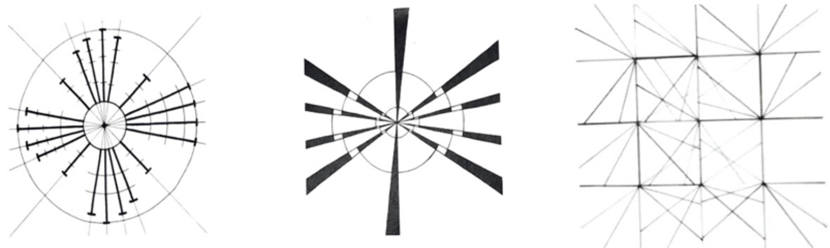
1b. Drawing – Study of order/ nested order



1c. Dynamic order of hand, action of the hand through drawing, photograph layered

Figure 11. Observation and analysis: The first phase of translation-transaction (first-year students work samples)

[38]. Ordering systems are things such as particular proportions, progression, repetition, symmetry, and so forth.



2

2. Diagramming – distilling the information – generalizing – removing specifics – identify systems

3

3. Object of the hand – stands as its own

Figure 12. Second phase of translational-transactional (first-year students' work samples)

The four steps mentioned above can be divided into two phases. Phase one, which is demonstrated in Figure 11, 1a, 1b, and 1c, is more focused on searching, investigating, and observing the object (the hand, in this example). Although metacognitive thinking can enter this phase of decision-making, the prescriptive nature of the process at this point suggests that cognition plays a more exclusive role. The analysis done in phase 1, observing the object and formulating generalizations, is deployed in phase 2 to inform a new object.

Not everything that was discovered during phase 1 is critical to the object that will be formed at the end of phase 2. Students are led to analyze the relationships among different parts of the extent object, which is done through diagramming, and make decisions (reflective process control) regarding which elements to utilize for their design in phase 2. Diagramming, an act of translation, moves the object from its pictorial form to a set of abstracted relationships. Therefore, metacognitive thinking and specifically metacognitive awareness through *reflective process monitoring* is likely more important in this phase. The analysis in phase 1 is more focused on observing and recording the qualities of the given object, and in early stages of phase 2, the focus is on quantifying the qualities discovered in phase 1.

3.2.1.2. ***B - Material, tool, and form tasks***

The discovery of the inherent nature of a given material is a critical component of the making process in this category of tasks. Here, the student engages in a direct action with the material-- engaging the material directly by hand or tool-- that leads to a conception of the material and its direct potential relative to form-making. The critical engagement of the material in this situation is defined as finding true expressions or manipulations, relative to the material's latent potential qualities, as opposed to the imposition of form onto the material. Figure 13 shows examples of a learning-task that was given to students as the Foundation Design Competition in 2005, and in 2012. The design learning-task instructed students to:

With one entire sheet of Bristol

19" x 24"

no more, no less

CRAFT A WORK OF PLAY

Similar exercises are given to students throughout the school year where they use different materials such as wood, plaster, string, glass, and so forth. The goal of these exercises is discerning potential and inherent material properties in tandem with intellectual positions. The examples provided are significantly different. In example (a), the material goes through a transformative process, which is an unusual case for this category of learning-task. This transformation exposes the material's latent quality; paper, when cut thin, curls. An Interwoven sphere is created by collecting the thinly cut strips of paper. In this example, paper loses one of its dimensions, which is one of its inherent traits. On the other hand, in example (b), the sheet of paper has kept its integrity; it is still a discernable sheet of paper with its original dimensions. The design, made with repetitive cutting and folding, demonstrates the possible depth of a thin sheet through its simple form found through a deliberate and thoughtful approach. These two examples demonstrate the variations in students' responses to the same learning-task.

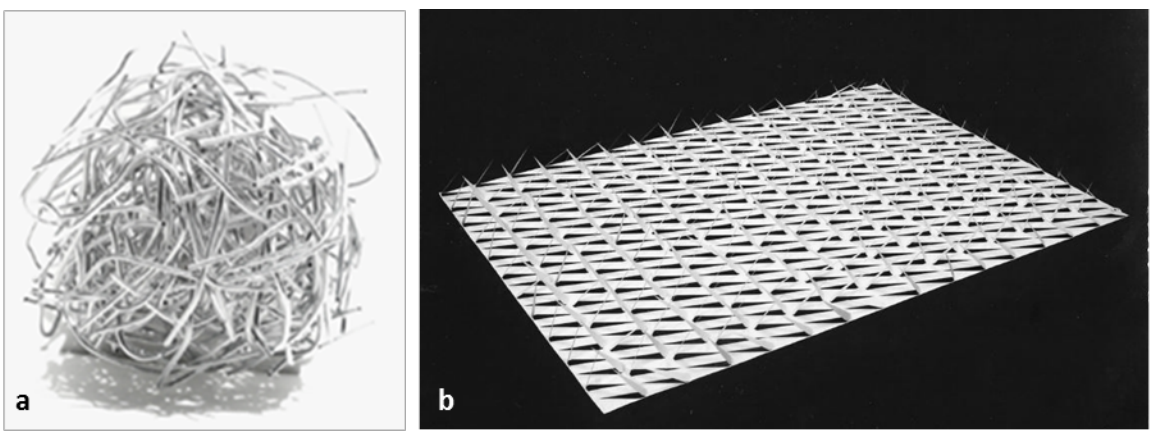


Figure 13. Response to a material, tool, and form learning-task, Foundation Design Lab (first-year student work sample 2005, 2012 competitions)

In this category of learning-tasks, students engage in metacognitive thinking by extracting the particular properties and characteristics of different materials. Students test and monitor how different materials respond to different processes, like cutting or folding in these cases, and develop a comprehensive knowledge regarding materials, and how tools may be utilized for articulating different materials. This approach encourages students to extract an inherent quality of a material and thus students become critical thinkers within the design world.

3.2.1.3. ***C - Ordering condition tasks***

Ordering conditions, as applied to such things as spatial boundaries, conceptual organizations, or sets of elements, are studied through making overt challenges to a given order and consequent engagement of an order's essential condition in this task type. Here, the design process often cycles through two-dimensional and three-dimensional studies so as to understand the system or conditions of an order. This design situation is formulated from an indirect approach, for example, in the concept organization study (see Figure 14), an iterative process was used that involved positioning two linear, two planar, and two volumetric components of varying dimensions within an eight cubic-inch boundary. As the process progressed, new additions and limitations were introduced by the professor, such as the integration of a cylindrical volume.

Each student was asked to utilize a master grid in which each modular design was in sequence with an overlaying order that began to appear as each individual design developed in relation to the preceding designs.

For this learning-task, each student supported his/her models with 2D and 3D drawings, and their work process roll[39], which depict the whole process of design, from beginning to end. An example of such a process is shown in Figure 14.

The purpose of the added elements was to help students to engage in metacognitive thinking by challenging students' understanding of their created spatial order when faced with change. The objective behind this task was to challenge students with changing conditions and improve their understanding of a regulating system. In order for students to successfully

[39]. The roll is the linear piece of paper, which is used in foundation to record the sequences of the design actions undertaken by students.

implement changes, they have to use *reflective process monitoring* and reflective process control to identify the parts of the design that need to be changed in response to a new requirement, and adjusting to those changes relative to the given grid order. This is an iterative process where students use *reflective process monitoring* to analyze and understand the ordering property of the grid, and reflective process control to make the appropriate decisions.

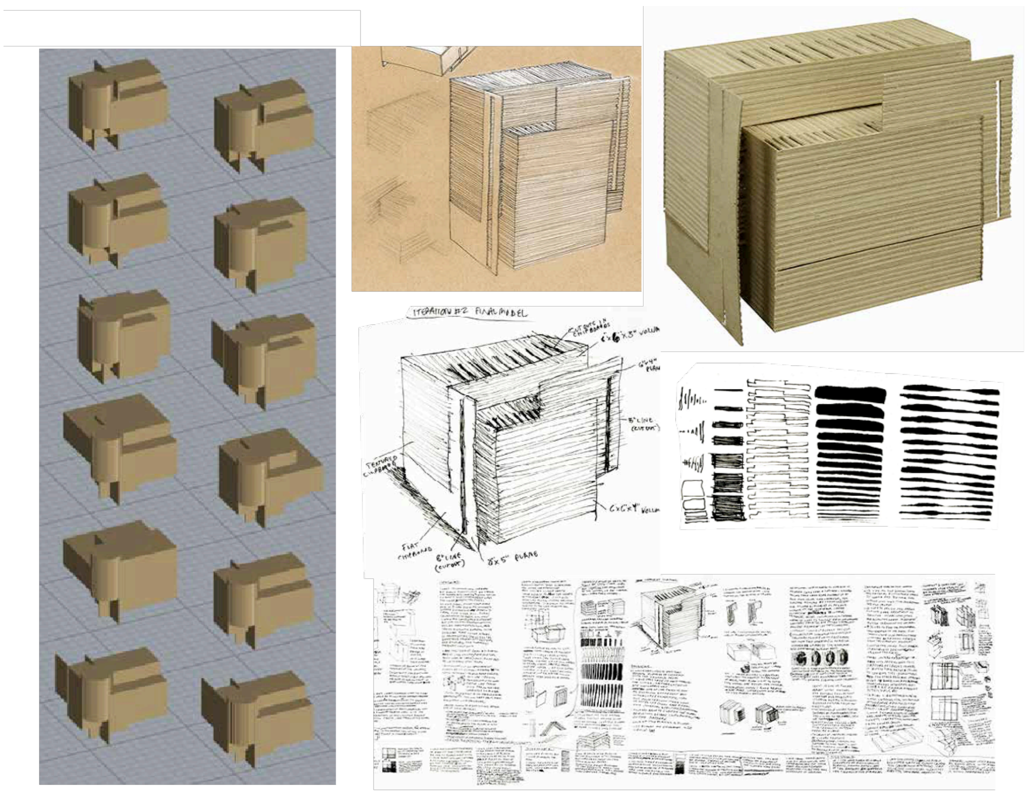


Figure 14. Examples of concept organization through 2 dimensional to 3 dimensional form with the roll, to drawing, to model (first-year student work sample)

3.2.2. **Learning processes**

The second category of learning methods is the learning process. At Virginia Tech, it is necessary to identify learning processes in addition to learning-tasks. Here, learning processes are embedded in every learning-task to build each student's intellectual and metacognitive abilities and expand their worldview in design. This category of learning methods encompasses:

discourse, skills, and iteration. In the following subsections, each of these subcategories are explained in detail.

Each learning process type helps students engage in metacognitive thinking at a personal or communal level. As students are engaged in building their individual skills or engaging in communal discussions, they engage in critical thinking regarding how new information may contribute to their projects. Iteration is metacognitive by nature. To improve the design within each iteration, students need to engage in *reflective process monitoring* (identifying what can be improved) and reflective process control (making the changes that improve the design).

3.2.2.1. *A-Discourse*

In this category, the intent of the professor is to develop a student's capacity to identify and articulate approaches to design thinking. This learning process's objective is to discuss overtly the broader implications of design and creativity with the students. The most visible form of such discourse is that which takes place once a week where all Foundation Design students gather for a talk and discussion. Sometimes there is a guest lecturer from various disciplinary backgrounds, such as the poet Nikki Giovanni[40] or musicians David Ehrlich[41] and Kent Holliday[42]. More intimate discourses take place in the Foundation Design Lab. The nature of the studio setting, as described in Section 3.6, promotes constant discussions among students of all years and faculties across programs, regarding all matter of design, individual to universal. This is not

[40]. Nikki Giovanni is an American poet, writer, commentator, activist, and educator. She is one of the world's most well-known African American poets.

[41]. David Ehrlich is a Violinist with the Tel Aviv Chamber Orchestra. Since 2004, Ehrlich has served as the Outreach Fellow of Fine Arts at Virginia Tech.

[42]. Kent Holliday is musician and has been a faculty member at Virginia Tech School of Performing Arts for more than 40 years.

brainstorming to make a project, but it is a communal environment to build the intellectual capacity of students and their knowledge through unexpected discourse, and thus, expand their world view relative to design. This also helps students see ideas outside of their particular disciplines, in areas such as philosophy, theories, politics, society, so forth, and expand their ability to discern and critique ideas.

3.2.2.2. ***B-Skills***

Skill building is not often[43] an end in itself, but part of a larger project[44]. The Oxford Dictionary has multiple definitions for skill; the two that relate to this study are: 1) *Reason as a faculty of the mind; the power of discrimination*. 2) *Capability of accomplishing something with precision and certainty; practical knowledge in combination with ability; cleverness, expertness. Also, an ability to perform a function, acquired or learned with practice*. The approach of the Foundation Design Lab is a combination of these two definitions, teaching students how to think critically (first definition), while increasing their expertise in very specific aspects of practical learning, i.e. controlling the pencil or using a snap-blade knife.

3.2.2.3. ***C-Iteration***

A logical response is repeated based on the outcome of a previous application; this serves as a means of deriving closer approximations for the solutions of problems through succession. Iteration is a design methodology which is based on a process that is cyclic, and it is used in prototyping, testing, analyzing, and redefining a process or product. Changes are made on a product or a process according to the outcomes of a prior test of a design. The main aim of the

[43]. Some faculty members make the skills task stand-alone; others embed the development of skills in other learning-tasks.
[44]. Projects have a longer duration relative to exercises; a project usually contains multiple tasks and exercises.

process of iteration is to improve the functionality and intelligence of the design. There are many ways through which these processes are presented; they can be found in students' sketch books, rolls, or sequenced models, as illustrated in Figure 15.

Figure 15. Six sequential iterations by one student as an example of an iterative (first-year student work sample)

3.2.3. **Rationale for selection of learning-task**

In this study, to collect the necessary data, three learning-tasks were used. The three learning-tasks were completed during the Foundation Design Lab (Fall 2015 – Spring 2016) for first-year design students (task 1 at the end of the first semester, task 2 at the beginning of the second semester, and task 3 about 10 weeks into the second semester).

As mentioned prior, the learning-task selected for the purpose of this study has significant influence on the type of data collected. The selection of the learning-task was done based on three major criteria (Goos & Galbraith, 1996):

- The projects had to be relevant to a prior learning-task.

• The projects had to be challenging enough to require, and elicit, metacognitive action, while simultaneously being within the capacity of the students to solve with existing design ability; and

• The learning-tasks needed to contain a blend of open-ended problems and routine exercises, to require the imagination/thinking of each student and individual, while being within a student's existing knowledge, so that initial success on the latter will help put students at ease with the former.

Although all the students started learning-tasks from the same point, because of the ambiguous and open-ended nature of the tasks along the design process, each individual formulated the learning-task differently, and each learning-task can be thought of as a "*point of departure*"[45].

3.2.3.1. ***Learning-tasks***

In the first learning-task, students were asked to look back to some design exercise that was undertaken near the beginning of the semester, reflect on its content, to develop an exercise/design related to the earlier exercises (the list of questions that students formulated is provided in Appendix F). As students proceeded through this exercise, it is inevitable that they engaged in metacognitive thinking about how they would have completed each task if they had the knowledge/experience that they have now. Perkins (1992) also emphasizes "problem finding" learning-tasks as a way to develop creativity in students. This also gives students a new

[45]. Inspiration from Salahuddin Choudhury, Foundation Design Lab professor at Virginia Tech

insight to evaluate how each decision they made led to success or failure. In her paper, Tanner (2012), has called this approach "retrospective post-assessments."

In this design learning-task, each student worked on designing and developing a new project through successive sketches. Students were asked to use freehand sketches or sketch models as a tool for designing. See more detail about first task in Figure 16. The first learning-task inherently required metacognitive thinking. Since students selected their own task to work on, they were free to choose from any of the previously mentioned learning-task types, translational-transactional, material, tool and form, or ordering condition. Students were able to independently formulate a question, and present their solution using 2-D and 3-D models. Because of the open-ended nature of the task, and since students formulated their own questions, the responses are diverse. Examples of students' designs are provided in section 3.7.3.

"Drawing Out a Question"

How do the projects of the semester open a question – What are the projects working on?
Read the projects to determine a thread –
Assess the work of the semester to draw out a question that is suggested by this examination
– this question should be used to create a project that conclude the semester.
Presentation, Wednesday, December 9th.
The prompts listed below may help with this investigation—what is the ...
quality
quantity
relation
where – place
when – time
action—what is it doing
how is being acted upon
what does it possess
order-what are the relation of the parts

Figure 16. First learning-task explanation

In the second learning-task, students were asked to form groups of two. Each pair was given a 22″ x 30″ sheet of 2-ply Bristol board and was asked to "make three changes" in 3 hours. The second learning-task encouraged students to reflect on their design process, and focused more on material, tool and form and ordering condition types of learning-tasks. Metacognitive data was collected through discourse between student groups during and after design work.

For the third learning-task, all first-year design students participate in the yearly first-year design competition[46]. In 2016, the students had over a week to complete a learning-task: "Demonstrate the Promise of Repetition." This task was developed for the competition in a discussion meeting by the Foundation Design professors, and is of the third learning-task category (Ordering Condition). Even though students' metacognitive thinking was not monitored and analyzed during the design learning-task, the students were asked to answer a

[46]. The competition is held annually in the School of Architecture + Design at Virginia Tech

questionnaire (Appendix G), after completing the design task that included their reflections about issues associated with the design task that changed or developed their perception of their judgment and ability during the learning-task. The answers provided the researcher with the means to understand the students' evaluation and development of metacognitive thinking.

3.3. Data Collection Methods

This section contains a detailed discussion of all the data collection methods used for the purpose of this research. Based on the literature reviewed and the results from the pilot study, the researcher employed a set of data collection methods: verbalization methods, elicited texts, card-sorting, and surveys to acquire the data (see section 2.8). The purpose of using a combination of methodological approaches is to enhance triangulation, and to boost the rigor and trustworthiness of the data, while reducing the influence of the researcher's bias.

3.3.1. Pilot study

The researcher conducted a pilot study to become familiar with various data collection methods and techniques and their respective advantages and disadvantages. The pilot study was conducted with second year design students at the beginning of the Fall semester 2014 (see Appendix A for IRB approval). The data collection methods that the researcher used in the pilot study were to interview students while they were working on their learning-task, and also after they completed the task. Interrupting students while they were working was counterproductive in that it would break students' thought process; interviewing students after the completion of the task had the disadvantage of information being lost due to the time interval between finishing the task and being interviewed. The researcher concluded that the best method to gather information for the study was retrospective and concurrent verbalization. Thus, the researcher used video/audio recordings of students as they were engaged in the design task, to refresh their memory while being interviewed. More details regarding the methods used for the study are provided in following sections.

The researcher also used card-sorting in the pilot study, which included giving students 14 cards with sentences written on them and asking students to order the cards based on their thought processes. Students could eliminate any card that they wanted, or write on blank cards if a particular process they felt was important was not included in the cards. The researcher concluded that the card-sorting method revealed student thought processes, so this was used for the study as well.

3.3.2. **Verbalization methods**

This study used two forms of verbalization, concurrent and retrospective, "*as a tool or a virtual window into the mind*" of the student (Dunlosky & Metcalfe, 2009, p.15). In retrospective verbalization students are interviewed after the completion of the learning-task, while watching the recorded video of themselves engaged with the learning-task. Video-stimulated recall enhances participants' memory while being interviewed; thinking cues were also provided to stimulate students' memory in describing their thinking processes.

In concurrent verbalization, students were not interviewed upon the completion of the learning-task. Instead their thought processes were recorded as they thought aloud or engaged in discussions with their teammates while undertaking the task. The concurrent verbalization method reduces the interval between students' action and its verbalization.

These tasks took place in the Foundation Design Lab of Virginia Tech's School of Architecture and Design. The researcher employed two learning-tasks in this research. The first learning-task used retrospective verbalization, and the second learning-task used concurrent verbalization. In learning-task one, two videos were used. The first video captured the students' actions while engaged in learning-task one (See Figure 17). The second video recorded the interview between the researcher and the student (see Figure 18).

Figure 17. Example, camera view from the first learning-task

The retrospective verbalization was used to avoid interfering with the student's thought processes while engaged in the learning-task. The researcher asked the students to explain "what they were doing and why," while watching the first video. The researcher intended to use students' points of view and experiences about the learning phenomena and quote them as part of the data analysis. While the students were watching the videotape of their behaviors, they were asked to recall and report what they were thinking while they were engaged in the learning-task. They were permitted to stop the tape and replay whenever they felt their report was lagging behind the video, until the end of the reporting exercise. Thus, the duration of the reporting for each student was dependent on the student’s speed and ability to move at the same pace with the videotape. The voices of the students were recorded alongside a video recording of their sketch screen through which their pointing gestures could be seen and recorded.

The best way to ensure the trustworthiness of data is to record the actions of students while engaged in the learning-tasks and then transcribe it from tape to text. Once the verbal data is transferred into text, content analysis is used to extract the underlying thought processes.

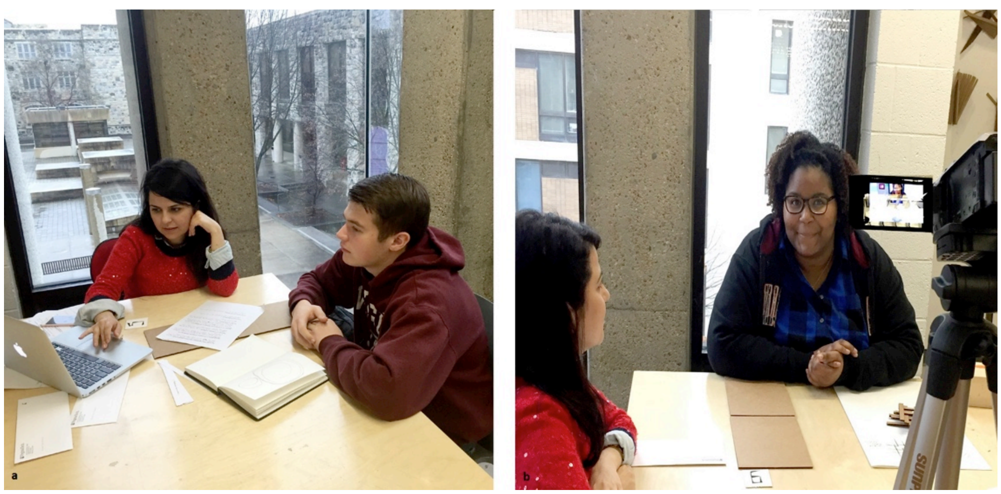


Figure 18. Session environment, retrospective verbalization. Researcher engages with students while watching video. A) watching the video, b) being recorded while talking about her process

Following the retrospective verbalization method, the researcher asked students three follow-up questions. Students’ answers to these questions were used to obtain supplementary information. This method of data collection has the potential of obtaining rich information by asking students additional questions. Figure 19 provides an example of the interview environment.

Figure 19. student interviews while they reflect on their design process using a variety of media a) 3D model, b) interview student regarding changes in strategy, c) roll, and d) 3D model

In the first learning-task, after the retrospective verbalization was completed, students were asked a series of questions (Q1 – Q3) to complement the description of their thinking process. Since the topic under examination is metacognition, the interviewees were allowed to naturally discuss their mental process (Peirce, 2003).

Q1. How did you actually approach your design task (strategies used to solve your design problem)?

Q2. Did you use any specific strategy that you think was successful?

Q3. Did you do your design task differently from what you are used to?

Question 1 intends to gather general information regarding students' approaches and strategies; asking the question specifically gives the researcher the opportunity to better differentiate between the approaches that students use. The second question examines students' metacognitive awareness regarding their strategies and judgment of the outcomes (goals and how they can be achieved). The third question is to identify if being under study influenced their normal processes to ensure that the phenomena under study is as natural as possible.

To counter the notion that retrospective verbal reports may not be sufficient enough to reveal a deep level of metacognitive processing, in concurrent verbalization, the students were not asked to analyze their statements but were asked to verbally express their thoughts while engaging in the process of learning. This is the reason why, for the second learning-task, students were asked to work in pairs.

In this way the verbalization is more like thinking aloud and does not involve a post action analysis or explanation. The researcher analyzes the recorded verbalization to determine the type of thinking that is occurring. learning-task 2 uses concurrent verbalization. Students were assigned the learning-task in pairs and worked together to prepare a design. The conversations were video recorded while students were engaged in the learning-task (concurrent verbalization). Similar to the retrospective verbalization data, the video recordings were transcribed and content analysis was used to extract the underlying thought processes from the transcriptions.

The students were not asked to decide if their thoughts were cognitive, metacognitive or emotional; all they were asked to do was to verbalize their thoughts while learning. The categorizations emerged from the data analysis, not from the students.

Thus, objectives of the research were clearly explained to the students and they were to understand that the researcher was in need of a natural thought processing, which occurred during the process of learning. The researcher informed the students that every form of thought was needed for the study, be it emotional, physical or any other thing they thought of during the learning process.

In the second learning-task (Figure 20), the use of a think-aloud protocols were employed because there was need for the members of each group to communicate, share ideas and make decisions about the design process together. Students were asked to review and confirm the transcriptions to ensure that the data collected were accurate. The downside of video recording the group effort was that the audio at some points was not clear and it took the researcher more time to separate the voice of each pair in the transcriptions.

Figure 20. Session environment, concurrent verbalization

3.3.3. **Elicited texts**

The researcher also asked students to write a bulleted report containing a brief description of their process for their first and second learning experiences. The researcher also used a series of questionnaires to acquire additional information regarding students' metacognitive thinking process.

At the beginning of the first learning-task, the researcher asked students to respond to these two open-ended questions before engaging with their design task: 1) Have you had a similar design experience before? Could you please share it with us? And 2) How will you resolve the situation? Students' responses were used in conjunction with data collected from their retrospective verbalization and card-sorting to further understand their thought processes (for more information see Section 5.1.5).

Furthermore, to evaluate students' metacognitive changes they were provided a questionnaire with two open-ended questions at the end of each of the two learning-tasks: "From the initiation of the task to its completion, has your perception about your ability to develop this design task changed?" and "From the initiation of the task to its completion, did your strategies change?" Student responses were coded and analyzed (more details in section 5.2.2), and the results were used to deductively and inductively develop the framework for the questionnaire that was provided to students at the end of the third learning-task.

The research also provided students with a Bristol board to be used for their sketching, instead of their personal sketch books. The sketches were collected at the end of each learning-task session to be used as a resource that shows the evolution of students' models. The information obtained from these elicited texts has been used to supplement the data obtained from other data collection methods in providing insight into how metacognition effects student's performance. Figure 21 provides samples of each of the texts mentioned above.

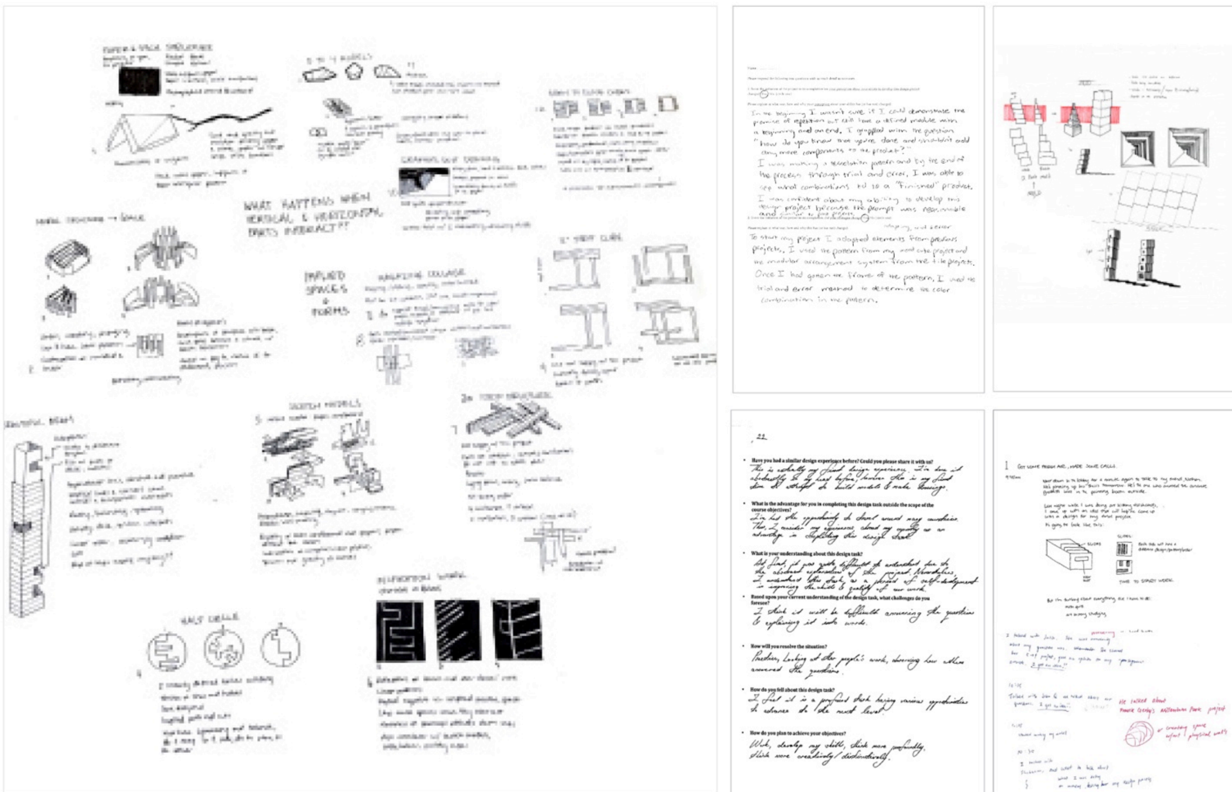


Figure 21. Examples of elicited texts (first-year students work samples)

3.3.4. **Card-sorting**

Fourteen metacognitive action statements (or action cards), each associated with one of the three metacognitive components (*reflective process knowledge*, *reflective process monitoring* and Reflective Process Control), were printed on cards. These metacognitive components have been transformed from the original literature that they were extracted from to align the results obtained from this exercise with the research framework established in the literature review chapter. Furthermore, blank cards were provided to enable students to describe and record a particular metacognitive activity when they felt it was not represented on any of the pre-printed cards. As mentioned earlier, one of the major concerns associate with card sorting is the danger of leading the students to conclusions other than their own. In this research, significant effort has been made to minimize the possibility. The statements on the cards (e.g., I thought about what I already know) are initially drawn from the literature on metacognition, and later revised for use in this study. Table 5 provides the list of pre-printed cards that were given to students.

Table 5. Classification of metacognitive action card (adopted from Wilson & Clarke, 2004)

Metacognitive action card	Component of Metacognition
I thought about what I already know	Reflective Process Knowledge
I tried to remember if I had ever done a problem like this before	Reflective Process Knowledge
I thought about something I had done another time that had been helpful	Reflective Process Knowledge
I thought 'I know what to do'	Reflective Process Knowledge
I thought 'I know this sort of problem'	Reflective Process Knowledge
I thought about how I was going	Reflective Process Monitoring
I thought 'Is this right?'	Reflective Process Monitoring
I thought about whether what I was doing was working	Reflective Process Monitoring
I checked my work as I was working	Reflective Process Monitoring
I thought 'I can't do it'	Reflective Process Monitoring

Metacognitive action card	Component of Metacognition
I made a plan to work it out	Reflective Process Control
I thought about a different way to solve the problem	Reflective Process Control
I thought about what I would do next	Reflective Process Control
I changed the way I was working	Reflective Process Control

The card-sorting occurred happened after the retrospective verbalization; students were asked to point to the particular card that represented their thinking and behavior at each moment of the learning-task process. To ensure that the students' card sequences were an accurate representation of their thinking, students were given the opportunity to rewind, or pause the video as many times as they needed while they were sorting the cards. Figure 22 shows an example of the setting in which the card-sorting exercise was executed.

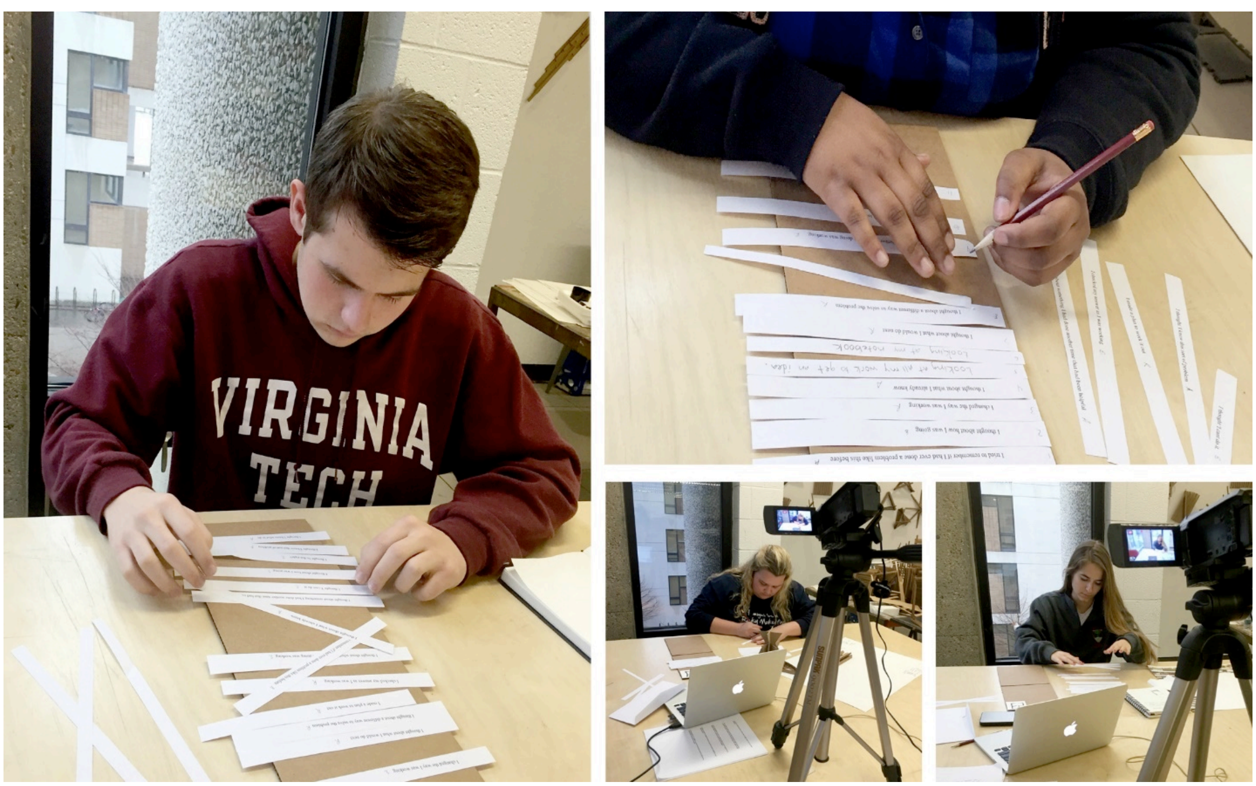


Figure 22. Card-sorting exercise environment

3.4. Participant selections

This study examines the occurrence and effect of metacognition and cognition, as well as other types of thought processes in Foundation Design learning. Foundation Design Lab was selected for the purpose of this study because research has revealed that since high school environments typically do not encourage metacognitive behavior, first-year students are generally unaware of their own metacognitive strengths and strategies (Matanzo & Harris, 1999). Many of the first-year students come from non-design backgrounds with little understanding of the cognitive processes that occur during creative thought processes. The fact that they have not been influenced by the pedagogy of higher education and many other additional environmental factors influencing their thought process makes it easier for the researcher to identify the metacognition that takes place during architectural design (reflective practice) in the Foundation Design Lab. The researcher's experience from the pilot study, which was conducted with second-year students, also confirms the selection of first-year design students for the purpose of this study. First-year students are more suitable for the study for two main reasons:

1) Completing a task with the complexity levels of the tasks used in the pilot study requires a high level of skill, experience and knowledge, which resulted in many additional factors influencing students' thought processes, thus, over-complicating the students' metacognition process.
2) On the other hand, completing a task with lower complexity levels was well within second year students' domain knowledge, and since knowledge at the object level was sufficient they did not need metacognitive monitoring and task control (Winne, 1996)

For this study, one Foundation Design lab consisting of 23 students was selected out of the 10 Foundation Design laboratories. The class was selected based on the fact that the researcher had more access to observe the students. Since the researcher was also the teaching assistant to the professor of the class, the researcher had the opportunity to observe students while they were engaged in design activities for two semesters (over 33 weeks), thereby gaining a better understanding of the phenomena.

Toward the end of the fall semester in 2015, the students in the selected class were asked to participate in this research, and all the 23 students agreed to participate (task 1). At the beginning of the spring semester, students were again asked to participate in another study in which 19 out of the 23 students were present and agreed to participate (task 2). Ten weeks into the spring semester the entire 206 students that were enrolled in the Foundation Design Lab were asked to participate in the study by filling a questionnaire regarding their thought process after they submitted their models for the first-year design competition (task 3).

Purposive sampling[47] was used to select the participants of this study; this involves "*selecting groups or categories to study on the basis of their relevance to your research questions*" (Mason, 1996, p.93-94).

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[47]. Purposive is the process of selecting the study population, which will provide rich information about the topic under examination. In simple terms, theoretical sampling implies seeking relevant data for the development of an emerging theory. The main aim of theoretical sampling is for the refinement and elaboration of the categories that make up the emerging theory. Theoretical sampling is closely associated with the grounded theory method.

3.5. Ethical approval

Due to the nature of the foundation design learning course, the researcher was able to incorporate data collection into the class-work of this course. Ethical approval was provided by the Institutional Review Board (IRB). (See Appendix B and C)

At the beginning of the course, students were informed that they had the option of participating in a research project. The students were made aware that their participation in the study was voluntary and that their participation would not affect their academic assessment and performance. The researcher also informed the students that "any data collected from them would be treated in confidentiality and every effort will be made to avoid exposing them to any form of harm." To protect students' identity and ensure confidentiality, pseudonyms were used during the data collection, transcription, and analysis. The researcher also informed the students that they were going to be under observation (video, audio and in-person observation) and some of their designs will be examined by the researcher. Afterward, the consent form (Appendix C) and photo release (Appendix E) were given to each student to sign.

3.6. Research setting

The setting of this research was the Foundation Design Lab as a community of practice [48] located in the School of Architecture + Design at Virginia Tech, at Cowgill Hall. Choosing the Foundation Design Lab as the setting for this research not only provides more convenience for

[48]. Wenger et al. (2002) describe CoP's as: '*Groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in the area by interacting on an ongoing basis'* (p. 4).

the researcher as the space is readily available, it also has the benefit of being students' natural setting, which limits the influence of any external factors on the collected data. Figure 23 demonstrate the schematic view of students' desks in the lab environment. In this setting, students from different cultural backgrounds and identities form a community where they learn to become independent and creative designers.

Figure 23. Students' desk layout

All first-year architecture, industrial design, interior design, and landscape architecture majors learn together in the Foundation Design Lab. The focus of the Design Lab is not on the professional design of any of the professional disciplines, but rather the first-year focuses on the basic elements of design, addressed visually and conceptually in two and three dimensions through the application of different materials and tools (Kavousi & Miller, 2014).

3.7. Data Analysis Procedure

The conclusions of this research are based on numerical, verbal (oral or written), experiential (video or notes about students' in action), and artifactual (objects like the sketch model, and model) evidence. Students' metacognitive design process can be documented and described through the use of Verbal Protocol Analysis (VPA). When using this method, students are interviewed after the completion or are required to think aloud while engaging in a reflective learning-task; both collectively and individually.

Formal and informal approaches have been previously used in protocol analysis for design process. Design is regarded as a rational process of problem-solving through "solution space" in formal protocol analysis (Suwa & Tversky, 1997). The main objective of formal protocol analysis is to provide a description of design in terms of basic problem-solving taxonomy (i.e. plans, operators, goals, states of problems, and strategies), while coming up with design methodology outcomes that can be generalized. On the other hand, in informal analysis design is considered as a process whereby the reality of a designer is constructed by his/her own actions that are responsive, opportunistic and reflective to the design state (Dorst & Dijkhuis, 1996). Classical examples of this informal analysis are the works of Schön (1983) on "designer as a reflective practitioner" and Goldschmidt's (1991) on the design cycle of "seeing-as" and "seeing-that" or Suwa and Tversky's work (1997) on design process as composed of cycles of focus shifts and continuing thoughts. In their study, Suwa and Tversky employed the use of informal analysis to reveal the way each cycle of focus shifts and continuing thoughts are guided by students' actions. Thus, their study views the process of design as a process of metacognition, which is made up of cycles of focus shift, and continuous thoughts, which are related and defined, from a metacognition perspective.

All the verbal protocols for each student were encoded into subclasses of information categories. Data analysis was performed simultaneously with data collection. Simultaneous data collection and analysis allow the researcher to make adjustments along the way, even to the point of redirecting data collection, and to test emerging concepts, themes, and categories against subsequent data (Merriam, 2002). Therefore, in this study one part of the results from the first learning-task was tested through survey in the second and third learning-tasks. By the use of questionnaires, the researcher was able to confirm the findings through triangulation.

Data analysis is a similar process of sorting, categorizing, grouping, and regrouping the data into piles or chunks that are meaningful (Rossman and Rallis, 2003). The researcher used a thematic data analysis process to develop an understanding of the data, and identify common themes that arose from the investigation. Themes were generated through the interpretation of the data in light of the literature reviewed, the research questions, and author's personal knowledge and intuition.

Data collected from the study were consolidated, transcribed, and subsequently coded using multiple layers of nodes in NVivo (see section 3.7.1). Denzin and Lincoln (2005) stated that some programs such as NVivo are appropriate to provide good support for coding. Coding forces the researcher to make judgments about the meanings of the text. The results from analysis of the data are presented in the form of common themes identified, which enhance the understanding of the metacognition process of learning and its interaction with other forms of conscious thought processing in design students. Themes chosen are abstract constructs that the researcher identifies before, during, and after data collection.

NVivo provides nodes[49] for keeping track of emerging and developing ideas, and for organizing data. The researcher used as many nodes as possible to ensure a thorough examination of the data. At each node, relevant text was coded using “structure” and “In vivo” coding. Occasionally “In vivo” quotations were picked up directly from the text and used as nodes. This process is carried on with all the texts in all of students’ transcription. When completed, the researcher has all the relevant texts coded at nodes. Nodes are used to catalogue categories and subcategories for ease of access and help the researcher clarify the concept (Richards, 1999).

The main method for the analysis in this study are the verbal protocols in which words, phrases and sentences are analyzed as proof of each subclass of information categories. When supplementing verbal protocols, ambiguous phrases should be augmented with interpretations (Suwa & Tversky, 1997). Therefore, this study employed the use of visual data from videotapes during the reporting portion of the research as a means of clarifying ambiguous statements. Also, with the help of visual data some information that was omitted in the students’ reports were revealed.

At the final stage of data analysis, a comparison of students’ varying metacognitive process of design thinking was completed based on the final findings so as to examine the possible associations between certain metacognitive patterns and student achievements (High-

[49]. A node is a collection of references about a specific theme, place, person or other area of interest.

performance (HP) - low-performance(LP)) (Figure 24). Thus, the use of cross-evaluation process was employed in order to validate the evaluations of the students' design projects (see section 3.7.3)

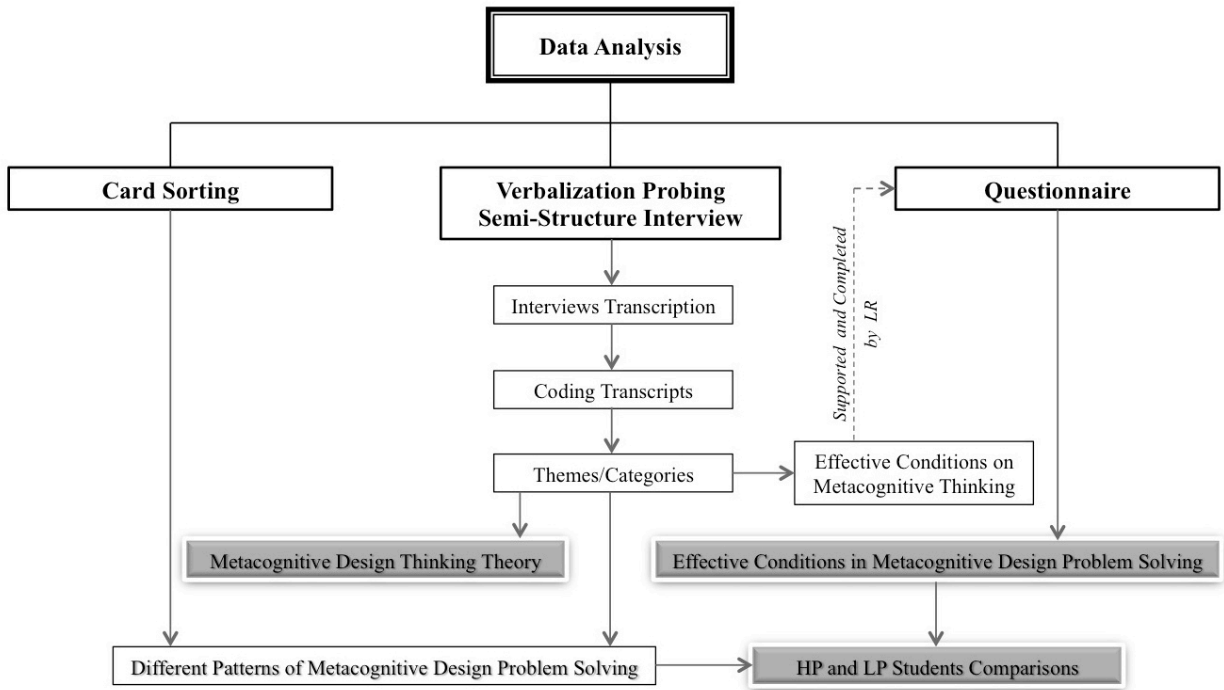

Figure 24. Data analysis procedure diagram

Note. *High Performance: HP, Low-Performance: LP, Literature Review: LR*

3.7.1. **Coding software**

In this study, data was transcribed from 37 hours (8 hours of interviews and 2 hours of presentations for the first learning-task, and 27 hours of think-aloud for the second learning-task of video and audio recordings into Microsoft Word and then transferred into the Qualitative Data Management software NVivo 11 plus, which facilitated the organization and analysis of the data. When working with large amounts of data, organization becomes a crucial factor in analysis. NVivo provided the platform to create the coding structure and the necessary functionality to modify the "nodes", combine multiple nodes into one, or break a node into multiple nodes. NVivo is a vital tool that assists the researcher in code segments of the transcriptions, linking research notes to codes, performing complex search operations, and helping examine possible relationships among the themes. The software also provides multiple reporting functionality where subsections of the data could be visualized within the software or exported to software packages like Microsoft Excel. The only problem that the researcher encountered while using the software was frequent crashes, which in many instances resulted in loss of work.

3.7.2. **Coding process**

In grounded theory the coding process is cyclical; the researcher must go back and forth in the data, hence, it should not be explained as a chronological or linear process. In this section, the process that the researcher employed to develop the codes is described. The data analysis framework for this research was adopted from Charmaz's (2006) constructivist grounded theory research framework (see section 2.7.2). In grounded theory the coding process starts with the end of the first learning-task and continues until the generation of the theory. The coding process for this research can be divided into three phases: initial, focused, and theoretical coding.

The initial phase started at the end of the data collection for the first learning-task; the interviews were transcribed. The transcriptions were then analyzed line-by-line to extract "action verbs and nouns." Action verbs are statements that clearly explain a single action, regardless of the length of the statement. The next step in this process is to define each code while keeping in mind that the definitions have to have these two characteristics: 1) narrowed down to only include a specific action, and 2) encompass all the thought processes in that code.

The next step in the coding process is focus coding. Charmaz (2006) defines focus coding as the coding process that follows the initial coding and involves developing the most relevant categories from the initial codes that analytically make the most sense. The action verbs and nouns that were developed as the result of the initial coding process were carefully analyzed to identify similarities and were accordingly categorized. Similarly, to the initial coding process, focus coding is an iterative process, which involves revisiting the categories and subcategories and reorganizing them.

Thematic coding is defined as "*how the substantive codes may relate to each other as hypotheses to be integrated into a theory* (Glaser, 1978, p.72)." In other words, thematic coding is the process of finding the relationships among the categories that emerged from the focus coding and identifying a core category to move the analytic storyline that is narrated by the main categories in a theoretical direction *"* (Charmaz, 2006*)*.

In Chapter 4, this coding process is used to code the data acquired in this research. This coding process resulted in refining and expanding the theoretical framework of Pintrich, Wolters, and Baxter (2000) to address the learning process that occurs in the design lab.

3.7.3. **Participant evaluation**

Each of the three learning-tasks were evaluated by the first-year studio professor(s). For the first learning-task, participants were the students from one of the ten studio sessions; the professor for that session evaluated students' designs. The evaluations were based on the complexity of the question that they formulated (Appendix F) and a 5-minute presentation that each student gave at the end of the task, which also required students to set up their desks (Figure 25 & Figure 26).

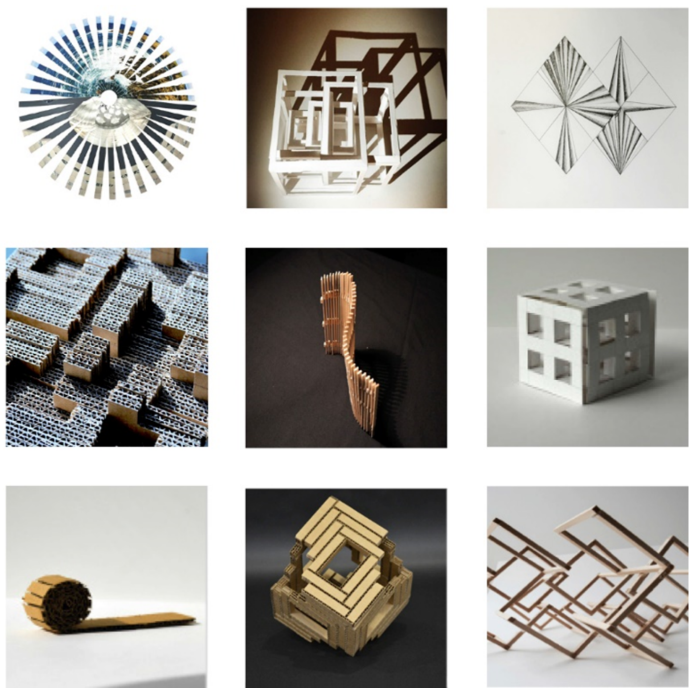

Figure 25. Examples of student submissions for the first learning-task

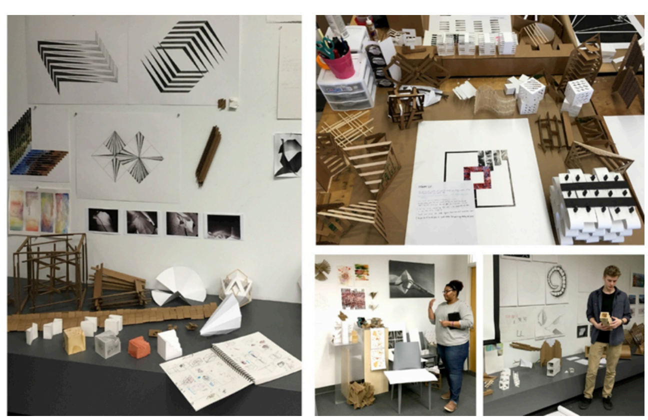

Figure 26. Examples of students presenting their designs for the first learning-task

For the second learning-task, the researcher asked three of the first-year lab professors to evaluate and rank each pair's design. As mentioned earlier, the second learning-task was a group exercise and students were divided into 9 groups, Figure 27 shows the designs developed by each group.

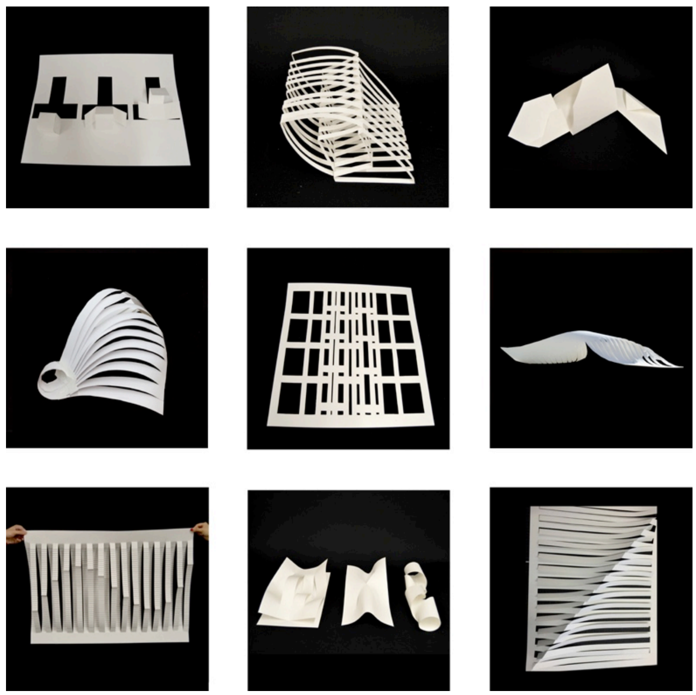

Figure 27. Example of the second learning-task project

For the third learning-task, all the ten studio professors jointly evaluated and ranked students' designs and to eliminate any bias, students' identifications were removed from their designs. The winners of the competition were announced in three categories: First award (3 students) – merit award (4 students) – honorable mentions (7 students). A selection of the designs are presented in Figure 28. The term "Leader" has been used to refer to this group of students.

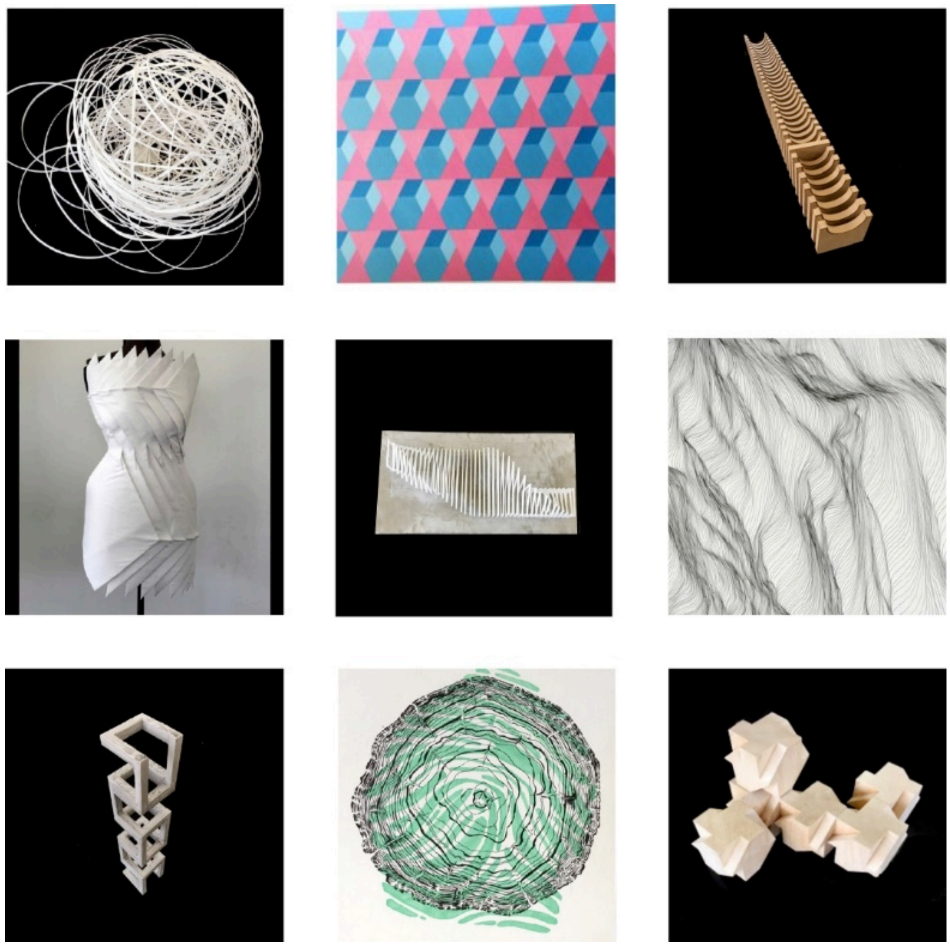

Figure 28. Examples of the designs developed by students for the third learning-task

3.8. Data Validation

In qualitative research, the data acquired is subjective and relates to human feelings and perceptions. It is important for the researcher to utilize all the available methods and techniques to ensure that the data acquired, and the analysis of the data, result in findings that are valid and trustworthy. Data validation is comprised of credibility, transferability, and dependability.

3.8.1. **Credibility**

In qualitative research, consistency between students' views and the researcher's interpretation of them are important (Koch, 2006). Dam (2008) also stresses the importance of having an external auditor in order to improve the credibility of data interpretation. In this study, the researcher has used triangulation, member checks, long-term observation, and peer examination to ensure the credibility of the findings. Table 6 provides more information regarding how each method was utilized in this study.

Table 6. Data validation techniques

Method	**Description**
Triangulation	To enhance the validity of the results, the researcher utilized multiple data collection methods (see Section 3.3).
Member Checks	After the data gathered from the verbalization methods were transcribed the researcher asked students to review the transcripts and verify their validity.
Long-term Observation	The researcher has had the opportunity to observe the students as they engage in similar learning-tasks due to her position as the teaching assistant for the class.
Peer Examination	To ensure a student's evaluation is valid, the researcher asked three of the studio professors to participate in the evaluation of student designs. In addition, the researcher discussed findings with colleagues and committee member through peer examination

3.8.2. **Transferability**

Since the main assumption in qualitative research is that the results cannot be generalized outside the research setting, the researcher needs to provide a detailed description of the research setting and provide readers with enough information so that they can judge if the results can be generalized to their situation (Lincoln and Guba, 1985). In this study, the researcher has provided a transparent view of the research setting and how the data has been analysed to enhance transferability of the results.

3.8.3. Dependability

To provide the reader with enough information to determine how dependable the results of the research are, the researcher needs to provide detailed information regarding how the data was analysed, and how the researcher arrived at the conclusions (Anfara et al., 2002). In this study the researcher has provided detailed information regarding her arguments to provide the readers with enough information to judge the reasonableness of the conclusions.

3.9. Summary

This chapter provided a detailed description of the grounded theory methodology that was used in combination with a constructivist paradigm to develop the theoretical framework for the research and guide the researcher in various phases of this research (data collection, data analysis, data validation). In section 3.2, first different learning-tasks (Translational-Transactional, Material, Tool, and Form, and Ordering Condition) and learning processes (discourse, skills, and iteration) in the Foundation Design Lab and their characteristics are provided. Then the learning-tasks that were used in the data collection process are described and the rationale for their selection is provided. In Section 3.3, various data collection tools (retrospective and concurrent verbalization, questionnaires, and card-sorting) that the researcher used to acquire the data are described. This chapter also provides the rationale for the selection of first-year Foundation Design students as the participants. Section 3.5 describes the process of getting the ethical approval for working with human subjects, and Section 3.6 provides information regarding the environment where this research took place.

After these initial topics, the researcher provided detailed information of how the collected data was analyzed using an informal analysis method to extract the shifts in students' cycles of focus that can be used to further our understanding of the process of metacognition. The final topic discussed in this chapter is regarding the processes that the researcher used to ensure that the data collected and the results obtained are valid.

4. Chapter: Development of a Metacognition Framework for Design learning

In order to understand the role of metacognition in the Foundation Design Lab, it is necessary to develop a theoretical framework to assess when metacognition is occurring. In order to develop the theoretical framework, the researcher started with the literature on metacognitive learning to determine the role it might play in Foundation Design learning; what came out of this process was a comprehensive understanding of various theoretical frameworks that have been used in the study of metacognitive thinking and the processes, such as reflecting, analyzing, drawing conclusions, and applying the findings accordingly, that was used to develop each. After this initial step, the researcher observed foundation design student behavior and activities as they were engaged in design learning and had discussions with the foundation faculty regarding the learning that was taking place in the lab. These observations and discussions indicated inherent metacognitive teaching approaches and highlighted the need to further expand the metacognitive framework with regard to design learning.

As previously mentioned in chapter 2, the researcher used a grounded theory methodology to further investigate the concept of metacognition in a first-year Design Lab at Virginia Tech. At the beginning of this process, the researcher did not have a specific hypothesis to prove or disprove but rather, the intent was to let the data define the direction of the research. The categories and the definitions were developed based upon a constant comparison methodology and constantly fine-tuned through an iterative process to a point of theoretical saturation. Theoretical saturation refers to the point that additional analysis of the data does not reveal any new information.

Based on the reviewed literature, because the framework with three main categories provides more details of metacognitive thought processing, and the initial analysis of the data showed similarities, the author started with the three categories of metacognition put forward by Pintrich, Wolters, and Baxter (2000) as the basis for her framework. In the next step, the researcher used the coding process described in Section 3.7.2 to order the data and generate the framework for this research. The application of the coding process is described below.

4.1. Application of the Coding Process

As mentioned in Section 3.7.2, the first step in the coding process (initial coding) is to extract the action verbs from the transcriptions of retrospective verbalization and the concurrent verbalization transcripts and questionnaire. In the first attempt, the coding structure was comprised of 45 distinct action verbs or nouns. These action verbs or nouns in some instances come directly from the phrases that students used, and in other instances were labels given to a phenomenon by the researcher. For example the action verb “planning” was extracted from the excerpt below. Table 7 provides the list of initial action verbs and nouns.

> *“I plan to achieve them by going back and thinking about each project, processes and all my ideas.”* (Autumn)

Table 7. List of initial codes

Discussing	Assessing	Declarative knowing	Trial and error	Evaluation
Not understanding	Choosing	Procedural Knowledge	Writing the idea	Task monitoring
Playing with the model	Controlling	Self-awareness	Writing up notes	Thinking about different alternatives
Problem-solving	Focusing	Task-awareness	Linking with prior Knowledge	Feeling confused
Making the model	Goal-Setting	Browsing	Lack of confidence	Tiredness
Reading	Planning	Chronologically ordering the experiment	Looking for inspiration	Having a break
Sketching	Regulating	Experimenting with the material	Wondering about other students	Playing with phone
Taking notes	Reviewing	Listening to the professor	Analyzing previous Knowledge	Talking to friends
Realizing	Conditional knowledge	Listing the material	Debugging strategy	Talking on the phone

After close examination of the emerged codes and their definitions, it was concluded that some categories were too broad and could be further broken down, and some categories were similar and could be combined, Table 8 provides some examples of how codes were re-allocated and ordered in the initial phase.

Table 8. Examples of initial coding changes

Initial Code	**Revised Code**
Feeling stuck Frustrated Feeling confused Feeling blank	Personal feeling of the task
Strategy knowledge	Procedural knowledge Conditional knowledge Declarative knowledge

Initial Code	Revised Code
Assessing	Assessing material Assessing friend's experiment Assessing own model
Reviewing	Reviewing previous works Reviewing friend’s experiments Reviewing the Previous Knowledge

With each iteration, the data acquired were analyzed again to move statements between codes as their definitions changed, and new data were also analyzed as it became available. This iterative process resulted in a new set of codes as listed Table 9.

Table 9. Final Initial Coding

Affective Processing	Preparing material	Conditional knowing	Procedure monitoring	Knowledge monitoring
Making model	Preparing physical environment	Declarative Knowing	Strategy monitoring	Physical process
Sketching	Choosing the idea	Procedural Knowing	Time monitoring	Physical discomfort
Browsing	Pace of doing	Self-awareness	Ask for confirmation	Tiredness
Discussing with Friend	Regulating the strategies	Task-awareness	Looking for inspiration	Unrelated behavior
Experimenting with material	Iterative -making model	Awareness of knowing	Uncertainty about the task	Having a break
Reviewing Previous Works	Following Prof's suggestion	Task analysis	Unsure how to proceed	Listening to friend's thought process
Taking notes	Inspirational environment	Task understanding	Unsure how to start	Play with phone
Thinking for solution	planning	Assessment of task difficulties	Wanting help	Spell checking

Consulting with Professor	Assigning a task	Personal feeling of performance	Wondering about other students	Talking to friends
Listening to Prof	Focusing on specific idea	Personal feeling of the task	Inspiration from another studio	Feeling of familiarity
Reading the task	prioritizing	Self-reliance	Inspiration from environment	Linking with prior Knowledge
Reflecting & Reviewing Existing Knowledge	iterative - Sketching	Lack of Confidence	Inspiration from Prof	Comprehension about Task
Writing Up Notes	iterative - Reading the Task	Confidence	Inspiration from Specific Friend	Adjusting
Control of Environment	Cognitive Strategies Knowledge	Outcome Monitoring	Inspiration from Teammate	Thinking about Different Alternatives

As was expected, given Schön's observation about design thinking, because of the nature of the thought processing in learning-tasks, students used different approaches in their designs which resulted in an uneven distribution of the codes listed in Table 9 for each student. This variation is both in terms of the codes each student used and the frequency with which they were used. Although some of the coded text did not elaborate on metacognitive thought processes, since a comprehensive study of metacognition requires examining its relationship with other types of thought processing (i.e. cognition, affective), no data were eliminated.

The next step in the coding process is focus coding, where similar action verbs are bundled together to form categories. For example, *browsing*, *listening to professor*, *experimenting with material*, *reading the task*, *sketching*, and *reviewing previous work* are all related to students' understanding of the task and not how to do the task. They were categorized under *idea generation,* which is one of the subcategories of *cognitive processing*.

Similar to the initial coding step, “focused coding” is also an iterative process in which the researcher constantly reviews the data coded under each category and where necessary, reorganizes the categories. For example, *Debugging Strategy,* which is defined as strategies used to correct comprehension and performance errors was originally categorized under *Reflective Process Control*, which is defined as students making decisions to regulate their learning process. After reviewing the statements coded in this category, the researcher realized that the processes described by students did not involve any decision-making; therefore, it was re-labeled as *Strategy Monitoring* and categorized as *reflective process monitoring*.

Since the purpose of this study is to examine and explore metacognitive process in the design context to better understand the student learning process, it is important to identify the codes that contribute to metacognition and categorize them accordingly. For example, the code *Inspired by Self-knowledge,* which is defined as students being inspired by their previous work while analyzing it was categorized under *reflective process monitoring,* which is one of the subcategories of *metacognitive processes*. On the other hand, *Reviewing Previous Work,* which was defined as students observing their previous work was categorized under *cognitive processing.* As the researcher engages in the coding process, it is important to constantly evaluate the codes and their definitions from the initial coding phase. After multiple iterations of categorizing and organizing the categories, and through constant comparison, the following coding structure was resolved for metacognition.

Table 10. Main constructs of metacognition (Extension of Pintrich et al., 2000)

Metacognition: When the students are thinking about how the learning-task proceeding is or should proceed		
Reflective Process Knowledge	Cognitive Strategies Knowledge	
	Self-Awareness	
	Task-Awareness	Task Understanding
		Task Familiarity
Reflective Process Monitoring	Personal Feeling Monitoring	Personal Feeling of performance
		Personal Feeling of the Task
		Self-Reliance
	Situational Actions Monitoring	Idea Development Monitoring
		Idea Generation Monitoring
Reflective Process Control	Control of Personal Feelings	
	Control of Environment	
	Control of Situational Actions	Control of Idea Generation
		Control of Idea Development

As mentioned previously, the core category that emerged from the coding process is metacognition. Metacognition and its subcategories help explain the theoretical framework for this study, which is to understand the process of learning in first-year design studio students (Table 10).

4.2. Development of Categories and Subcategories

Each of the three categories that resulted from the thematic coding process are defined below in terms of how they relate to learning in the Design Lab and how they were refined and expanded based on the data collected for this study. In addition to the three subcategories of *Metacognitive Thought Processes*, *Cognitive* and *Affective Thought Processes* are also defined.

As mentioned previously, themes were generated through the interpretation of the data in light of the literature reviewed, the research questions, and researcher's personal knowledge and perception. To determine how foundation students, understand their metacognitive process as they are engaged in learning-tasks, and subsequently the results that are presented in Chapter 5, it is important to understand how the acquired data were categorized, what differentiates each category from another, and why each category was created. In the following sections, each of the categories are defined and excerpts are provided to demonstrate what type of thought processing exists under each category. The main categories that emerged from the data are: *metacognitive process*, *cognitive process*, *affective process*, *physical processing*, and *unrelated behavior*. Since *physical processing* and *unrelated behavior* categories were limited in the number of instances and thus deemed not influential in design student thought processes, the discussion of these categories is limited to their definitions as provided in Appendix H.

4.2.1. **Metacognitive process**

Metacognitive processes are divided into three categories: *Reflective process knowledge*, *reflective process monitoring*, and *reflective process control*. The common factor among all the data coded under these categories is that students realize that they are learning, and they have control over the process of learning to improve it as necessary. Definitions of the main categories of metacognitive process are provided in Table 11.

Table 11. Main categories of metacognitive processing

Category	Definition
Reflective Process Knowledge	Learner's knowledge regarding how to learn, which could influence the process of learning
Reflective Process Monitoring	Judgments made by learners regarding the status of learning (how learning is progressing, how learning should progress)
Reflective Process Control	Decisions made or actions taken by learners that influence the progress of the learning-task

4.2.1.1. ***Reflective Process Knowledge***

The first category of metacognitive design thinking is *reflective process knowledge*, which is the understanding that students have regarding their knowledge of how design occurs. Learning in design is different from other disciplines; design students learn how to design by trying different strategies while consciously or un-consciously monitoring each step within their strategy to determine if it was successful or not.

The main knowledge that students require and review to do a design task is called *cognitive strategy knowledge*. The knowledge of how to design increases with student experience to learn what strategies in which conditions were more successful. Moreover, the other part of knowledge, which is effective in metacognitive design thinking is *self-awareness,* which is understanding about themselves and ability in doing the task. *Task-awareness* is the final category of *reflective process knowledge*, and plays a significant role in student metacognitive thinking, which refers to their understanding of the given task and its requirements.

The three categories of knowledge that were described above along with their subcategories, form *reflective process knowledge,* which is one of the main subcategories of

Metacognitive Design Processing. These subcategories are inter-related and influence each other; the combination of *cognitive strategy knowledge*, *self-awareness*, and *task-awareness* provides learners with the knowledge of how to learn, which in turn could influence their process of learning.

To provide a more detailed picture of *reflective process knowledge*, it has been divided into three subcategories. Definitions and examples for each of the subcategories are provided in Table 12.

Table 12. Definitions and examples of Reflective Process Knowledge subcategories

Subcategory of Reflective process Knowledge	**Definition**	**Excerpt**	**Memo**
Cognitive strategies knowledge	Thinking about cognition and cognitive strategies	*"I tend to skim stuff [learning-task] so if I read it in more detail then it becomes more clear to me."(Catherine)*	Catherine's knowledge regarding her cognitive process is to start with skimming the material and once she finds something interesting she reads it more carefully to understand it.
Self-awareness	Thinking about how learners as individuals learn	*"Music helps me; it helps entertain me and helps me to focus, kind of settle down."* (Kara) *"I am kind of slow."* (Linda)	Kara *realizes based on her previous knowledge that, listening to music helps her focus on her learning and designing.* Linda *believes that she is slow in making a model/ understanding a task/ making a design decision.*

Subcategory of Reflective process Knowledge	Definition	Excerpt	Memo
Task-awareness	Thinking about the learning-task and how to proceed based on their existing understanding	*"Lots of my projects deal with more planes than intersections which was originally my big idea and so I decide to kind of connect… yes there are intersections but it has also more to do with like how you can define a space with this plane."*(Catherine)	Catherine's thinking about her previous leaning task comes into play, informing her how she could complete the task better, using prior knowledge.

Cognitive strategy knowledge

Based on the collected data, the most common strategy that students used to achieve the objectives of the learning-tasks were: sketching, reviewing their sketchbook or their roll, making sketch models, and reading the learning-task. *Cognitive strategy knowledge* is the knowledge and comprehensive understanding of cognitive processes and outcomes. Autonomously or through thoughtful conscious control, designers use their previous experiences to select strategies that they deem most effective in finding a solution.

Cognitive strategy knowledge and *task-awareness* are interrelated. The strategies that students use depend on their understanding of the requirements of the learning-task. For example, when Noah was asked about his most successful strategies he thinks that the nature of the first learning-task requires more reviewing than sketching so he dedicates more of his time to reviewing his sketchbook.

"Normally I would say 70% of the time I'll be sketching, ideas, ideas, maybe a day, two days and three days, sketch, sketch, sketch and then maybe 30% are working on the project actually.

So I have lots of time but this time working since it's looking back at the stuff, I look back at my sketches that I have been doing…I'll say for this time looking at my sketchbook. [was my most successful strategy] (Noah)."

On the other hand, Catherine did not recognize the difference between the first learning-task and the previous tasks; therefore, she did not adjust her strategy accordingly.

"Usually pretty much the same thing. I am not really much of a writer, I usually sketch and use my hand more often. So it was pretty much the same as what I was doing today." (Catherine)

Students use the knowledge from their previous experience of failed or successful design strategies to select a cognitive strategy knowledge that they think will result in the best outcome. For example, Hana knew the limitations of using glue in her model based on previous experience and looked for alternative solutions.

"Because this one attached with glue and the relationship depends on glue I tried to not use glue and without these boundaries [points to the outside of her model], I use cotton thread to tie them together and I found, it is not very stable, it can move, there is some movement, so this movement gives me some alignment. So I used this steel to do this. [pointed out to her steel model] small cubes to make movement more apparent and I found that this is because it can move sometimes it becomes a line when I hold hand [she shows with hand gesture] become like this [like cube]." (Hana)

On the other hand, Steve and Autumn used calculations and mathematics in their designs; which they regarded as successful designs in the past and as a result they continue to employ that strategy in their current designs as well.

*"I like to do a lots of calculation and I come up with weird formulas when I do this [*learning-task*] … for example, When [Professor] for one of our projects, asks us to cut the circle in half and use the same circle, I like to figure out where to put the center to make it exactly half. I enjoy to work with numbers. I also like doing drawings that involve a lot of calculations."* (Steve)

As it can be seen from the excerpts above, instances where students use their knowledge to select a strategy to develop their ideas is categorized under "Cognitive Strategy Knowledge".

Self-Awareness

This subcategory of *reflective process knowledge* includes everything that students as learners know regarding their own previous knowledge. Statements that were coded under this category usually have phrases similar to, "I know this about myself," or "I work better when I do this." Based on their previous experience, students know their strengths and weaknesses in design, or the environment that helps them develop their best designs.

This knowledge also influences the strategies that they use for their designs. For example, Nicky knows that she tends to spend a lot of time thinking about various solutions without doing any sketching. She also identifies that this strategy is problematic and for this learning-task she tried to change her strategy to improve her design.

> *"It's a problem that I have. I think it would be better if I start sketching and see what I can come up with while sketching. My problem is that I just sit and stare at a blank sheet of paper and kind of run through ideas in my head instead of sketching it out and seeing what I can come up with, it probably would be better. It is very hard for me to start a project sometimes."* (Nicky)

It is important for students to have an accurate *self-awareness* and to be able to recognize their own strengths and weaknesses. This will help students to take advantage of their strengths and work on their weakness and become a better designer. In the excerpt below, Tanya recognizes that she has problems with developing such a *self-awareness*.

> *"I think it is going to be very difficult to point out the strengths in my works due to the fact that I'm very critical of myself."* (Tanya)

In addition to knowing how students tend to approach their designs, *self-awareness* also contains information regarding other factors that could influence their designs. For example, Taylor, Kara, Daisy, William, Max, Ava, Noah, and Catherine state that listening to music helps them in their designs by making them more relaxed, increasing their focus on the learning-task, changing their mood, or motivating them.

> *"I listen to music and look through my notebook."* (Taylor)

> *"When I am designing or when I am doing design work I listen to music without lyrics, sometimes classical stuff like melodies."* (Catherine)

> *"It depends on my mood, that day I was just listening to country type music to let my brain kind of relax but at times that I need to get stuff done I listen to "go, go, go" kind of music." (*Taylor)

In general, the researcher's observation has been that a first-year student's lack of experience results in not having strong and/or accurate *self-awareness*. As students become more experienced, their self-knowledge becomes stronger.

Task-Awareness

Understanding the task requirements or *task-awareness* is an important first step in delivering a successful design. As students receive the design task and listen to the professor, they use their previous experience and analyze the learning-task to better understand the requirements of the design task.

> *"From what I understand, we are taking a look at our old projects and developing the underlying idea or question about them either holistically or individually and creating a project from that question."* (Catherine)

Since the first learning-task required students to develop a question based on their previous designs, almost all of the students started their design process by reviewing their previous projects. Students use different approaches to review their previous learning-tasks. For example, Noah drew a concept map by taking notes of the significance of each of his previous designs and how the professor described the task.

> *"so here I drew a map maybe small bubbles just words like unity, connections, so very like random words but I start mapping them out, like different ideas and I look through to my sketch book a lot rather than my projects and I took a lot of notes about what she [professor] said. I wrote down in my sheet and those words that I saw start coming up with the questions."* (Noah)

Nicky analyzed the task to identify what its requirements are and how she can address those requirements.

> *"I basically start to think about the prompt that she gave us on the task sheet and she asked what was the quality, those kind of the questions. Where are the forces? So I tried to answer those, the ones seem to me clear and I wrote about their basic characteristic I guess."* (Nicky)

A majority of the students listened to the professor and took notes, while the professor, was explaining the learning-task. This helped them better understand the learning-task and clarify any parts that they did not understand.

> *"I'm listening to Professor talk because I think she's talking to the class…. then I think I wrote down few things on this sheet of what she said. I wrote down 'using less to get more,' it might be the idea that I had written down in my sketchbook." (Bill)*

> *"I know for fact whatever she said is extremely important. [laughter] so I tried to listen." (Noah)*

> *"I took a lot of notes what she [professor] said. I wrote down in my sheet and those word that I start coming up with the questions." (Noah)*

In the excerpts below, students discuss the task and its requirements with each other to gain a better understanding of the task.

> *"I asked and double check with Catherine about how we should use the big sheet." (Bill)*
>
> *"I was talking to them, I think they were just explaining the project again, together to be clearer."* (Ava)

An important concept within *task-awareness* is task-value or how the learning-task fits into an individual's current and future plans and goals. As illustrated in the excerpt from Daisy, if students believe that the learning-task will help them achieve their personal or professional goals, it influences how they approach their design learning-task by increasing their motivation. Instead of trying to satisfy the professor, they will look beyond the course objectives and try to master the necessary skills.

> *"My work is more personal to me than just for the scope of course objectives. It has been my main priority for the past few months. Taking it a step further with this process. It is going to help me discover something that'll help me in this process. It is going to help me discover something that'll help me in the future. (Daisy) …This task is going to help me focus in the design picture rather than just individual projects. It is going to help me realize a trend, how in my projects that I can catch upon and take further with my final project and further studies*. "(Daisy)

Similar to Daisy:

> *"I see that is very valuable to be able to analyze my past projects, the success and mistakes, to find a thread between them. It could help me open my eyes and mind more as a designer."* (Bill)

While you can see different metacognitive behavior from Catherine:

> *"I came to one of my more recent projects that Professor told me 'that was interesting' because it was connected with this watercolor that I did and both of this one and here so I really want to focus more on that so I did a couple of them like this one, I did this*

one and I have this little bit down here so lot of my projects deal with more planes than intersections which was originally my big idea and so I decide to kind of connect maybe to this which has to, yes there are intersections but it has also more doing with planes like you can define a space with this plane." (Catherine)

Although students use a variety of techniques to increase their understanding of the task and its requirements, they recognize its importance in developing a successful design. This thought process is more common toward the beginning of the tasks, and students spend time and resources to increase their understanding.

4.2.1.2. ***Reflective Process Monitoring***

Another part of metacognitive design thinking is the judgments that students made regarding their situation and the status of their design solving process or *reflective process monitoring*. *Reflective process monitoring* is the judgments made by students regarding the status of learning. *Reflective process monitoring* is divided into two subcategories: *personal feeling monitoring*, and *situational actions monitoring*. The first subcategory, *personal feeling monitoring* is related to students' feelings and emotions regarding the learning-tasks, themselves, and their performances. The second subcategory, *situational actions monitoring* or judgments, is made by students regarding the design development process. This subcategory is further divided into two main sub-categories: idea generation monitoring and idea development monitoring. Of the three main categories of *metacognitive process*, *reflective process monitoring* occurs most often. Table 13 provides definitions and examples for each of the subcategories.

Table 13. Definitions and examples of effective process monitoring subcategories

Subcategory of Reflective Process Monitoring	**Definition**	**Excerpt**	**Memo**
Personal Feeling Monitoring	Learner's thinking about his/her influential emotional state during the design process	*"The learning-task was difficult; it was kind of broad. It was so broad. We kind of find a path of our own."* (Bill) *"This is going to look so cool once we finish."*(Linda)	Bill makes judgments regarding his feelings about the task and how difficult the task is and how it influences his learning and designing. Linda makes judgments regarding her positive emotion about the outcome of the task.
Situational Actions Monitoring	Learner's thinking about decisions made or actions taken in the process of design tasks	*"Just kind of thinking about the answer. First I just list down all the projects then you can see a little bit drawing I did and also wrote down themes, some codes from the notes that I work on. …help me to find connection through all the projects."(Linda)*	She monitors her thinking and makes a judgment regarding what to do next.

In the following section each of the subcategories is described.

Situational Actions Monitoring

An important part of learning how to design is to make judgments of how certain decisions or actions influenced the process of the design task. This information then forms students' knowledge regarding what strategies were successful and unsuccessful.

Students also use their *situational actions monitoring* to generate and develop ideas. These judgments help students identify sources of inspiration and also how to overcome obstacles.

Idea Generation Monitoring

Students use different internal and external sources for inspiration, and use different strategies to overcome hindrances in their design process. Students look for inspirations to generate ideas; these inspirations may come from external sources like friends and classmates, or internal sources like previous sketches.

As students engage in discussions with other students in the lab, they get inspired by what others are doing or by getting suggestions from them. Such collaboration is seen, for example, in the first excerpt below. Catherine receives a suggestion from one of her colleagues regarding the use of a different material. In the second excerpt, students compare their ideas and get inspired by what others are doing:

> *"I started to think to do this and Liana said to me maybe trying it in different material might help me and just I have been doing this."* (Catherine)

> *"I think from me talking to classmates because I have done that pretty much in all of my projects so they come to my desk and look at what I am working on and I go to their desk and look at what they are doing. so we can compare the ideas."* (Steve)

Many of the students look to the professor as a source of inspiration. As the professor is describing the learning-task, students take notes or ask for the professor's opinion.

> *"I think I wrote down some things that Professor said like, a competition of questions what you should come up with and she said [Professor]?" what makes you excited."* (Bill)

A common habit among students is to walk around the studio space or the lobby and different labs and observe other students as they work on their projects to get inspiration.

"I always go around not only like my studio but also Burchard hall to the lobby, I go upstairs everywhere almost but if it is specifically in this studio I walk around." (Noah)

"I look around when I get stuck." (Taylor)

The studio and the surroundings are filled with objects that are used by students as sources for ideas, inspiration, and challenges.

> *"Realizing that I thought what everybody else doing. So I walked around and I normally check whenever there is an open path I just stop at a random desk."* (Edward)

The inspirational sources mentioned above are all external to the student, but there are also internal sources that students use to generate their design ideas. For example, students use their previous knowledge and experience to generate design ideas.

> *"So what I did I checked all my works that I have done and then I thought I did a lot with intersection and plane and this stuff so I took that and kind of wrote down words and these kind of explain what I am doing."* (Marie)

The other side of resourcefulness is hindrance. There are a number of reasons that cause students to not be able to generate design ideas. These hindrances are usually due to lack of self-esteem where students are afraid to design, not fully understanding the task requirements, or not being able to focus on the design because of what is happening in their surroundings. Since some students were wondering about how other students in the class are approaching the learning-task, they did not focus on their own ideas.

> *"I went to walk around see if anybody's working. I realizing that I thought what everybody else is doing. So I walked around and I normally check whenever there is an open path I just stop random desk."* (Edward)

In some instances, students feel that they cannot proceed by themselves and require others to help them. This help may be because of lack of self-esteem as in the case of Catherine, or lack of necessary skills as in the case of Max.

"I go over and start to talk to Marie about it and I was like I don't really know where to go with this one. I know I want to do something but I am not sure how to do it. "(Catherine)

"We talk about their projects. because I am working on like the mold I was talking about that stuff. I am always asking one of my friends whenever he has time to finish my mold. Because he helps me sometimes. Because he had done a lot of projects with rockite so I can get good advice from him. "(Max)

Idea Development Monitoring

Once students have generated an idea, the next step is to develop the idea further. Students use metacognitive thinking to monitor the development of their ideas in terms of time, strategy, process, and outcome. Since the first learning-task required students to develop a question based on their previous designs, for most of the students the first step was to review their previous designs. Although most students reviewed their previous work about what they looked for in their previous designs and how they organized their thoughts differed.

Linda looked for discoveries in her previous work and organized them based on their outcomes. On the other hand, Daisy organized the previous learning-tasks based on the ideas that she had when she was developing them.

"Recording the qualities and discoveries of each, and hopefully I will see a connection in that." (Linda)

"I am just basically writing down my ideas that I used so maybe organizing it is going to help me find a way. My basic thing will be figuring out something that is common."(Daisy)

Nicky analyzed each of her previous designs by developing a schematic sketch and describing the strengths and weaknesses of each of her previous works (Figure 29).

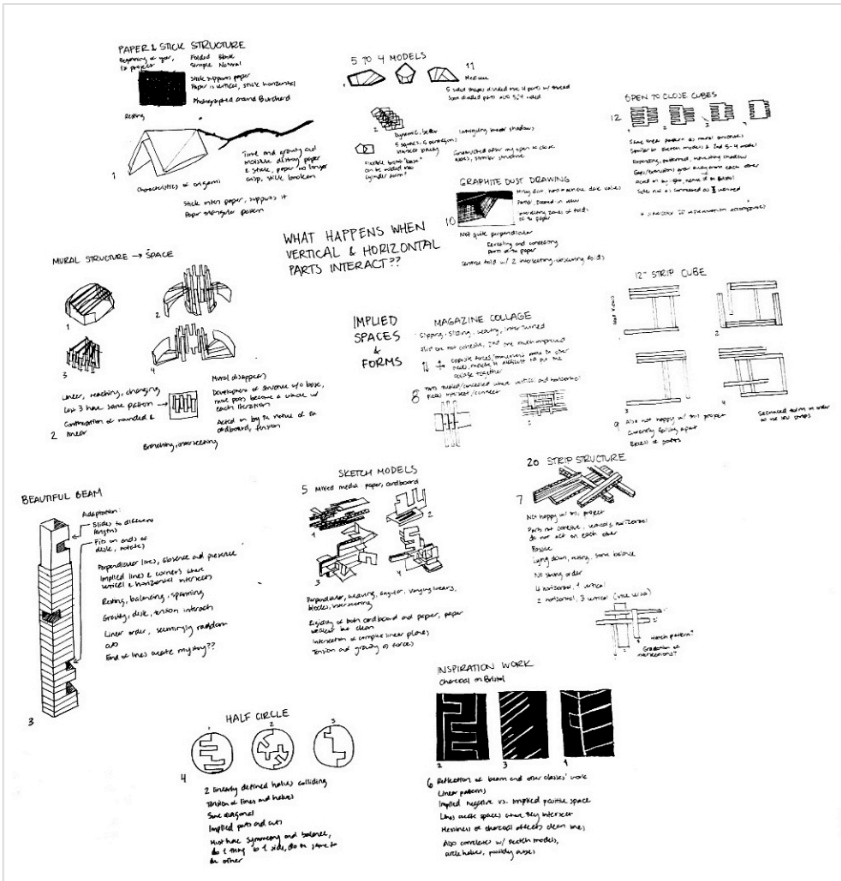

Figure 29. Nicky engages in evaluating her ideas

A separate aspect of developing an idea is to monitor the time to make sure that they are able to finish making their models on time.

> *"I think I don't have time to finish it, might be able to try it and professor said "that's fine, you can try it."*(Steve)

To develop an idea from its generation to building the model, students need to consider many influential factors such as time, required skills, and the outcomes. Metacognitive thinking can help students with monitoring this process to ensure its successful completion.

Personal Feeling Monitoring

Personal feeling monitoring, which is a subcategory of *reflective process monitoring*, is concerned with learners' judgment regarding their emotional states during the design progress. A student's emotional state may influence their judgment regarding their performance, which can be positive, negative, or neutral. Student judgments regarding the difficulty of the learning-task and the level of confidence in doing the task can influence their performance.

Student judgments regarding their current or past performance influence their emotional state. In the excerpt below, after reviewing her previous learning-tasks, Catherine makes a positive judgment regarding her performance in previous designs that she uses to plan for the next step in her process. On the other hand, Andres has a negative view of his performance and feels that he has not accomplished what he had expected to achieve.

> *"… some were better and had stronger points since some of them are very good, it is kind of like I started really good and went backwards. I only got to four of them and then think about them. "(Catherine)*

> *"I had a very unproductive day. Talked to Professor again. I told her I am little bit stuck." (Andres)*

A student's general feeling towards the task, which also includes their perception regarding the difficulty of the task, can influence their performance. In the excerpts below, Taylor has a positive reaction to the task and she is excited to start her design; on the other hand, Edward has a negative emotional state relative to the learning-task.

> *"I like this project that we are doing because we kind of make the assignment our self so I also thought having to figure it out to come about the question that you are presenting and I can show that like a project. "(Taylor)*

> *"Right now I am a bit nervous about this task, but I usually get nervous before starting a new task in the studio, because I want every task to be perfect." (Edward)*

In the excerpts above, students have positive, or negative emotion relative to the task. In some instances, similar to the one provided below, the effect is both positive and negative. Instances like this have been categorized as neutral since they do not influence student performance. *"I feel exited but somehow worried about the final outcome at the same time." (Steve)*

Students' perceived level of task difficulty can also influence their emotional state relative to the task, which may in turn influence their performance. Excerpts below show how different students perceived the difficulty of the first learning-task.

> *"This is a tough project." (Taylor)*

> *"I can foresee the problem of actually finding connections between my works. I am worried that I won't be able to find connections, or if that ends up not being a problem, I'm afraid that I won't be able to show the connections in this task." (Edward)*

> *"At first, it was quite difficult to understand due to the abstract explanations of the project. Nevertheless, I understood this task as a period of self-development while improving the skill sets and quality of our work.* "*(William)*

Self-reliance or student perception regarding their ability to successfully complete the learning-task (confidence or lack of confidence) also influences their affective state relative to the learning-task. Learner's judgment (positive or negative confidence) relates to his/her confidence to do the design task. Excerpts below provide both positive and negative encounters.

> *"Usually I don't erase, usually if I come up with something, I don't usually erase it. I keep it because I thought that I can do something better to it. Kind of leave it and see if I can come up with something and try to make it better." (Steve)*

> *"I never think I cannot do it." (Marie)*

> *"How far I am behind…I observe how she [Marie] likes to work with planes a lot like different intersecting and it is almost how to define ideas and she has a lots of question for the projects. I thought I don't really have that question in my mind." (Eric)*

> *"Compare myself with other students by observing them and see what they are doing." (Autumn)*

The reflective process monitoring category and its subcategories contain student thought processes in which they think about what they are doing and how the learning is progressing. Based on the outcomes of their monitoring thought process, when necessary, students make decisions, which is the category described in the *reflective process control* section.

4.2.1.3. ***Reflective Process Control***

Reflective process control is a subcategory of metacognitive design thinking that is concerned with the decisions students make and the corresponding actions to influence their process of design problem-solving. This thought processing category is divided into three main subcategories, *control of personal feelings*, *control of situational action*, and *control of environment*. Table 14 provides definitions and examples for each of the subcategories.

Table 14. Definitions and examples of for Reflective Process Control subcategories

Subcategory of Reflective process Control	Definition	Excerpt	Memo
Control of Personal Feelings	Thinking about what actions to take to change, or maintain, emotional state	*"I am playing music." (Daisy)*	To improve her design she controls her emotional state by playing music.
Control of Environment	Thinking about what actions to take to control (change/maintain) the physical environment before the start of, or during, the design process	*"I think at first, I was organizing my desk, a lot of my models were in my trunk so I was moving stuff to the desk"* (Andres)	He makes three decisions to prepare the environment (desk), before he starts his design learning-task.
Control of Situational Actions	Thinking about what actions to take to complete/finish the design task	*"I was thinking about what I was going to do."* (Steve) "I *had an idea [plan] that the cube could change this way and then this can go [the] other way and then they reconnect together."* (Andres)	Steve questions what to do to influence the learning process, while Andres plans his next steps to improve his design.

In the following sections, each of the subcategories are defined and excerpts from the data are provided to further clarify the types of thought processes that are categorized under the *reflective process control* category.

Control of personal feelings is related to student actions to maintain or change their feelings and emotions regarding the learning-task. This subcategory of *reflective process control* includes action verbs such as choosing, adjusting, and focusing that relate to student affective and emotional states. As shown in the excerpts below, students use various methods to control their affective state, but listening to music is the most common way.

> "*I worked on collage to help relax and inspire me*" (Taylor)

> *"Now I am listening to the music. Usually I love music because if I listen to beach music it reminds me of beach houses, and trees. I might draw something, Whatever I draw might become something else. I might have questions. It is like whatever emotional situation that you are in the artwork produced by that emotion."* (Taylor)

> *"Now I am looking to Christen and see how she is playing with her little thingy… one of her assignments. Then I decided to start to play my music so I can focus because she was focused and I was like I should probably start mine. Try to zone out everything so I can focus on my project. I turned on music to help zone into my work."* (Taylor)

> *"At this point I'm just listening to the music I don't remember exactly but I put my ear buds in at one point. It [music] helps me to concentrate, I put all types of music it is not just a specific kind. Sometimes I like classical music, it helps me concentrate and then I walk out [inaudible]."* (Steve)

> *"I am listening to music to help me focus."* (Ava)

Student *personal feeling of the task* is an important factor in their design process and students use various methods to adjust how they feel about their design learning-task.

Control of situational actions includes the decisions made by students regarding their design solving process and how to make progress with their design. This subcategory can be further divided into two main sub-categories, *control of idea generation* and *control of idea development*.

Control of idea generation is concerned with student actions and decisions such as planning, iterative reading the task, and following the professor's suggestions that help them generate suitable ideas for their design task. In the excerpt below, Ju Ju and Autumn are planning to generate ideas by looking at their previous designs. On the other hand, Pandora is planning to generate her design idea by making a lot of different sketches.

"I plan to look at all my work and hopefully come up with an answer." (Ju Ju)

"I plan to achieve them by going back and thinking about each project, processes and all my ideas." (Autumn)

"To resolve this problem [generate idea] I will sketch a lots of ideas to carry on with my projects." (Pandora)

Students also tried to generate ideas by iterative reading the task description multiple times. As shown in the excerpt below, Kara used this method to become familiar with the task requirements to help her generate a design idea. This should not be mistaken with *task-awareness* where students read the task description to analyze its requirements; in this category iterative reading the task is done as a method to generate ideas.

"Probably 20 times. I kind of restate it in my head and try to rethink it. I was just glancing around while I was thinking, I wasn't getting feedback from them I was just glancing around." (Kara)

Professors also play an important role in helping students generate their design ideas. As shown in the excerpts below, both students changed their design ideas after talking with the professor.

> *"After talking to the professor I had thoughts of how to improve my cube. She also helped me understand how to improve my judgment, which is something that I've had a tough time understanding through the semester." (Edward)*
>
> *"After our discussion I am thinking about changing my direction." (Marie)*

Students also control their idea generation by changing their inspirational environment. As shown in the excerpts below, Ju Ju walks around the studio to find a source of inspiration, while

Bill sees a model developed by a fifth year student that interests him, so he tries to generate an idea based on that model.

> *"I look and then if I'm really stuck and just not getting anywhere I get up and walk around and see,* [Left the table]. *Walked around studio to look at everyone's project. Went around and asked other students their questions." (Ju Ju)*

> *"No just looking at the fifth year student desk nearby, I think at one point I looked at the model that I kind of was interested so I went over there." (Bill)*

The second subcategory of control of situational action is *control of idea development*. This subcategory is concerned with how to further develop the ideas that were generated. An important part of developing ideas is using regulating strategies to make sure that what one is doing will result in a successful design. As shown below, Ava adjusts her idea development by using a different size of wood. On the other hand, Catherine tried to control the development of her idea by using a different material.

> *"I thought that the first type of wood I used is too thick and if I used another type smaller one, it would better help my project." (Ava)*

> *"I need to do something and one thing that was very helpful to me was I changed part of my material, I was kind of sticking to cardboard and Bristol and I did find some wood in the shop over there and that really helped." (Catherine)*

Students also used their previous design experiences to adjust the strategies that they previously used to improve their outcome. The excerpts below show that Steve and Marie, changed their regular idea development strategies.

> *"… usually I don't sketch that much but I did sketches because I thought that I had many ideas I want to see them on paper and I want to see which one is the best." (Steve)*

> "*I kind of change my strategy to more on model making instead of drawing*." (Marie)

The last subcategory is *control of environment* or actions taken by students before or during the design process, to control (change/maintain) the physical environment where design is happening. This environmental adjustment can significantly influence students thought processing. Many of the students started working on their learning-task by cleaning and organizing their desks.

> *"Cleaning my space, it made me think about like other projects that I want to go back and look at. So I was kind of prepared, when I was putting away scraps I would find scraps that I made something with earlier in the year. So I kind of saw something that I want to go back and review."* (Nicky)

> *"Cleaning my desk because I get cluttered and the professor suggested I clean it so I could put the big paper on my desk."* (Marie)

> *"I think the first part of the class, I was organizing my desk, a lot of my models were in my trunk so I was moving stuff to the desk." (Andres)*

> *"My stuff on my desk bothered me. I am pretty OCD about certain things. I had to move it [laughter]…because I like my desk. I can't have my desk messy, I can't. Usually I have a lot of things everywhere so I just kind of all over my desk. It is kind of cleaning it is not really important. Now I put the roll away." (Tanya)*

The *reflective process control* category and its subcategories contain student thought processes in which they try to adjust their design learning process by making decisions. The following figure illustrates the conceptual map of coded themes and sub-themes (Figure 30).

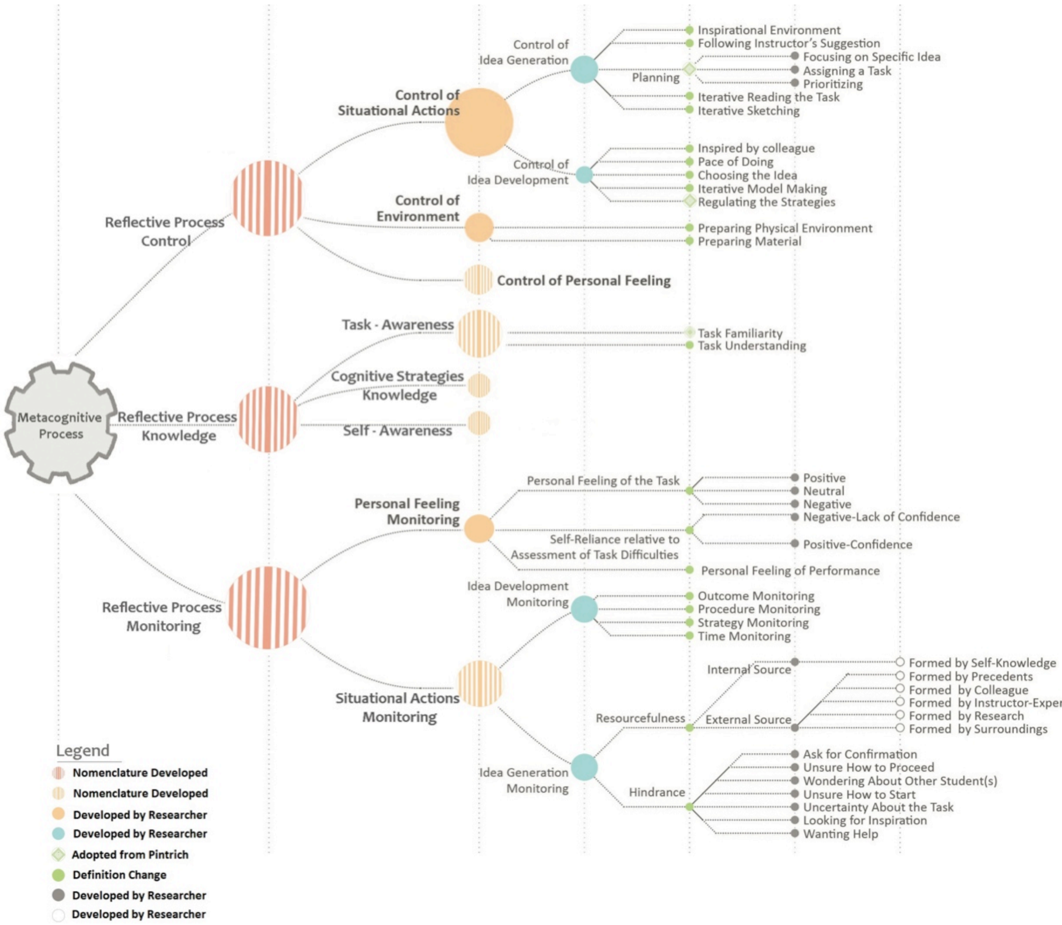

Figure 30. Conceptual map of coded themes and sub-themes, size of circles are proportional to the number of codes in that category. Adapted from issues in the measurement of metacognition (p. 47) by P.R. Pintrich et al., 2000, Lincoln, NE: Buros Institute. Copyright 2012 by the Buros Center for Testing.

4.2.2. Cognitive processing

Cognitive process focuses on students' ability to acquire and build new knowledge, process information, and ultimately solve problems. In this regard, cognitive processing is defined as the act of learning. In this research, activities that students engage in to develop an idea like sketching, building models, and experimenting with materials are categorized as cognitive activity.

The original framework divided the cognitive process category to "individual" and "communal" based on the data that was acquired from the first and second learning-tasks. In later revisions of the framework and because of the resemblance of the two subcategories, they were merged together. Each of these categories and their subcategories are explained, and excerpts are provided to further clarify them.

Cognitive process is further divided into *idea generation* and *idea development*. The difference between *idea generation* and *idea development* categories and those in reflective process control is that here students are not thinking about the activities that they are engaging in. It is extremely difficult to separate between these two seemingly similar types of thought processing, but it is important to clearly distinguish between those instances where students are thinking about how to generate/develop an idea (metacognition), and where students work to generate/develop an idea (cognition).

In the excerpt below, Ava is looking through her notes to acquire the necessary knowledge regarding her previous tasks; hence this activity is categorized as cognitive processing. Steve is also trying to learn a technique that would help him better generate his idea.

> *"Now I am reading my notes. I look through all my notebooks." (Ava)*
>
> *"I was looking at how to do an isometric view. I was looking at the angles and what angles to do. I found the picture of a cube [from internet] in isometric view and used the dimensions for that to guide me." (Steve)*

Instances where students experimented with different materials or where students experimented with a model are also categorized as cognitive processing. In the excerpts shown below, Hana is learning about a material that she has not previously used in her designs, while Bill is re-organizing parts of his previous model to generate new ideas.

> *"Because I found this paper is easy to change a cube's shape so I tried wood and steel and changed a material, and for wood I found that wood dependent on glue as well to be the shape of cube like this. so I am still experimenting with material."* (Hana)

> *"I think here I started to play around with the piece of that one. Originally these were all evenly spaced but I just experimented with it. I don't know what you call this but they are close together but gradually get further apart just playing around with that."* (Bill)

Idea Development

The idea development category under *cognitive processing* includes the activities like making models, or sketching that students engage in to further develop the ideas that were previously generated. It should be noted that similar to the *idea generation* category, the difference here with the *idea development* category that is under *reflective process monitoring* that here students are not thinking about how to develop their ideas, rather they are engaging in activities that will progress their designs. The excerpts below further describe the type of activities that were under this category.

Autumn is developing her idea by cutting the Bristol into the pieces that she needs to build her model. On the other hand, Eric is further developing his idea by writing a brief description of each of his previous projects to help him with developing a question.

> *"Cutting on my desk. I was cutting my pieces. That's the end and I work on some part of my file. I made a small one and I finished that."* (Autumn)

> *"However, I had the idea to write a paragraph about each of my projects. I did this for most of the time in studio."* (Edward)

Sketching is also under this category; it should be noted that as students engage in sketching their ideas, it is inevitable that they also engage in a metacognitive thought process by thinking about how to improve their idea. Excerpts below show the types of sketching that were categorized under *cognitive processing*.

> *"That part I was drawing down the dimension to scales, the ratio of the parts, I just had to do the isometric view to figure out the ratio of the parts and show the perspective."* (John)

> "*I drew this from my photographs [she is picking one of her drawings and starting to draw*." (Kara)

In general, *cognitive processing* includes activities that students engage in the course of their design learning-task that results in building knowledge. Figure 31 illustrates the coded themes and sub-themes in cognitive process.

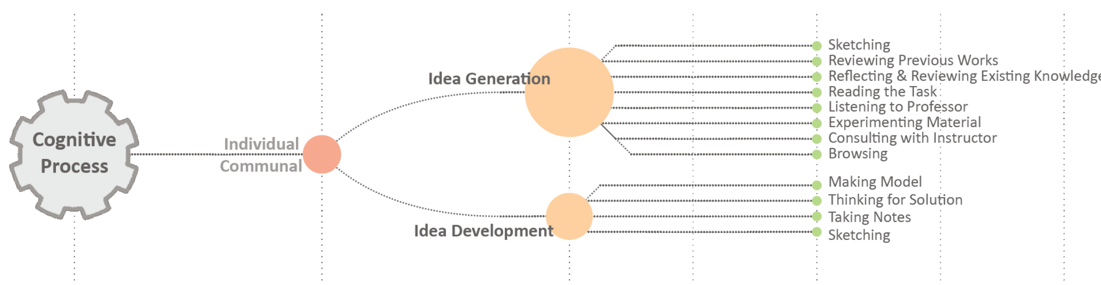

Figure 31. Cognitive process themes and sub-themes

4.2.3. **Affective processing**

A student's affective state plays an important role in their design learning process. Affective processing is divided into three subcategories of *positive* like excitement, *negative* like frustration, or *neutral*, where there is not any discernible impact (Figure 32).

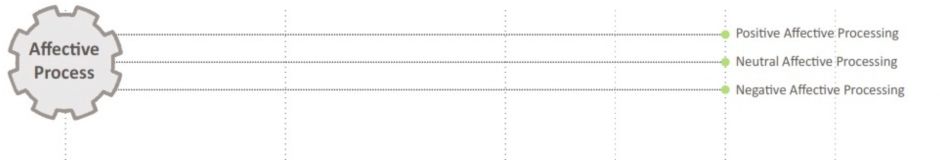

Figure 32. Affective Processing themes and sub-themes

In the excerpts below, various types of affective processes are demonstrated. Paul, Noah, and Bill demonstrate positive affective processing by showing their excitement in working on their design learning-task.

> *"I'm excited to get to work."* (Paul)
>
> *"I feel motivated. … Just try to push the envelope. …I was like "oh, this is great!"* (Noah)
>
> *"I am excited to see what I can find in each project and then to see what will result as my final project."* (Bill)

On the other hand, Catherine, Nicky, and Edward have negative affective thoughts in with regard to the learning-task, which is demonstrated as frustration.

> "I *just had a different bunch of models of different ideas and there was no connecting and so Monday night I was kind of freaking out because I didn't know where any of this was leading to*." (Catherine)
>
> *"I was kind of tired and frustrated in the class yesterday because of lack of sleep, back from break and everything. So I was kind of stressing out about what my project was going to be like."* (Nicky)
>
> *"I was getting a little frustrated…Somewhere around that I got frustrated. …As time went on, my progress slowed and my distractions increased."* (Edward)

Affective thought processing may also be related to a student's personal life and may occupy their mind. In the excerpt below, Max is having some personal problems which are preventing him from focusing on the design learning-task.

> *"I had a big fight with one of my friends last night which I've been thinking about all morning and it is making it harder for me to focus" (Max)*

In the excerpts below, students demonstrate affective processing that are not positive or negative. To differentiate between these thought processings, the *neutral* affective processing category is created.

> *"I'm a little unsure of what we are going to do, but I think that is expected and we will figure it out."* (Edward)
>
> *"Every project for me is like I know it is very important so I put lots of time and effort into it. So there is a lot of thinking."* (Noah)

4.3. Conclusion

In this chapter, the process that the researcher used to develop the theoretical framework of *metacognitive process* was described in further detail to familiarize the reader with the framework. The researcher also elaborated on the categories and subcategories, and the types of thought processing categorized under each. It is important to have a good understanding of how the data was categorized to be able to understand the results presented in the following Chapter, the role of metacognition in the Foundation Design Lab. The intension of Figure 30 is to show the relationship between various categories and subcategories of the metacognitive thinking process, which as illustrated in Figure 41 is a cyclical process. The researcher illustrated the framework in this way to show the component and subcomponent of metacognitive process.

Figure 30 provides a conceptual map of the themes and sub-themes for the developed framework. It should also be noted that the size of the balloons corresponds to the number of codes in each category and subcategory, illustrating the importance of a thought processing category or subcategory. When compared with the original framework developed by Pintrich, Wolters, and Baxter (2000), it can be seen how the researcher has extended Pintrich's framework to develop a framework that is suitable for learning in a design environment. The similarities and differences between the two frameworks are as follows.

The basic tri-partite division of *metacognitive process* as seen in Pintrich's original framework (Section 2.3.3.1) is maintained in the framework developed by the researcher (see Figure 30). In the developed framework, the *reflective process knowledge*, *reflective process monitoring*, and *reflective process control* categories correspond to Pintrich's "metacognitive knowledge," "metacognitive judgment and monitoring" and "self-regulation and control" categories, respectively (Pintrich et al., 2000). After the initial division, the framework developed by the researcher is significantly more differentiated to correspond more specifically to the kinds of metacognitive tasks and activities undertaken by a designer, and here specifically in the Foundation Design Lab environment.

In the *reflective process knowledge* subcategory of metacognitive process, the differences between the two frameworks are minimal. *Task-awareness*, *self-awareness*, and *cognitive strategy knowledge* correspond to Pintrich's *knowledge of task*, *knowledge of self*, and *knowledge of cognition and cognitive strategy*.

In the *reflective process monitoring* subcategory of *metacognitive process*, there are wide differences between the two frameworks due to the different inherent natures of the learning-tasks from design compared to disciplines like reading or mathematics. For instance, Pintrich's tasks are typically tied to memory and recall, whereas design work has more ambiguous processes and thus fewer defined outcomes. In the researcher's framework *task difficulty* is categorized under *personal feeling of the task* which itself is categorized under *personal feeling monitoring*. On the other hand, Pintrich categorizes "Task difficulty or ease of learning judgments" directly under "metacognitive judgment and monitoring". Pintrich claims that students use their metacognitive knowledge of the task and metacognitive judgments of the self to form their perception of task difficulty and it happens during the acquisition phase of learning. The researcher's subcategories emphasize the importance of students' emotional perceptions during design problem-solving activities and thus, a design student's emotions play a more significant role as juxtaposed to mathematics in which judgment is tied to right or wrong, knowing or not knowing. Because of the open-ended nature of design learning, students' perception regarding the difficulty level of a given task changes more frequently than in other disciplines like mathematics; hence, task difficulty and students' emotional state have a bilateral relationship. In other word, the difficulty level of the task influences students' emotional state and their emotional state influences their perception of task difficulty.

The main difference between the framework developed by the researcher and that of Pintrich relative to the *reflective process monitoring* category is due to the fact that *resourcefulness* has a significant influence on the outcome of design, whereas in tasks like reading or mathematics *resourcefulness* plays a less significant role. To reflect this, the researcher has divided the *idea generation monitoring* category into *resourceful* and *hindered* to account for the factors that help design students generate an idea or the factors that they need to be overcome in order to generate an idea.

Learning and comprehension monitoring, or the judgments learners make regarding their learning, which Pintrich categorized under "metacognitive judgment and monitoring," corresponds to *situational actions monitoring* in the researcher's framework. In Pintrich's framework, "feeling of knowing" refers to the learner's inability to completely recall a piece of information which in its original form does not occur in a design environment. A somewhat similar feeling that occurs in a design environment is when learners have the feeling that they have done a similar task before. This is categorized under *task familiarity*, which is a subcategory of *reflective process knowledge*. Learning processing, categorized by Pintrich as "confidence judgments," relates to the learners' judgments regarding the correctness of their responses; does not correspond in a design environment where there are no right or wrong answers; and the focus is on the process of design itself. Therefore, the researcher categorized students' judgments regarding the correctness of their design process as *self-reliance*, which is categorized under *personal feeling monitoring*.

As mentioned earlier, the researcher's *reflective process control* category corresponds to Pintrich's "self-regulation and control" category. Both frameworks categorize thought processings where a decision is made to change a cognitive activity under this category but to account for the types of cognitive activities that occur in design learning. The researcher has modified the subcategories of *reflective process control* in her framework. The majority of differences are because of the introduction of *control of idea generation* and *control of idea development* subcategories. Pintrich's "volitional control" relates to learners' emotions, and directly corresponds to the researcher's *control of personal feelings* category. Pintrich's "strategy selection and use" category directly corresponds the *regulation of strategy* category in the researcher's framework. Pintrich's allocation of resources category corresponds to multiple subcategories of *control of idea development* in the researcher's framework.

5. Chapter: The Role of Metacognition in the Foundation Design Lab

This chapter will discuss the results obtained from the learning-tasks that will help rationalize and refine the framework developed in Chapter 4. The results are organized by learning-tasks; as discussed in Chapter 3: methodology, different methods were used to collect data on different learning-tasks. These methods were retrospective verbalization, concurrent verbalization, card-sorting, and questionnaires. The data were coded and then assessed using the theoretical metacognitive framework developed in Chapter 4, Figure 30, for this purpose (see Chapter 4).

For each of the learning-tasks, sub-components of main thought processing categories are examined by looking at the coded data in terms of its frequency and sequence. Each of the sub-components of *metacognitive process* were then examined in terms of their role in student learning, and what differentiates high-performing students from low-performing students.

5.1. Finding from Task 1

In the following sections, results of the analysis performed on the data collected are presented. For more detail regarding data collection and analysis, refer to Sections 3.2.2 and 3.3.3 respectively. The retrospective verbalization data for this learning-task were analyzed and three different types of results were generated: 1) the time a student spent on each thought process, 2) the number of instances of each thought process, and 3) the sequence of student thought processing. The data for this learning-task also included card-sorting, and a questionnaire which was analyzed independently.

As discussed in Section 3.2.3.1, learning-task 1 required students to review their design learning-tasks from the beginning of the semester and come up with a question similar to the learning-task that they were given by the professor. Once students formed their trajectories, the next step was to develop drawings, sketches, and models that would develop their identified questions (See Appendix F). Twenty-one students individually participated in this learning-task. After reviewing the video from the interview and comparing it with the video recording of one of the students (Edward), while he was engaged in the learning-task, it was clear that he did not take the interview seriously and there were clear inconsistencies between the self-reported actions and what was evident from the video. This was the only instance of such behavior throughout the process of data collection. Therefore, the data from Edward's retrospective verbalization was eliminated from the data-set. Other than the fact that students were videotaped, the other environmental factors were similar to regular studio sessions. During this session, students were free to interact with each other and ask for guidance from the professor. As mentioned in Section 3.7.3, students were evaluated based on the complexity of the questions they formed, and the quality of the drawings and models they developed in response to the question. Student grades are provided in Table 15.

5.1.1. Retrospective verbalization: Time spent on various thought processing in learning-task 1

Once all the data from all the learning-tasks were collected and analyzed utilizing the metacognitive framework, the researcher went back to the video recordings of the first learning-task to estimate the amount of time students spent on cognitive versus metacognitive thought processing. Time spent on the different types of thought processing was not something that can be easily determined from the video recordings. To develop an accurate judgment regarding the time when students switched from one type of thought processing to another type, the researcher analyzed the video recordings of students working on their designs simultaneously with the retrospective verbalization interview video. The decisions to allocate categories were based on students' description of what they were doing (interview video) and what they were actually doing (class video recording).

Table 15 shows the percentage of time each student spent on the two types of thought processing, *cognitive process* and *metacognitive process*, and also unrelated behavior that is not a type of thought processing. Initially the researcher recorded the amount of time each student spent on each of the "action verbs" that were identified in Section 4.1, and added up the durations to calculate the amount of time students spent on *cognitive process*, *metacognitive process*, *unrelated behavior*, *physical process*, and *affective process*. Physical processing, or how physical environment impacts student learning, and affective processing, or learners' moods and motivations, did not have a significant presence and thus an influence on the results, and they were eliminated from Table 15. Therefore, in some cases the sum of all the reported processes in Table 15 is not 100%. Students are grouped together based on the grade they were assigned by the professor for this learning-task, and then sorted from the highest grade (A) to the lowest grade (B). This makes it easier to interpret the data presented in the table to extract trends.

Table 15. Observed percentage of time spent on various processing types (from 3-hour learning-task)

Students (pseudonym)	Grade	Metacognitive processing				Cognitive processing	Unrelated Behavior
		Reflective Process Monitoring	Reflective Process Knowledge	Reflective Process Control	Total Metacogniti on		
Nicky	**A**	54%	4%	9%	67%	15%	11%
Noah	**A**	64%	4%	5%	73%	22%	2%
Bill	**A**	57%	11%	1%	69%	13%	14%
Linda	**A**	68%	3%	5%	76%	22%	3%
Average for A		61%	5%	5%	71%	18%	7%
Marie	**A-**	18%	2%	28%	48%	52%	4%
Daisy	**A-**	21%	1%	7%	30%	69%	2%
Pandora	**A-**	37%	8%	6%	51%	25%	14%
Average for A-		25%	4%	14%	42%	49%	7%
Hana	**B+**	2%	2%	5%	9%	84%	3%
Layla	**B+**	7%	3%	18%	28%	66%	5%
Andres	**B+**	27%	8%	14%	49%	35%	16%
Ava	**B+**	10%	3%	12%	25%	58%	11%
Kara	**B+**	17%	1%	12%	30%	66%	7%
Autumn	**B+**	42%	1%	8%	51%	41%	7%
Average for B+		18%	3%	11%	32%	58%	8%
Catherine	**B**	6%	3%	16%	25%	44%	28%
Taylor	**B**	7%	2%	28%	37%	44%	17%
William	**B**	1%	1%	15%	17%	70%	13%
Ju Ju	**B**	5%	3%	6%	14%	44%	39%
Tanya	**B**	3%	2%	11%	16%	51%	32%
Max	**B**	1%	4%	4%	9%	68%	24%
Steve	**B**	5%	6%	18%	29%	66%	5%
Average for B		4%	3%	14%	21%	50%	23%
Total Average		**37%**				**46%**	**16%**

Note. 100% = all processing that occurred during the learning-task[50]

[50]. Percentages are rounded to whole numbers, as a result summation of subcategories may slightly differ from their respective categories.

The percentage of time spent by each student on different types of thought processing suggests that on average students spent more time on *cognitive process* during doing the task, in comparison with other reported processes (*cognitive process*: 46%, *metacognitive process*: 37%, *unrelated behavior*: 16%). Although on average students allocated a higher percentage of time to *cognitive processing*, this is not the case for high-performing students who allocated more time to metacognitive processes. As described in section 4.2.1 these main categories are: *Reflective process monitoring* or judgment about what needs to be done, *reflective process knowledge* or thinking about what knowledge or skills should be used (tools to be used), and *reflective process control* or what decisions should be taken. As shown in Figure 33 across the subcategories of *metacognitive processing*, several trends are visible.

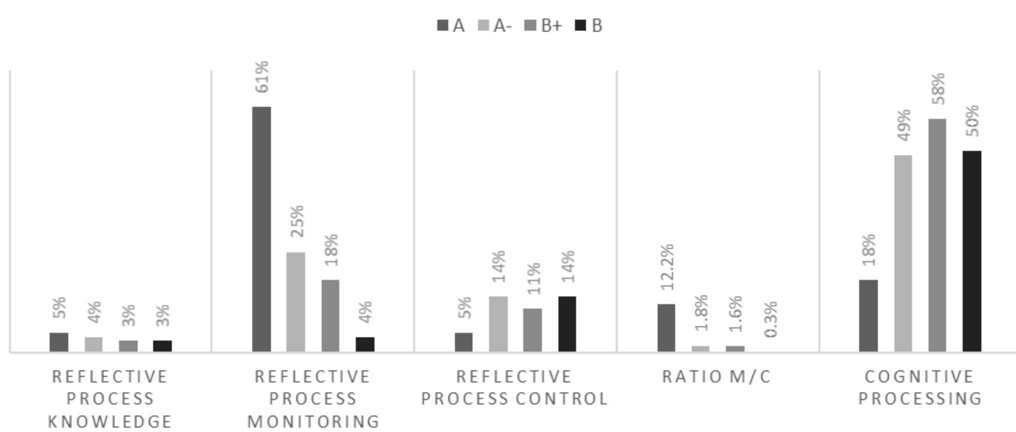

Figure 33. Percentage of metacognitive thought processing subcategories

- On average, thinking about what needs to be done (*reflective process monitoring*) has the highest percentage (22%), versus what decisions should be taken (*reflective process control*) (11%), and which knowledge or skills should be used (*reflective process knowledge*) (4%.)

- *Reflective process monitoring* is directly related to performance. High-performing students engage in this type of metacognitive thinking more than low-performing students.
- Although *reflective process control* does not consistently increase from high-performing students to low-performing students, the ratio of *reflective process monitoring* to *reflective process control* reduces from high-performing students to low-performing students. This ratio is an indication of how much of student decisions are informative decisions that have been intentionally made to improve the process of designing.
- *Reflective process knowledge* decreases from high-performing to low-performing students.
- Low-performing students spent more time on *cognitive processing*, and they engaged more with doing the learning-task (sketching, making models) as opposed to high-performing students who engaged more with thinking about how to do the learning-task.

5.1.2. Retrospective verbalization: Percentage of various processing types in learning-task 1

This section presents the results of the retrospective verbalization analysis done for learning-task 1 in terms of the percentage of the instances spent on various processes. The results for each of the subcategories of metacognitive thought process are organized in separate sub-sections. The data used in this part is extracted from the coding process that resulted in the development of the framework as described in Section 3.7.

Data from the retrospective verbalization was also analysed to extract the number of instances of each of the thought processing types. Instances represent a switch from one thought process to another; therefore, a higher number of instances does not necessarily mean students spent more time on that thought process. As a result of this, any direct comparison between the results presented in this section with those presented in section 5.1.1 should be done with caution. Since the total number of instances for each student had a wide range (55 - 127), instead of using the number of instances for each thought process, the researcher calculated the percentage instances of each thought process. This was done by dividing the number of instances of each thought process by the sum of all the instances for each students. Table 16 provides the percentage of each type of thought process; similar to Table 15, students are divided based on the grade they received for this task.

Table 16. Total of all types of instances and the Percentages of each type of Processing

Students	Grade	Total Number of instances	% Affective	% Cognitive	% Metacognitive				% PHY	% UB
					K	M	C	Total Metacognition		
Nicky	A	80	4%	23%	10%	29%	23%	60%	3%	11%
Noah	A	88	3%	17%	9%	42%	10%	61%	0%	18%
Bill	A	81	1%	14%	15%	44%	14%	73%	1%	11%
Linda	A	61	0%	36%	7%	43%	10%	59%	0%	5%
Average for A			2%	23%	10%	39%	14%	63%	1%	11%
Marie	A-	127	0%	28%	9%	38%	24%	71%	1%	0%
Daisy	A-	75	0%	44%	9%	17%	9%	36%	0%	20%
Pandora	A-	82	0%	33%	12%	35%	20%	67%	0%	0%
Average for A-			0%	35%	10%	30%	18%	58%	0%	7%
Hana	B+	63	0%	71%	2%	11%	13%	25%	2%	2%
Layla	B+	101	0%	32%	9%	31%	14%	53%	0%	15%
Andres	B+	80	1%	25%	11%	29%	21%	61%	0%	13%
Ava	B+	100	0%	41%	8%	23%	28%	59%	0%	0%
Kara	B+	127	1%	34%	13%	26%	21%	60%	1%	5%
Autumn	B+	99	1%	38%	6%	22%	16%	44%	0%	16%
Average for B+			1%	40%	8%	24%	19%	50%	1%	9%
Catherine	B	110	1%	29%	4%	36%	26%	66%	0%	4%
Taylor	B	95	1%	29%	10%	27%	27%	65%	0%	4%
William	B	64	0%	50%	3%	5%	11%	19%	0%	31%
Ju Ju	B	84	0%	36%	7%	26%	23%	56%	0%	8%
Tanya	B	120	0%	40%	6%	16%	15%	36%	5%	19%
Max	B	55	0%	56%	7%	15%	18%	40%	0%	4%
Steve	B	99	0%	46%	12%	17%	18%	47%	0%	6%
Average for B			**0%**	**41%**	**7%**	**20%**	**20%**	**47%**	**1%**	**11%**
Total Average			**1%**	**36%**	**8%**	**27%**	**18%**	**53%**	**1%**	**10%**

Note. 100% includes all processing that occurred during learning-task 1
K = Reflective Process Knowledge; M = Reflective Process Monitoring; C = Reflective Process Control; Physical Processing = PHY; Unrelated Behavior = UB

Each code shows that the student switched from one type of thought processing to another, for example from *reflective process monitoring* to *reflective process control,* or from *metacognitive processes* to *cognitive processes*. The results in this table contradict the results from Table 16 in that here the average for metacognition is higher than the average for cognition. It should be noted that metacognition is a thought process that does not require a long time; rather, its strength is in the instances of its use. This table shows how different students managed their thought processes and the difference between high-performing students and low-performing students in how they've managed their thought processes during the first design learning-task for all the 20 participants. What is clear from the data is that high-performing students have higher metacognitive process compared with low-performing students (63% as opposed to 47%). On the other hand, low-performing students have a higher cognitive process compared to high-performing students (41% as oppose to 23%)

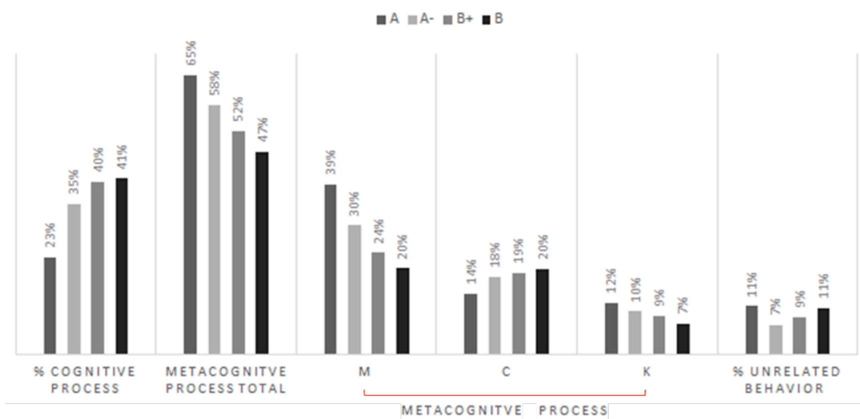

Figure 34. Percentage of various thought processes and subcategories of metacognitive process

As shown in Table 16, several trends are visible from the data: on average, students have more instances of metacognitive processing relative to *cognitive processing* (53% as opposed to 36%). What this result suggests is that students who undertook the first learning-task focused on a metacognitive process, or thinking about how to do the task, more than on doing the task and content of the task, which emphasizes the significance of metacognitive thought processes in design learning-tasks. Also, in subcategories of the metacognitive process, *reflective process* *monitoring* has the highest percentage (*Reflective Process Knowledge*: (8%), *Reflective process monitoring*: (27%), and *reflective process control*: (18%).

- The average ratio of *metacognitive process* and *cognitive process* was lower in LP students. (3.26 as appose to 1.30). This ratio suggests that students who use metacognitive thinking to plan, regulate, and evaluate their reflective process perform better than students who mostly focus on *cognitive process* and less on *metacognitive process* to evaluate their process and solution. In other words, HP students think about how they are designing and try to improve their process more than LP students. By thinking more about how to the do the task, HP students are able to search for solution better and see a bigger range of possible outcomes.
- Similar to the results from section 5.1.1, the *cognitive process* in HP students is lower than LP students (23% as opposed to 41%); and *metacognitive process* is higher in HP students (63% as opposed to 47%).
- *Reflective process monitoring* is higher in HP students (39%) as opposed to LP students (20%). HP students better monitor their design process and make better judgments regarding their learning process in comparison to LP students.
- *Reflective process control* has an inverse relationship with student performance: HP students (14%) and LP students (20%). In combination with the results of *reflective process monitoring*, this shows that LP students jump from one design concept to another without spending enough time to monitor and understand why a particular design concept was not successful.

- *Reflective Process Knowledge* increases from LP students (7%) to HP students (10%). HP students think more about the information and knowledge that they need to use in their learning-task.

Results suggest that *metacognitive process*, when done appropriately, greatly influences student performance in the Foundation Design Lab. *Metacognitive process* does not necessarily result in improved performance. Situations where decisions are based on inaccurate or incorrect metacognitive knowledge, may negatively influence student performance. Since metacognitive thought process is the main focus of this research, the results for each of its subcategories are also presented in terms their subcomponents.

5.1.2.1. ***Analysis of subcategories of reflective process knowledge instances in learning-task 1***

Reflective process knowledge or the understanding that students have regarding their knowledge of how design occurs, is divided into three subcategories of Cognitive Strategy Knowledge, Self-awareness', and 'Task-knowledge'. In this section, the results regarding the percentage of each of these subcategories are provided in Table 17.

Table 17. Instances and percentages of Reflective Process Knowledge

Students	Grade	Total Number of Instances	Reflective Process Knowledge	% Reflective Process Knowledge			
				% CSK	% SA	% TA	Total
Nicky	A	80	8	3%	3%	4%	10%
Noah	A	88	8	1%	2%	6%	9%
Bill	A	81	14	2%	1%	14%	17%
Linda	A	61	4	2%	2%	3%	7%
Average for A			10	2%	2%	6.8%	11%
Marie	A-	127	11	1%	5%	4%	9%
Daisy	A-	75	7	1%	1%	7%	9%
Pandora	A-	82	11	1%	1%	11%	13%
Average for A-			10	1%	2.3%	7.3%	10%
Hana	B+	63	2	1%	0%	2%	3%
Layla	B+	101	9	0%	5%	4%	9%
Andres	B+	80	11	2%	1%	11%	14%
Ava	B+	100	8	1%	1%	6%	8%
Kara	B+	127	17	0%	11%	2%	13%
Autumn	B+	99	6	1%	2%	3%	6%
Average for B+			9	0.8%	3.3%	4.7%	9%
Catherine	B	110	4	2%	2%	0%	4%
Taylor	B	95	10	3%	5%	2%	10%
William	B	64	3	1%	0%	3%	4%
Julia	B	84	6	2%	1%	4%	7%
Tanya	B	120	7	1%	3%	2%	6%
Max	B	55	4	0%	2%	5%	7%
Steve	B	99	12	2%	6%	4%	12%
Average for B			6	1.6%	2.7%	2.9%	7%

Note. Cognitive Strategies Knowledge = CSK; self-Awareness= SA; Task-Awareness = TA

Several trends are visible from the data presented in Table 17:

- On average, among the subcategories of *Reflective process knowledge*, 'ask-knowledge has the highest percentage. In the first learning-task, since they needed to develop a question first, this manifested itself as students trying to understand the objectives of their previous learning-tasks to gain the necessary knowledge to develop a question. Figure 35 provides an example from one of the students who summarized the objectives of previous learning-tasks.

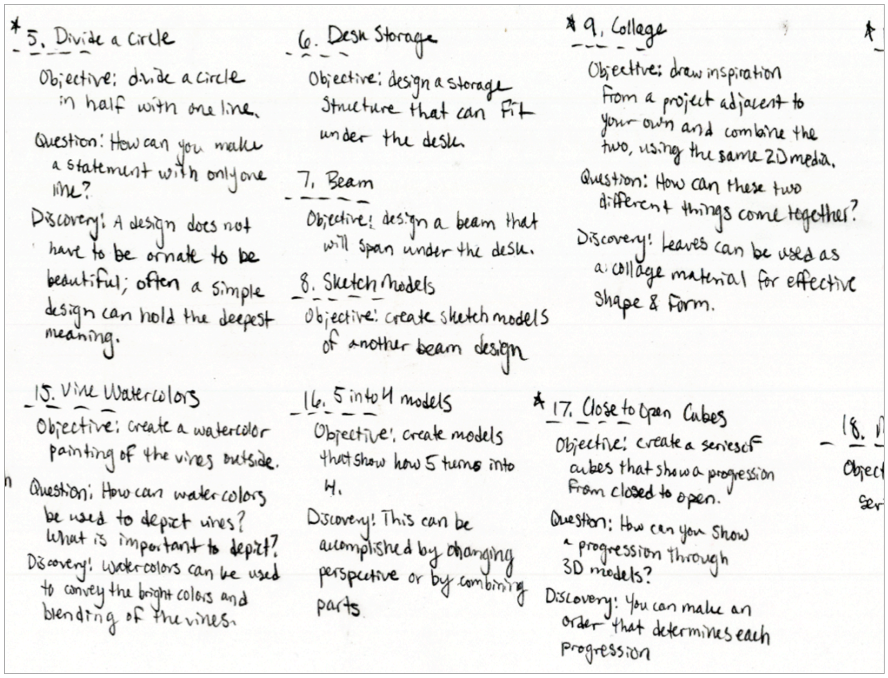

Figure 35. Example of a student engaging in 'task-awareness'

- Cognitive strategy knowledge (CSK) has the lowest percentage. Sub-elements of CSK, declarative knowledge, procedural knowledge, and conditional knowledge, could not be differentiated as they occurred in the form of a single thought process that contained two or all three elements; therefore, they are not included in Table 17.
- Task-knowledge is lower for LP students (2.9%) than for HP students (6.8%). HP students gain a clear understanding of the task and its requirements before they start the task.

Discussion regarding the results presented for *reflective process knowledge* and its subcomponents is provided in Chapter 6.

5.1.2.2. ***Analysis of subcategories of reflective process monitoring instances in learning-task 1***

Of the three main categories of *metacognitive process*, *reflective process monitoring* has the highest percentage (RPM: 27%, RPC: 18%, and RPK: 8%). *Reflective process monitoring* or thinking about the status of the design solving process, is divided into two subcategories: "personal feeling monitoring," and "judgment of situational actions,"

Table 18. Instances and percentages of Reflective Process Monitoring

Students	Grade	Total Number of Instances	Reflective Process Monitoring	% Reflective Process Monitoring		
				% PFM	% SAM	Total%
Nicky	A	80	23	8%	21%	29%
Noah	A	88	37	1%	41%	42%
Bill	A	81	36	10%	35%	44%
Linda	A	61	26	2%	41%	43%
Average for A		77	31	5%	34%	39%
Marie	A-	127	48	5%	33%	38%
Daisy	A-	75	13	4%	13%	17%
Pandora	A-	82	29	4%	32%	35%
Average for A-		85	30	4%	26%	30%
Hana	B+	63	7	0%	11%	11%
Layla	B+	101	31	8%	23%	31%
Andres	B+	80	23	11%	18%	29%
Ava	B+	100	23	3%	20%	23%
Kara	B+	127	33	2%	24%	26%
Autumn	B+	99	22	5%	17%	22%
Average for B+		95	23	5%	19%	24%
Catherine	B	110	40	9%	27%	36%
Taylor	B	95	26	2%	25%	27%
William	B	64	3	0%	5%	5%
Ju Ju	B	84	22	5%	21%	26%
Tanya	B	120	19	8%	8%	16%
Max	B	55	8	4%	11%	15%
Steve	B	99	17	5%	12%	17%
Average for B		90	19	5%	16%	20%
Average		89	24	5%	22%	27%

Note. Reflective Processing Monitoring = RPM Personal Feeling Monitoring = PFM; Situational Actions Monitoring = SAM

As shown in Table 18, across the subcategories of *reflective process monitoring*, several trends are visible:

- On average, thinking about situational actions has a higher percentage (22%) than personal feeling monitoring (5%). This suggests that students focused more on monitoring their strategies than focusing on their emotions and moods while engaged with the learning-task.
- Thinking about situational actions is higher for HP students (34%) than for LP students (16%). This suggests that HP students monitor their progress more as they engage with learning-tasks than LP students.

As will be further discussed in Chapter 6, the results presented for *reflective process monitoring* suggest that teaching students how to monitor their design strategies can improve the outcome of their design tasks.

5.1.2.3. ***Analysis of subcategories of reflective process control instances in learning-task 1***

As illustrated in section 5.1.2, *reflective process control* or the decisions students make and the corresponding actions that influence their process of design problem-solving is one of the subcategories of the metacognitive thought process. *Reflective process control* itself is divided into three subcategories, Control of Personal feelings, Control of Environment, and Control of Situational Actions.

Table 19. Instances and percentages of Reflective Process Control

Students (Pseudonym)	Grade	Total Number of Instances	Reflective Process Control	Reflective Process Control			
				% CPF	% CE	%CSA	Total
Nicky	A	80	18	0%	14%	9%	23%
Noah	A	88	9	1%	1%	8%	10%
Bill	A	81	11	0%	2%	11%	14%
Linda	A	61	6	0%	0%	10%	10%
Average for A		77.5	11	0%	4%	9%	14%
Marie	A-	127	31	0%	1%	24%	24%
Daisy	A-	75	7	3%	1%	5%	9%
Pandora	A-	82	16	0%	4%	16%	20%
Average for A-		96	18	1%	2%	15%	18%
Hana	B+	63	8	0%	0%	13%	13%
Layla	B+	101	14	1%	0%	13%	14%
Andres	B+	80	17	0%	5%	16%	21%
Ava	B+	100	28	3%	3%	22%	28%
Kara	B+	127	27	2%	0%	20%	21%
Autumn	B+	99	16	0%	4%	12%	16%
Average for B+		94	18	1%	2%	16%	19%
Catherine	B	110	29	1%	2%	24%	26%
Taylor	B	95	26	7%	1%	19%	27%
William	B	64	7	2%	0%	9%	11%
Ju Ju	B	84	19	0%	1%	21%	23%
Tanya	B	120	18	0%	5%	10%	15%
Max	B	55	10	2%	2%	15%	18%
Steve	B	99	18	1%	0%	17%	18%
Average for B		89.5	18	2%	2%	16%	20%

Note. Control of Personal feelings = CPA, Control of Environment = CE; Control of Situational Actions = CSA

Several trends are visible from the data presented in Table 19:

- On average, students have more instances of Control of Situational Actions compared to other subcategories. During the learning-task, students regulate their strategies and plans more than focusing on changing their environment or mood.
- On average, Control of Situational Actions is less for HP students than for LP students. One explanation for this is, that while LP students regulate their plan and strategies

more than HP students, since they don't have the necessary *reflective process knowledge* (as mentioned in section 5.1.2.1), the decisions made do not positively influence their learning process.

Based on the results presented, making decisions to regulate the process of learning does not result in an improved learning outcome by itself. As it will be discussed in Chapter 6, a combination of factors is necessary for an improved learning outcome.

5.1.3. **Retrospective verbalization in learning-task 1: Sequences**

To further analyze the data, the researcher also extracted thought processing sequences from the data. The results are presented as the most common sequences for low-performing students (Table 20) and high-performing students (Table 21), and also as a color-coded map of students' thought processes as they work on their learning-tasks (Figure 36). The data suggests a clear difference between HP and LP students regarding the thought processing sequences and the overall thought process. Studio instructors can take advantage of these results to improve the learning process of LP students.

Table 20. Interaction sequences in LP Students

Sequence	Frequency in LP students	Excerpt
Co-Co	79	*"reading the [learning-task]"_"I was drawing down the dimension to scale"(Steve)*
Co-UB	*37*	*I am just thinking about the strips that how to make the strips and I figured out it is not gonna be both because the strips kind of make it fragile." _ "Check his phone" (Max)*
UB - Co	35	*"I [check] my emails and answering emails." _ "Then again I worked on my paper." (Tanya)*
Co -C	23	*"In this case, I kind of had an idea like I was thinking ahead I guess, I was thinking about the project, so that's kind of present difficulty for me." _ "I was thinking about what I was going to do." (Steve)*
C-Co	23	*"I thought if I finish it becomes too plain so I kind of make small cube and build another cube around it, I want it to go from the smallest to biggest possible...," _ "So I kind of make a small cube and build another cube around it." (Steve)*
K-Co	9	*"Listen to professor [in order to understand the task that we have]" _ "I was thinking [about the task] I was thinking I don't do anything. "(Max)*
UB-UB	8	*"Just taking break! I check the news!" _ "Then we are talking about at the summer academy they cut the piece of wood in a way that actually move." (Edward)*
C- UB	8	*"…I was looking at it and how I want to glue it together or just like this and if I wanted to do like this. That's why ultimately I decide to do it like this." _ "[left the table]."* (Catherine)
UB -C	7	*"I helped Max create a file to use on laserconm." _ "I get back to my desk and thought of what I needed to do."* (Edward)
C-K	4	*"[preparing the environment]."_"I was just kind of staring at my cubes."(Ju Ju)*

Note. Cognition = Co; Unrelated behavior = UB; Reflective Process Monitoring = M; Reflective Process Control = C; Reflective Process Knowledge = K

Table 21. Interaction sequences in HP students

HP students	Frequency in HP Students	Excerpt
M-M	37	*"I am still looking for commonality between these all the works and I think I can distinguish also the one has horizontal and vertical intersection are more interesting, and more cohesive or more exciting than the others" _ "but I am still not sure how I can cooperate this in my final project that's my main concern. So I cannot see the common concept but I am not sure how to cooperate in the best possible way and to one final piece."* (Nicky)
Co -M	22	*"I think writing down everything kind of helps me understand it further I guess, I kind of think kind of got me going, strategy for the day..." _ "The task was kind of difficult to focus at all of them at once."(Andres)*
M-Co	15	*"Then here I started to going through, and this where I bring out all my previous projects and analyze them" – "and start writing things down"(Bill)*
M-UB	11	*"I again checking my notebook and wrote down question based on my project in the sketchbook" _" I listen to the music."(Noah)*
M-C	11	*"I was asking professor how I can do this and what type of wood I can use?" _ "Then she was telling me about how someone did this to the leafs and then separate until it like particle of the leafs."* Marie)
K-M	11	*"I think I wrote down few things on this sheet of what she [professor] said 'keeping the strengths and leave everything else out.'" _ "...I was thinking about that a lot." (Bill)*
C-M	9?	*"Iterative -reading the task" _ "I wrote down first stick and paper title then I wrote down the different themes and notes and then I moved on the projects use in this list here. What did I do in all."* (Linda)
M-K	9	*"I got through my sketch book again and add notes." _ "[listening to professor's talk] when she was talking." (Noah)*
UB -M	8	*"I was talking to friends [Tanya]"_"I came up with most of our projects have the idea of space into it..." (Ava)*

Note. Cognition = Co; Unrelated behavior = UB; Reflective Process Monitoring = M; Reflective Process Control = C; Reflective Process Knowledge = K

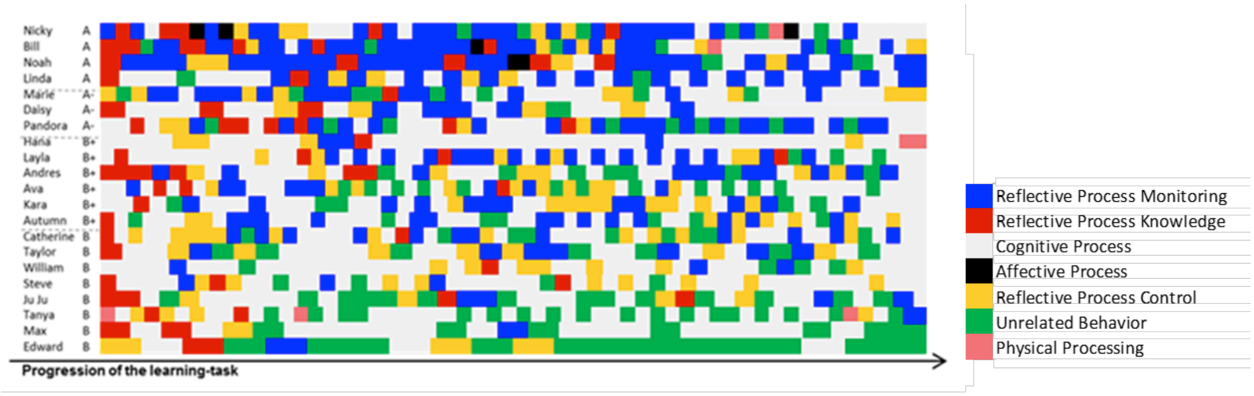

Figure 36. Color-coded map of student thought processing for the first learning-task

As illustrated in Figure 36 the thought processing patterns are complex and non-linear; the only common theme that occurs for all students regardless of their performance is the high number of thought process switching. This switching can be between *cognitive process* and *metacognitive process*, or between the subcategories of metacognitive process. There are a number of different thought processing patterns visible in Figure 36 that differentiate high-performing students from low-performing students.

The density of the Blue *reflective process monitoring* is higher for HP students, and it is spread throughout the design task process. On the other hand, the density of light gray (cognitive process) is stronger for low-performing students in general, and it is stronger in the beginning of the process. In HP students, *cognitive process* is stronger toward the end of the process. HP students monitor their progress more often than LP students. Activities such as making the models are coded under cognitive process; this suggests that LP students do not interrupt their model making process as often and this results in their poor performance.

Another difference between the thought processes that LP students and HP students employ is that *unrelated behavior* (dark pink) happens less in HP students, and it happens more toward the end. This suggests that HP students are better focused in their learning process and take fewer breaks.

Knowledge happens more for HP students and throughout the process, where as in LP students the focus is only toward the beginning of the process. Students evaluate the task at the beginning of the learning-task, but what differentiates HP students and LP students is that, HP students re-visit the task requirements more often during the learning process, ensuring that their designs satisfy the objectives of the learning-task.

Almost all students start with knowledge (red) and end with *cognitive process* (light grey). LP students have more light orange (control), and for all students, control is scattered throughout the learning-task process. This is intuitive in that it shows that students start their learning process with analyzing the learning-task to understand its requirements and objectives, and finish with activities related to doing the task. Along the process, instances of control are present, which suggests the decisions students made to alter the course of their design learning-task. Hana is an outlier in the identified trends, although she is one of the HP students her thought process resembles LP students.

5.1.4. **Card-sorting in learning-task 1**

The data collected from the card-sorting exercise is analysed for the percentage of each of the subcategories of metacognitive process and the order in which the action cards were sequenced. In the following sections, results from each of the analyses are presented. Table 22 shows the percentage for each of the subcategories of *metacognitive process* regardless of the order in which the cards were used. Since the pre-printed action cards were all subcategories of metacognitive process, Table 22 only presents the data for the subcategories of metacognitive process, which are *reflective process knowledge*, *reflective process monitoring*, and *reflective process control*. Students were able to add their specific thought processes on the blank cards; cases where the total column is less than 100% is due to the fact that students added thought processes other than *metacognitive process*. Only two of the students, Catherine and Layla, added sentences that were categorized as Cognitive processes.

Table 22. Percentage of each of the subcategories of metacognitive thought process in card-sorting

Students	Grade	Metacognitive Process			
		Reflective Process Knowledge	Reflective Process Monitoring	Reflective Process Control	Total Metacognition
Nicky	**A**	33	44	22	**100**
Noah	**A**	22	44	33	**100**
Bill	**A**	40	33	27	100
Linda	**A**	38	31	31	100
Average		33	38	28	100
Marie	**A-**	23	31	38	92
Daisy	**A-**	50	13	38	100
Pandora	**A-**	33	30	38	100
Average		35	24	38	97
Hana	**B+**	38	13	50	100
Layla	**B+**	33	33	27	93
Andres	**B+**	50	0	50	100
Ava	**B+**	36	36	27	100
Kara	**B+**	25	50	25	100
Autumn	**B+**	42	17	42	100
Average		37	25	37	99
Catherine	**B**	22	33	33	89
Taylor	**B**	27	27	47	100
Ju Ju	**B**	60	0	40	100
Tanya	**B**	38	25	38	100
Steve	**B**	33	44	22	100
Max	**B**	20	40	40	100
Average		33	25	40	96

A review of the data presented in Table 22 results in the following observations:

- The pre-printed sentences that were given to students were all components of the metacognitive process; since low-performing students engage in more cognitive process; to describe their thinking process they added cognitive processes on the blank cards.
- Similar to the results presented in Section 5.1.2, high-performing students have, on average, higher monitoring and lower control and cognitive than low-performing students.
- Task familiarity, which is a sub-category of reflective process knowledge, is higher for low-performing students. The reason behind this may be that many (Taylor, Layla, Autumn, and Tanya) low-performing students have high degrees of task familiarity, but it is evident that this has provided them with a false sense of confidence that in turn has negatively influenced their performance.
- For Kara (LP student), the high level of monitoring is mostly negative factors, like lack of confidence and assessment of task difficulty. She added these two sentences to her card-sorting (*"I thought I wish the objective was clearer," "I thought this is going to be a difficult project").* This is an indication that she is not monitoring how the design process is progressing or how to improve this process; rather she is frustrated. She is monitoring her design process, but since she does not have a clear understanding of the objectives of the task she cannot progress in her design, which has resulted in her frustration.

An examination of the relationship between the card-sorting exercise and the retrospective method shows that high-performing students have a higher similarity between the two methods. In other words, high-performing students are better able to describe their thinking process in the card-sorting exercise. Paris and Winograd (1990), emphasize the importance of the relationship between metacognition (in this case retrospective verbalization) and action (in this case, the card-sorting exercise). Lawanto, (2010) also refers to this phenomenon as a central factor in learning.

Based on the analysis of thought process sequences, Bill and Noah, who are high-performing students, have the highest number of similar sequences between their card-sorting and their retrospective verbalization. One possible explanation could be that HP students have established a thought process that they follow for each learning-task; hence, when they are using the cards to describe their design thought process, it is more consistent with their retrospective verbalization.

Low-performing students had a high percentage of cognitive thought process in their retrospective verbalization (refer to Table 16), and as mentioned earlier, the pre-printed cards did not have a statement regarding cognitive actions. Therefore, they had trouble using the pre-printed cards to describe their thought process; hence, low-performing student card-sorting did not match their retrospective results. This further confirms the results obtained from the retrospective verbalization, suggesting that focusing too much on the design of the task without thinking about it results in less than ideal performance.

5.1.5. **Questionnaire in learning-task 1**

The researcher provided students with two open-ended questions at the beginning of the first learning-task. In addition to the retrospective verbalization method, the open-ended questions provided the researcher with an opportunity to confirm the results of other data collected. This allowed a way to discover more about student metacognitive thought processes, and the potential factors that influence their metacognitive thought processes. The questionnaire is used as a complementary method. Below are specific core questions which were prepared to be asked at the beginning and the end of the first learning-task.

Have you had a similar design experience before? Could you please share it with us?

Based on the answers provided by the students to this question, some trends can be identified between the low-performing (LP) students and high-performing (HP) students. The answers from some of the students are provided here as examples.

It can be seen that high-performing students not only have prior exposure to similar tasks, they were also able to correctly identify the task requirements and successfully link the requirements with previous experience.

- *Nicky (HP): Somewhat, in my Advanced Art class, in 11th grade we were required to come up with overarching theme for all our work. Each piece had 10 own unique requirements though.*
- *Marie (HP): In one of my design art classes, we did a lot of projects in different medium and different assignments and in the end she asked us to look at what we did and create or do a final project that interest us. One of the thing interested me was taking an emotion and creating an image but it couldn't be your normal image.so I did a series of emotions. I still use that in coming up with a concept for my painting class.*

- *Bill (HP): Yes, I have been to a design camp in the past. Although it engaged my design thinking, it was not easily as critical as serious as this studio. I have learned and discovered more here as a result of the intensity of the studio class.*

On the other hand, low-performing students, in many instances, could not think of any similar tasks, or they identified the task requirements incorrectly, which was clear from the past experiences that they identify as similar to this experience. This further confirms the results from the retrospective verbalization, where it was shown that low-performing students have less 'Task-awareness' than high-performing students.

Excerpts below provide some of the responses LP students gave to the question. Catherine identified a previous learning-task that is not similar to this learning-task. On the other hand, Taylor and Tanya could not identify any similar experience with what they have been asked to do for this learning-task.

- *Catherine (LP): When we did the open to close project, that was one that really made me question the relation of the pieces to the whole and hard I could make it different.*
- *Taylor (LP): No, this project has an open-ended question that each individual must find for themselves within our previous projects that were already given a question we had to answer.*
- *Tanya (LP): No I don't think I have had a similar design experience when it comes particularly to this project. Throughout the semester we have had to answer these questions, so I am familiar with the ideas, but examine my work as a whole is rather challenging.*

How will you resolve the situation?

High-performing students also had a better idea of how to approach the problem. Also, it is to some extent evident that HP students were emotionally more prepared to tackle the problem than LP students. Although the results regarding "affective processing" have not been reported in this study, but are based on the results of numerous other research studies (i.e. Pressley & Afflerbach, 1995), motivational factors play an important role in student performance.

- *Nicky (HP): I plan to spend more time in studio, doodle and sketch more even if it is not concrete idea for my project, and be more open minded overall.*
- *Marie (HP): Keep trying to draw it and then build something that kind of shows what I want and try to draw it again.*
- *Linda (HP): I will carefully analyze each project and the criteria we were given for each project, recording the qualities and discoveries of each, and hopefully I will see a connection in that.*
- *Noah (HP): I feel motivated.*
- *Bill (HP): I am excited to see what I can find in each project and then to see what will result as my final project.*

On the other hand, low-performing students do not have a clear strategy for approaching the learning-task, and many of them are relying on trial and error methods or are hoping that by spending a lot of time on the task, they would be able to come up with a solution. This suggests that they have low “cognitive strategy knowledge” and cannot effectively strategize for the learning-task, which further confirms the results from the retrospective verbalization analysis.

- *Taylor (LP): I resolve the situation through trial and error with brainstorming.*
- *Hana (LP): Experimenting with different materials to make small models to see the effect and deciding how to develop.*
- *Steve (LP): I think I should follow my instincts more and perhaps think less as that strategy has worked before*
- *Ju Ju (LP): Because this is not being graded I will brainstorm and do my best with the T-square out in way to translate my answer to the paper.*

- *Tanya (LP): I will resolve the situation by putting a lots of time and thought into examining and ordering my projects for my presentation. My idea will be clear and drive me in a good direction for my final project.*
- *Ju Ju (LP): Before I originally thought I was going to be working on my projects and being evaluated on how I answer the questions. But I feel like coming up with an answer to such a vague question is frustrating and will take a lot of time.*

The results obtained from these two open-ended questions provided more insight into the thought processes of design students while engaged in a learning-task, and confirmed some of the results presented earlier.

5.2. Findings from Task 2

In this section, the results generated from the analysis of the data gathered in the second learning-task are presented. The results include the analysis of the concurrent verbalization (Section 5.2.1) and the open-ended questionnaire (section 5.2.2).

As mentioned in Section 3.2.3.1, for the second learning-task students were asked to work in pairs. This resulted in 8 pairs and a group of three students (19 students in total). Each group was given a 22″ x 30″ sheet of 2 ply Bristol board; the goal of the learning-task was for students to develop a design by making three changes in 3 hours. The data for this learning-task was gathered using a concurrent verbalization method. The data was analyzed using the theoretical framework described previously, and the number of instances for each category and subcategory for each of the pairs were extracted. Since the theoretical framework for this research is developed from all the data acquired, the definitions for each category and subcategory of thought processes remains the same for all the learning-tasks.

Each of the three learning-tasks were evaluated by the first-year lab professor(s). (see section 3.7.3) For the second learning-task, the researcher asked three of the first-year studio professors to evaluate and rank each pair's design. Section 3.7.3 shows the designs developed by each group.

Students were ranked based on their performance, at the end of the class. Table 23 provides the ranking for each pair. The rankings of student designs are used to distinguish between high-performing students and low-performing students.

Table 23. Ranked task Performance for Learning-task 2

Students (Pseudonym)	**N- D**	**S - P**	**A- L**	**L - T**	**P- E**	**A-W-H**	**N -K**	**C - M**	**B - M**
Rank	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

Note. Steve - Pandora =S-P, Noah - Daisy =N-D, Autumn- Layla =K-L, Linda - Taylor =L-T, Paul- Edward =P-E, Ava - William, Hana =A-W-H, Nicky -Kara=N-K, Catherine - Marie =Ch-M, Bill - Max =B-M

5.2.1. **Concurrent verbalization: Percent of various processing types in Learning-Task 2**

This section presents the number of instances and the percentage of each thought processing category and subcategory. To facilitate the comparison between the results presented here and those presented in Section 5.1.2, a similar organization has been used. The number of instances for Physical Processing, and Unrelated Behavior were not significant and were eliminated from the results. Table 24 provides the percentage of metacognitive, cognitive, and affective thought processing for each of the groups. The table is organized based on the ranking of each group's design, with the most successful designs on the top and the least successful designs on the bottom. Similar to the retrospective verbalization, the total number of instances for each group has a wide range (154 – 351). Since students are working in groups, which requires them to share (verbalize) their ideas and thought process, the number of instances are much higher in the concurrent verbalization.

Table 24. Instances and the percentages of all types of processing

Group	Rank	Total Number of Instances	% Affective	% Cognitive	% Metacognitive			
					K	M	C	Total Metacognition
Noah - Daisy	**1**	154	**0%**	14%	10%	55 %	14 %	78%
Steve - Pandora	**2**	196	1%	9%	23%	51 %	16 %	90%
Average			0%	11%	16%	53 %	15 %	84%
Autumn-Layla	**3**	190	2%	17%	4%	42 %	31 %	76%
Linda - Taylor	**4**	236	2%	19%	8%	42 %	28 %	78%
Average			2%	18%	6%	42 %	29 %	77%
Paul-Edward	**5**	159	3%	11%	8%	38 %	40 %	86%
Ava - William, Hana	**6**	154	0%	25%	10%	39 %	25 %	74%
Average			1%	18%	9%	38 %	32 %	80%
Nicky - Kara	**7**	161	2%	13%	16%	42 %	27 %	85%
Catherin e - Marie	**8**	351	2%	22%	5%	41 %	29 %	75%
Bill - Max	**9**	178	3%	17%	2%	43 %	35 %	80%
Average			2%	17%	8%	42 %	30 %	80%
Average Total			2%	16%	10%	44 %	27 %	80%

Note. 100% = all processing that occurred during the learning-task

Steve - Pandora =S-P, Noah - Daisy =N-D, Autumn- Layla =K-L, Linda - Taylor =L-T, Paul- Edward =P-E, Ava - William, Hana =A-W-H, Nicky -Kara=N-K, Catherine - Marie =Ch-M, Bill - Max =B-M M = Reflective Process Monitoring; C = Reflective Process Control; K = Reflective Process Knowledge

Since students were free to choose their teammates, the composition of each group varies with respect to HP and LP students (based on the grades each student received for their first learning-task[51]), which decreases the variation in the data acquired using the concurrent verbalization method.

Table 24 shows how students managed their thought processes when they were working as a part of a group, and the difference between high-performing groups and low-performing groups. Based on the results presented in Table 24, the following trends can be identified between the thought processes of high-performing and low-performing groups.

Similar to the results reported for learning-task 1, *metacognitive thought processing* has a much higher percentage than *cognitive thought processing*. Group interactions require students to engage in more metacognitive activity, hence the percentage of cognitive activity to metacognitive activity has significantly changed from the first learning-task (Cognitive: 36%, Metacognitive: 53%) to the second learning-task (cognitive: 17%, metacognitive: 80%). This further emphasizes the importance of group learning-tasks in Design Lab.

Similar to the results presented for the first learning-task, from the subcategories of *metacognitive process*, *reflective process monitoring* has the highest percentage (*reflective process knowledge*: 10%, *reflective process monitoring*: 44%, and *reflective process control*:

[51]. Noah – Daisy (HP-HP), Steve – Pandora (LP-HP), Autumn – Layla (LP-LP), Linda –Taylor (HP-LP), Paul – Edward (LP-LP), Ava – William – Hana (LP-LP-LP), Nicky – Kara (HP-LP), Catherine – Marie (LP-HP), Bill– Max (HP-LP)

27%) Similar to the results presented for the first learning-task, cognition on average increases from high-performing (11%) students to low-performing students (17%). Since metacognitive thought process is the main objective of this study, the results for each of its subcategories are presented in the following sections.

5.2.1.1. ***Analysis of categories and subcategories of metacognitive thought process instances in learning-task 2***

In this section, the categories and subcategories of the metacognitive thought processing category are further discussed. The trends that differentiate the thought process of HP groups and LP groups are also presented.

- From the subcategories of *reflective process knowledge*, on average, HP students have a higher 'task-awareness' (TA) relative to LP students (10% vs. 1%). LP groups engage in more discussions on what strategies to use to complete the task, while HP groups engage in more discussions regarding the task and its requirements. Since students did not engage in discussions regarding how they perform the best when working in a group, self-awareness did not have a significant influence on groups' performance, and therefore was eliminated from the results.

The importance of task-awareness can be best presented with examples of how two of the groups' designs (Figure 37) were evaluated by the professors. The excerpt below is from the conversation between the three professors who were evaluating the designs. It can be seen that the most significant criticism that was made regarding the designs is that they have failed to address what was asked in the learning-task. It should also be noted that both pairs have the lowest percentage of task-awareness compared with rest of the students. The first excerpt is for Bill and Max (Figure 37 b), and the second excerpt is for Catherine and Marie (Figure 37 a).

> *Professor 1: They (Bill-Max pair) cut it (Bristol sheet) in three pieces and made three different models not operation within the limit …*
> *Professor 2: Yeah it's been cut in half, you lose the oneness of the Bristol board*

> *Professor 1: This one because of all of the extra noise because of the joint*
> *Professor 3: Yeah. If you count the changes, you can see four. They haven't counted gluing as a change I think*

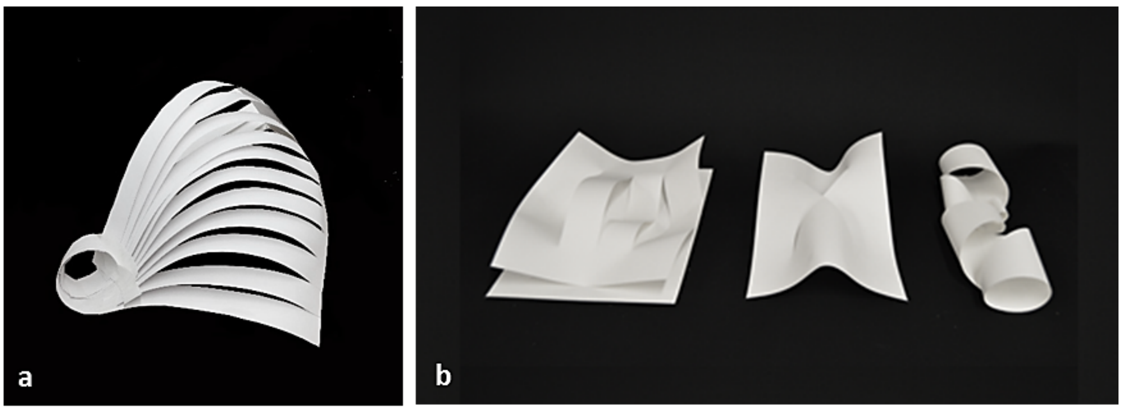

Figure 37. Example of second learning-task project in LP, first-year student work samples

In contrast to the two examples that had the lowest Task-knowledge, the excerpt below is from the pair with the highest Task-knowledge (Steve and Pandora). It can be seen that before starting their design, the pair analyzed the task and its requirements, which resulted in a successful design (Figure 38 b).

> *Once presented with the prompt, we proceeded to define the term change. At first, we thought that every physical action would in fact be a change. In the specific case of the Bristol sheet, this change could range from a cut, or a fold, to something more simple like a drawing. … What is a change? Is it chemical or physical? Does it have to be one action? Or can it be multiple actions that have one singular purpose?*

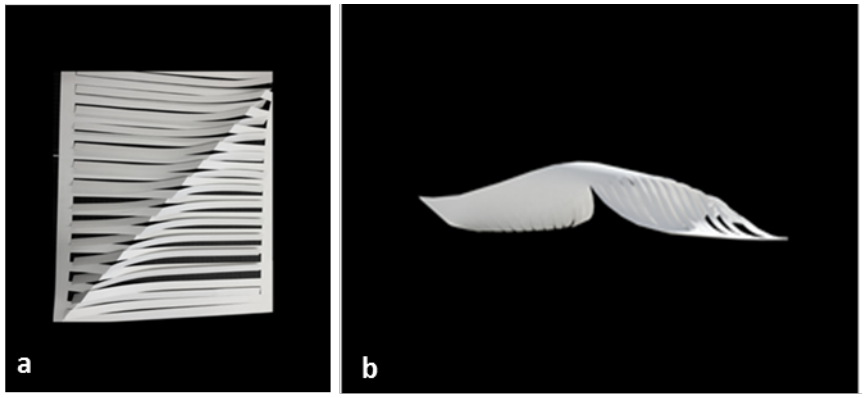

Figure 38. Example of second learning-task project in HP, first-year student work samples

- From the subcategories of *reflective process monitoring*, on average 'Situational Action Monitoring' has the highest percentage (SAM: 34%, AM: 9%). Similar to the first learning-task, groups emphasized more the monitoring of their progress toward the completion of the task, in comparison with monitoring how they feel about task.
- Students in HP groups engaged in more "situational action monitoring" compared with students in LP groups (49% as opposed to 27%). This further confirms the results presented in Section 5.1.2.2.
- Similar to the results presented for learning-task 1, students emphasized more regulating the progress of their design, in comparison to controlling the environment, or their personal feeling regarding the task. The percentage of "'control of environment" (CE) and "control of personal feelings" (CPF) was insignificant and therefore they were eliminated from the results presented.
- Similar to the results presented for the first learning-task, students in LP groups engaged in more "control of situational action" in comparison with students in HP groups (30% as opposed to 16%).

Table **25. Percentage for subcategories of metacognitive thought processing**

Groups	Group Rank	Reflective Process Knowledge			Reflective Process Monitoring			Reflective Process Control	
		CSK	TA	Total	PFM	SAM	Total	CSA	Total
N-D	**1**	5%	4%	9%	8%	49%	57%	16%	16%
S-P	**2**	6%	15%	21%	10%	38%	48%	17%	17%
Average		6%	10%	15%	9%	44%	53%	17%	17%
A-L	**3**	2%	3%	5%	13%	31%	44%	25%	25%
L-T	**4**	6%	0%	6%	11%	32%	43%	22%	22%
Average		4%	2%	6%	12%	32%	44%	24%	24%
P-E	**5**	4%	2%	6%	4%	33%	37%	24%	24%
A-W-H	**6**	11%	5%	16%	4%	35%	39%	27%	27%
Average		8%	4%	11%	4%	34%	38%	26%	26%
N-K	**7**	6%	1%	7%	12%	29%	41%	32%	32%
C-M	**8**	4%	1%	4%	7%	29%	36%	26%	26%
B-M	**9**	4%	0%	4%	9%	27%	36%	30%	30%
Average		5%	1%	5%	9%	28%	38%	29%	29%
Average Total		5%	3%	9%	9%	34%	42%	24%	24%

Note. 100% = all processing that occurred during the learning-task
Steve - Pandora =S-P, Noah - Daisy =N-D, Autumn- Layla =K-L, Linda - Taylor =L-T, Paul- Edward =P-E, Ava - William, Hana =A-W-H, Nicky -Kara=N-K, Catherine - Marie =Ch-M, Bill - Max =B-M

The most significant takeaway from the second learning-task was that students engaged in more metacognitive activity when working in groups. The results also further confirm what was presented in the previous sections for the first learning-task.

5.2.2. Open-ended questionnaire

The researcher intended to use a questionnaire to evaluate the change/development of metacognitive thought process in students. To develop this questionnaire, the researcher provided each student with two open-ended questions at the end of the second learning-task. The researcher used students' answers to the two open-ended questions (see section 3.3.3), and an inductive and deductive framework (Lawanto, 2010), and through a constant comparison analysis developed the questionnaire.

Table 26 provides evidence for how students' answers to the open-ended questions were used to develop the questionnaire (inductive).

Table 26. Extracted effective factors based on the content analysis of student

Factors	Relative to this project **did you find yourself**	**Evidence / Coded Text**
F1	Having an incorrect impression of task difficulty	*"At first I thought 3 changes were not enough to accomplish but after analyzing and experimenting I realized that the challenge was more to actually have 3 different changes of equal importance. Now it seems that 3 changes are almost too much to accomplish." (Steve)* *"I consider each action a change but at the end I realized that one action repeated over and over could make one big change." (Steve)*
F2	Thinking you needed to have more knowledge before taking a design action	*"Using rockite for the first time was really intimidating and so I believe my skills of using it have developed a lot. The more molds I did, the easier it got and the more confident I became when using it, the models came out great."* (Catherine)
F3	Requiring more knowledge and skill	*"I also still lack skills and experience in rockite, wood and metal."* (Nicky)
F4	Developing ideas/Formulating ideas	*"Our idea changed and evolved as we worked." (Edward)* *"I don't think the process was about solving the problem but rather it was a process of experiencing and exploring in order to obtain a new idea. My feelings about my ability did change a little because I've always tended to try thinking of an idea before an idea. But I think the*

Factors	Relative to this project **did you find yourself**	Evidence / Coded Text
		opposite way is better." (William) *"I started with one idea and ended with one completely different from it. I also became more in touch with the question was asking." (Autumn)* *"I changed ideas again and again and used my peers for help." (Fred)*
F5	Fear of failing or not being able to satisfy self-expectations	*"I wasn't quite confident in my ability to create a good place." (Nicky)* *"At first I was not fully confident that I could solve the project." (Linda)*
F6	Not fully understanding the project directives /objectives at the beginning	*"At first when I received the project, I was extremely confused and was unsure what to do." (Noah)*
F7	Being inventive	*"we [were] both creative."(Layla)*
F8	Underestimating his/her ability	*"In the way that at first I thought maybe I cannot come up with a good idea in a limited time, but I proved it to myself that it's possible" (Max)* *"In the beginning of the competition I was really unsure of what I would do. I had a lot of doubts about my ability to complete the task, but as I worked and figured it out, my doubts went away and now that I am done, I have complete confidence in myself." (Edward)*
F9	Having over-confidence at the beginning of the project	*"My feeling about our abilities has not changed because we [were] both creative and I knew if we used our old projects then we could create/ design a really cool project even without much direction from a prompt." (Layla)* *"Since receiving the project, I have been confident in ability to answer the prompt and create a project." (Linda)* *"I was always confident that we would be able to*

Factors	Relative to this project **did you find yourself**	Evidence / Coded Text
		solve the design project and being able to discuss and work with a partner to solve any issues." (Edward)
F10	Having ability to complete the task	*"… we could solve the problem." (Catherine)* *"I was still able to address the task that was posed and found it pretty simple, and my partner and I worked well together." (Autumn)*
F11	Employing inaccurate design/planning strategies	*"It [strategy] definitely changed. At first we thought of 3 simple ideas of applying to the Bristol paper. Then we shifted directly to making a model applying our 3 changes to it." (Ava)*
F12	Successfully adopting new strategies	*"…But after talking and making a small sketch model, I realized that we had a sense of direction." (Noah)* *"… I could see that this design process was leading somewhere because every sketch model created new questions and ideas." (Noah)*
F13	Benefiting from peers' advice/work	*"I was always confident that we would be able to solve the design project and being able to discuss and work with a partner to solve any issues." (Edward)* *"I developed a much more different idea and understanding of the question that developed through the conversations my partner and I had." (Fred)* *"Once my partner and I began to work together, it was definite that we would be able to solve the question and create a good design together." (Linda)* *"We had a similar thinking process and agreed upon most of our thought, which definitely made it easier to solve an issue." (Daisy)* *"I constantly asked upper class mates, played around with wooden blocks and sketched." (Noah)*
F14	Utilizing a new means of exploration	*"At first I was thinking about drawing some different stuff on the paper to make the changes, but I changed my strategy afterwards." (Max)*

Factors	Relative to this project **did you find yourself**	Evidence / Coded Text
		"I started out by looking up different repetitive designs, but then moved more into just starting to build models and experimenting with materials." (Kara) *"It changed because in the beginning we were thinking about the purpose behind our project, but it shifted to us just experimenting with different designs and then executing." (Layla)*
F15	Being challenged during the design process	"I changed the whole structure of the model when I tried to combine all my pieces of elements to show repetition. The elements and the previous structure were too similar so that the whole model looked strange. Therefore, I changed the whole structure." (Hana)
F16	Using newly acquired knowledge in design task	"Using Rockite for the first time was really intimidating and so I believe my skills of using it have developed a lot. The more molds I did, the easier it got and the more confident I became when using it. The models came out great." (Catherine)
F17	Having produced an unsuccessful design	*"Yes, we messed up on our first attempt." (William)* *"I had a plan in mind and it didn't work out…" (Autumn)*
F18	Using multiple approaches	*"For most of the project we did trial and error and found points of interest in each trail and fixed them to come up with the final." (Pandora)* *"I made a beginning sketch and as I made my project, I changed my idea a couple of times and in the end ended up doing something very similar to the first design." (Layla)*
F19	Searching for alternative solutions	*"I believed it has opened my mind in the way I see what three changes can be, whether it be cutting the paper three times or making many cuts and making 3 separate structures." (Bill)*
F20	Enhancing/developing the design approach	*"It's put a new outlook on the way I see prompts, specifically the 'promise of repetition'" (Bill)* *"I took my competition piece from a previous*

Factors	Relative to this project **did you find yourself**	Evidence / Coded Text
		project but I just had to decide how to arrange it. I liked the repetition in my storage piece so I improved on that" (Pandora).
F21	Searching for a simpler design strategy	*"We decided to change our idea to a more simplistic idea to better our chances of completing it." (Taylor)*
F22	Strategizing in response to changing conditions of the project	*"We had to compensate for the folds. We created by curving the other strips." (Nicky)* *"We use the strategies that just do it and then think about it later. So we do random cutting first and then talk about it to find the second step that we want to apply. Then the theme of the project comes out itself." (Hana)*
F23	Experiencing unanticipated problems	*"My strategies of how much to cut the various pieces of the cube changed. I found that the dado saw was not as precise/smooth as I would have liked. Instead, on some pieces I used the jigsaw, but in the future it might be better to take time and use hand tools to avoid splitting of the wood. I also had a lot of trouble drilling holes for the hinges. The drill bit was so thick that it would bend and not go straight, which compromised the final project. New strategies for drilling holes need to be implemented."* (Andres)
F24	Significantly changing the initial design	*"It definitely changed. At first we thought of three simple ideas of applying to the Bristol paper. Then we shifted directly to making a model applying our three changes to it." (Ava)*
F25	Finding new materials and using them effectively	*"At first, I thought maybe I cannot finish this project in a good way because I was working with a new material and actually in the sketch models I couldn't make a good thing but at last I did it and I felt like I have the ability to work and try any new materials" (Max).* *"I had a plan in mind and it didn't work out, but I found out I could use new materials and I realized I need to experiment within my projects more" (Autumn).* *"I decided to use a new material and that was*

Factors	Relative to this project **did you find yourself**	Evidence / Coded Text
		already going to be a little more difficult but I think I handled it well. I realized that when making a mold it matters what material you use" (Marie).
F26	Overcoming limited time	*"I wasn't quite confident in my ability to create a good place in such a limited amount of time." (Nicky)* *"This was a project that I would have wanted two days on because there were so many possibilities." (Catherine)* *"The time limit was a major factor in our design. Our ideas were too complex to be completed in such a minimal the amount of time." (Taylor)* *"Even with communication, it's hard to come up with something when you both are unsure. I realized that under amount of time we had you can't just work on every idea you had. I feel like if we had more time to work through it we would have achieved what we wanted." (Marie)* *I feel that with more time I could develop something interesting that clearly and beautifully explains the prompt. (Kara)* *I knew what I wanted to do from the get-go. I experimented with the design so I took longer than I wanted on that than on the final piece so I knew my abilities but wish I had considered it along with time more. (Megan)* *With the limited time my initial idea had to be changed because there was not enough time for the idea to fully be implemented. (Taylor)*
F27	Working to satisfy the professor's expectations	*"As we talked more with professor [prof] we come to different conclusions in the definition."(Pandora)*
F28	Discovering a focus in the design process	*"It changed because in the beginning we were thinking about the purpose behind our project but it shifted to us just experimenting with different designs and then executing." (Layla)*
F29	Having a sense of satisfaction with the design outcome	*"I was working with a new material and actually in the sketch models I couldn't make a good thing but at last I did it and I felt like I have the ability to*

Factors	Relative to this project **did you find yourself**	Evidence / Coded Text
		work and try any new materials." (Max) *"The models came out great." (Catherine)*

In addition to these factors, a review of the literature (Lawanto, 2010) and interviews with studio professors revealed five additional factors that were necessary to include in the questionnaire (deductive) (Table 27). This questionnaire was distributed among 206 students at the end of the third learning-task (for a sample of the questionnaire see Appendix G).

Table 27. Additional possible factors

Factors	Relative to this project **did you find yourself**
F30	Strongly relying on one solution to focus the project
F31	Lacking the ability to focus on the project
F32	Focusing on smaller details of the project
F33	Discovering a new interpretation of the stated project directives / objectives
F34	Receiving suggestions from others in the school

5.3. Findings from Task 3 - Result of Open-ended Questionnaire

For the third learning-task, the researcher acquired data from the Foundation Design Lab students (206 students). After students completed their designs for the Foundation Design Competition (see section 3.2.3.1), they were provided with the questionnaire that was developed earlier (see section 5.2.2 for more information regarding the development of the questionnaire).

The researcher analyzed student responses to the questionnaire by calculating the percentage of students that selected "yes" on the questionnaire in response to each of the factors. Results highlight the effective metacognitive conditions in students while they were engaged in the design learning-task. Results in Table 29 and Table 30 were analyzed to identify the factors that students deemed the most effective in their design thinking process.

The questionnaire had two separate sections, one for student perceptions regarding their judgment,[52] and one for student perceptions regarding their ability[53]. Student responses were used to evaluate which of the 34 factors influenced their metacognitive thinking, either their judgment or ability for solving the design problem. The 34 factors were analyzed and ranked based on the number of students who answered "yes" on the questionnaires. From the thirty-four (34) factors, seven of them highly influenced both students' judgment and ability in design problem-solving (Table 28). The results suggest that 16 factors were significant in changing student judgment during design problem-solving (Table 29), and 25 factors affected student ability in this regard (Table 30).

Among all the factors, there are seven main causes that resulted in change/development of many students' metacognitive thinking. Based on the result, the role of others, especially colleagues, is highlighted, *receiving suggestions from others in the school*, and *benefiting from peers' advice/work*. Moreover, *using newly acquired knowledge in the design task*, and finding new materials and using them effectively shows the importance of the evolving process of design thinking where learning and using the new knowledge are dynamically happening during the process. In addition, students themselves have a vital role as they want to improve their expectations and enhance the outcome creatively, *having a sense of satisfaction with the*

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[52]. Students' Judgment regarding the state of their knowledge or their ability to accomplish a task (Paris & Winograd, 1990).

[53]. Students' ability to plan, monitor, and revise ongoing performance (Paris & Winograd, 1990).

design outcome, *being inventive*, and *fear of failing or not being able to satisfy self-expectations*.

Table 28. Effective factors on both student judgment and ability in design learning (percentage of students answering yes)

Factors	**Effect on Student judgment**	**Effect on Student Ability**
Receiving suggestions from others in the school	72.5%	79.0%
Having a sense of satisfaction with the design outcome	78.0%	77.5%
Benefiting from peers' advice/work	77.0%	72.5%
Being inventive	70.0%	73.0%
Using newly acquired knowledge in design task	71.0%	69.5%
Finding new materials and using them effectively	51.5%	58.5%
Fear of failing or not being able to satisfy self-expectations	59.0%	53.5%

Based on descriptive analysis, results show that factors such as *having ability to complete the task*, *having a sense of satisfaction with the design outcome*, and *successfully adopting new strategies* have the highest influence on student judgment in their design problem-solving. On the other hand, factors such as *lacking the ability to focus on the project*, *having an incorrect impression of task difficulty*, and *requiring more knowledge and skill* have the lowest influence on student judgment in their design problem-solving.

Table 29. Ranked factors affecting judgment (Highest to Lowest)

Factors	Did you find yourself	All Students[54]	Leaders
F10	Having ability to complete the task	84.5%	86%
F29	Having a sense of satisfaction with the design outcome	78.0%	84%
F12	Successfully adopting new strategies	77.5%	78%
F13	Benefiting from peers' advice/work	77.0%	79%
F2	Thinking you needed to have more knowledge before taking a design action	76.0%	78%
F34	Receiving suggestions from others in the school	72.5%	86%
F16	Using newly acquired knowledge in design task	71.0%	56%
F7	Being inventive	70.0%	57%
F26	Overcoming limited time	61.5%	63%
F5	Fear of failing or not being able to satisfy self-expectations	59.0%	42%
F25	Finding new materials and using them effectively	51.5%	42%
F6	Not fully understanding the project directives /objectives at the beginning	44.5%	21%
F8	Underestimating his/her ability	43.5%	28%
F3	Requiring more knowledge and skill	37.5%	35%
F1	Having an incorrect impression of task difficulty	33.0%	35%
F31	Lacking the ability to focus on the project	19.5%	14%

The result of analysis on the factors that affect student ability in their design problem-solving show that factors such as *searching for alternative solutions*, *enhancing/developing the design approach*, and *receiving suggestions from others in the school* have the highest influence. On the other hand, factors such as *having over-confidence at the beginning of the project*, *significantly changing the initial design*, and *strongly relying on one solution to focus the project* have the lowest influence of student ability in their design problem-solving.

[54]. All students except for the leaders

Table 30. Ranked factors effecting ability (Highest to Lowest)

Factors	Did you find yourself	All Students[55]	Leaders
F19	Searching for alternative solutions	81.5%	86.39%
F20	Enhancing/developing the design approach	80.0%	92.00%
F34	Receiving suggestions from others in the school	79.0%	70.31%
F14	Utilizing a new means of exploration	77.5%	70.53%
F29	Having a sense of satisfaction with the design outcome	77.5%	77.50%
F28	Discovering a focus in the design process	76.5%	84.92%
F4	Developing ideas, Formulating ideas	76.0 %	70.68%
F27	Working to satisfy the professor's expectations	74.0%	65.12%
F7	Being inventive	73.0%	79.57%
F13	Benefiting from peers' advice/work	72.5%	63.08%
F16	Using newly acquired knowledge in design task	69.5%	63.25%
F21	Searching for a simpler design strategy	69.5%	56.99%
F23	Experiencing unanticipated problems	68.5%	78.09%
F15	Being challenged during the design process	65.5%	41.92%
F18	Using multiple approaches	59.0%	34.22%
F25	Finding new materials and using them effectively	58.5%	42.71%
F32	Focusing on smaller details of the project	58.0%	41.18%
F22	Strategizing in response to changing conditions of the project	54.0%	79.38%
F5	Fear of failing or not being able to satisfy self-expectations	53.5%	42.80%
F11	Employing inaccurate design/planning strategies	45.5%	42.77%
F17	Having produced an unsuccessful design	40.0%	49.60%
F33	Discovering a new interpretation of the stated project directives / objectives	39.0%	27.69%
F30	Strongly relying on one solution to focus the project	37.5%	36.75%
F24	Significantly changing the initial design	37.0%	20.35%
F9	Having over-confidence at the beginning of the project	22.0%	7.04%

[55]. All students except for the leaders

As mentioned in (Section 3.7.3) for the third learning-task, 14 students were selected by the studio professors as “leaders.” The responses of leaders were compared with the rest of the students to extract the patterns that differentiate the two group (Table 29 and Table 30). This section provides the analysis of the most influential factors.

Factors such as *receiving suggestions from others in the school* mostly influence leaders’ judgment in design problem-solving, rather than other students. On the other hand, factors such as *not fully understanding the project directives/objectives at the beginning*, *underestimating his/her ability*, and *fear of failing or not being able to satisfy self-expectations* were more significant to the rest of the students’ judgment in design problem-solving, as compared with leaders.

Factors such as *strategizing in response to changing conditions of the project*, *having produced an unsuccessful design*, and *enhancing/developing the design approach* directly influence leaders’ ability. On the other hand, factors such as *having over-confidence at the beginning of the project*, *significantly changing the initial design*, and *using multiple approaches* inversely influenced leaders’ ability.

Based on the comparison between leaders’ responses and the rest of the students that was provided previously, in this section the significant factors that were extracted from the responses are explained.

- Factors Affecting Metacognitive Judgment
    - *Not fully understanding the project directives /objectives at the beginning (INT)*

This factor represents *task analysis* which is one of the components of *reflective process knowledge*. The importance of this factor comes from the fact that almost half of the students (44.5%, Table 29, Row F6) have difficulty analyzing the focus and the objectives of the design task. As evident by Linda's response to the questionnaire, "*At first I was not completely sure what the project was about* ", also from Noah, "*I thought that I was okay with the competition prompt because most of my* first-year *work consists of repetition. I thought I understood the prompt clearly. However, I was completely wrong."* On the other hand, leaders had significantly fewer problems in this area; only 21% of leaders answered "yes" to this question, which is significantly less than rest of the students. Based on these results, it can be concluded that knowing and understanding the task, which is relative to *reflective process knowledge*, influence student performance.

- ❖ Receiving suggestions from others in the school

This factor, which is based on the theoretical framework developed in chapter 4 for this research, is a subcategory of *reflective process monitoring*, has a high importance (72.5%, see Table 29, Row F34) for all the students, and is stronger in the high-performing student (86%). This shows that the lab environment positively influences all the students, and also that leaders could better utilize the lab as a learning community by engaging in conversations with other students and faculty members regarding their designs. Similar results were also reported in Section 4.1.2. *"After talking [with classmate], I realized that we had a sense of direction where we were headed and started to really engage in the projects (Noah)."*

Engaging in conversations increases student metacognitive process knowledge, and subsequently metacognitive process control. Also, this will increase student consciousness regarding where and how they learn (Ku & Morgan, 2006). As mentioned in Section 3.6, the studio setting is intentionally open to facilitate dialogue and conversation between students and faculty. The fact that utilizing this will improve students' performance, shows the importance of having an open setting for the studio, where students can easily engage in conversations with their classmates or students from other studios.

❖ Underestimating his/her abilities

In comparison to the rest of the students, leaders have a lower tendency to underestimate their abilities (From Table 29, Row F8, leaders: 28%, rest of the students 43.5%). This further reinforces the results from the first and second learning-tasks, where it was shown that LP students have less *self-awareness*. This suggests that underestimating one's abilities may ultimately result in producing less successful designs.

- Factors Affecting Metacognitive ability
    - Working to satisfy the professor's expectations

A high percentage (See Table 30, Row F27, 74%) of students feel that they have to fulfill the expectation of their professor instead of developing a creative design that expresses their own thoughts -- performance-oriented instead of mastery-oriented[56]. "*I was thinking 'what does professor want me to do' and something like that, and that's the good thing to do because she*

[56]. Performance-oriented refers to the desire to present oneself as competent in the eyes of others; while mastery goal is a desire to achieve competence by acquiring additional knowledge or mastering new skills (Ormrod, 2008, p. 498).

[professor] is the professor so you want to impress your professor." (Catherine) This factor is lower among leaders relative to the rest of the students (From Table 30, Row F27, leaders: 65%, rest of the students: 74.0%). This suggests they were less concerned with figuring out what the professor wants.

- Strategizing in response to changing conditions of the project

Results suggest that only 54% (See Table 30, Row F22) of the students are able to adjust their strategies as the conditions of the project change. The percentage is higher for high-performing students (79% for leaders and 54% for the rest of the students), which suggests they can adjust their strategies as the result of changes in the project requirements. High-performing students have stronger metacognitive monitoring and control, which they utilize to frequently monitor the progress of the task and the conditions (again examples would be helpful) of the project, and then make the necessary metacognitive control actions.

- Fear of failing or not being able to satisfy self-expectations

As supported by literature (Lawanto, 2010), students who are afraid of failure are less likely to use complex cognitive and metacognitive routines to improve learning. "*I began the project unsure of whether or not I would be able to complete the task & accurately portray the ideas in the prompt*" (Kara). A high number of students (See Table 30, Row F5, 53.5%) answered "yes" to the question of "Fear of failing or not being able to satisfy self-expectations," which suggests that they don't have the necessary self-esteem and that they fear they will not be able to produce designs that will satisfy their expectations. The percentage is lower for high-performing students (42.8%).

❖ Having produced an unsuccessful design

One of the advantages of students who are aware of their thinking process is that they tend to trace back the success or failure of a design to the decisions that to led to that design. HP students take advantage of their failed designs to draw conclusions of why they were not successful and use the experience in the future. This suggests that they better utilize metacognitive skill. This is evident from the fact that this factor is higher in HP students relative to the rest of the students (From Table 30, Row F17, leaders: 49.60%, rest of the students: 40%).

❖ Focusing on smaller details of the project

This factor was suggested by one of the lab professors who was interviewed for the purpose of developing the questionnaire. Relative to HP students, LP students focus more on smaller details of the project; this factor is lower in HP students relative to all students (From Table 30, Row 32, leaders: 41.18%, rest of the students: 58%). Focusing too much on smaller details, like making the models (a cognitive activity), may prevent students from stepping back, looking at the bigger picture, and thinking about how the design satisfies the requirements. By focusing too much on the small details of the design, students may not be able to search the entire solution-space. Alternatively, this could be because LP students fail to efficiently manage their time (failing to use metacognition), and by spending too much time on a small detail, they miss the opportunity to work on the rest of their designs.

- ❖ Significantly changing the initial design - Using multiple approaches

As opposed to LP students who use the trial and error strategy which results in frequent changes to the initial design, HP students tend to plan better and have a better vision of what they want to do. This results in fewer significant changes to the initial design (From Table 30, Row F24, leaders: 20.35%, rest of the students: 37%). This is also evident from the responses to the *using multiple approaches* tactics that are lower in HP students (From Table 30, Row F18, leaders: 34.22%, rest of the students: 59.0%).

- ❖ Having over-confidence at the beginning of the project

This factor is lower in HP students relative to other students. This suggests that HP students have better *self-awareness* and are more open to suggestions from others in the school in the areas that they feel they lack the required abilities. This can also be inferred from the fact that HP students less often *significantly change their initial design process* (20% vs. 37%, See Table 30, Row F24).

6. Chapter: Discussion of Results

The objectives of this research were to understand the metacognitive thinking that takes place during architectural design learning (the reflective process) in the typical Foundation Design Lab exercises, and the conditions that lead to the development or change in student metacognition thinking in Design Labs. Figure 39 provides an overview of the process that was used to accomplish the research objectives. The study's three research questions were: (1) What are the metacognitive thinking processes that design students use to engage a design learning-task? (2) What are the effective conditions in metacognitive design problem-solving? and (3) How do metacognitive thinking and actions influence students' design learning?

In the following sections, the researcher sought to answer the three research questions posed earlier by using the results presented in Chapter 5. To answer these research questions, the researcher used the findings from the full data set, encompassing all participants and all learning-tasks. This chapter includes the researcher's suggestions regarding how lab professors can utilize the findings of this research to improve student learning experiences in the Foundation Design Lab.

In metacognition, there is more at stake than just the dimension of success or failure. It involves the fine-tuning or adjustment of mental schemata, which in turn affect future decisions. Schemata "limit us to familiar ways of thinking and acting," therefore, it would make sense that the enhancement of our schemata will allow us to think and act in more ways than were previously available, which in turn grants us the ability to be more adaptable and flexible. (Ku and Morgan, 2006).

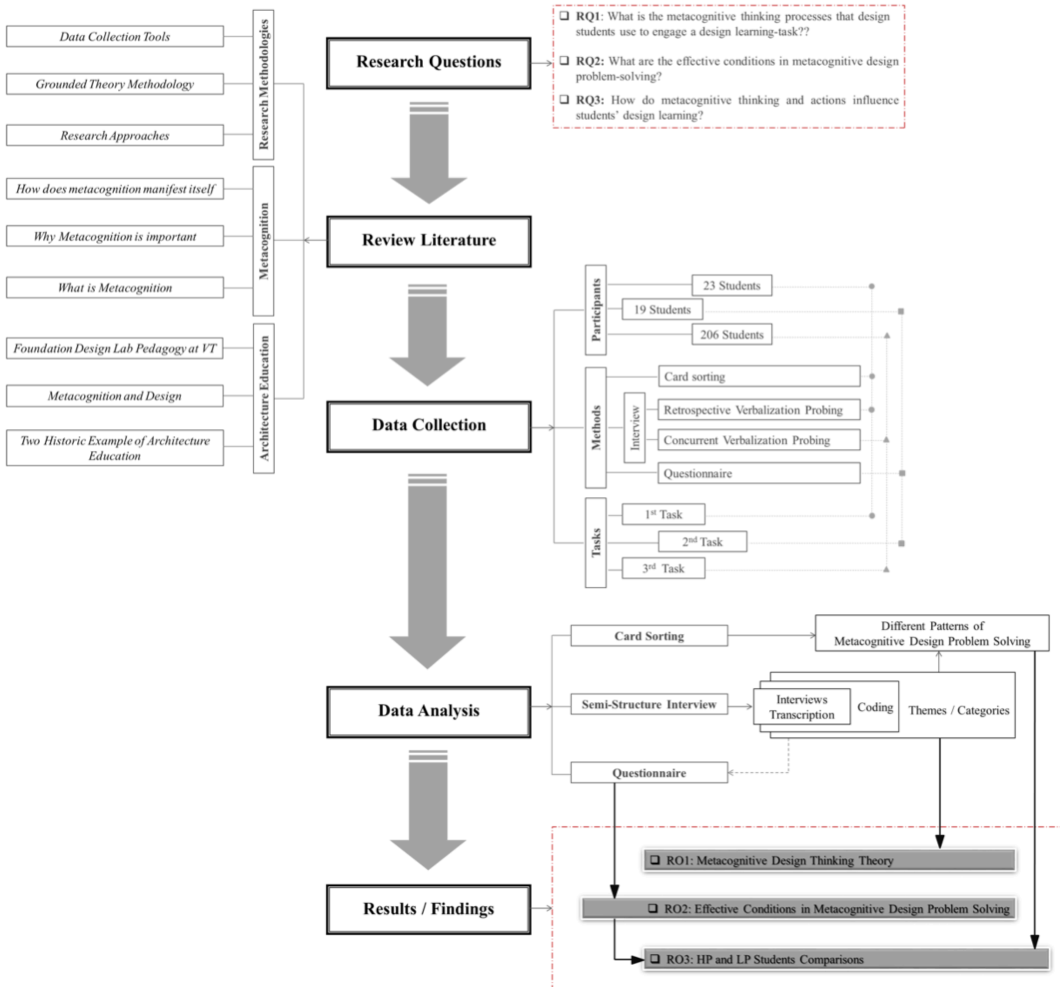

Figure 39. Research overview

In the following sections, the researcher uses the results of the data analysis presented in the previous chapter to answer the three research questions.

6.1. Metacognitive Process of Design

In order to answer the question of "what are the metacognitive thinking processes that design students use to engage a design learning-task?," the researcher developed the fundamental components and the configuration of a coherent model of metacognition in the domain of the reflective processes. The model was developed using the data gathered from students while they engaged design learning-tasks in the Foundation Design Lab (first year). A detailed description of the process that led to the development of this framework is provided in Chapter 4. This section discusses the interactions that exist between and within various thought processing categories.

The main thought processing categories discussed previously in chapter 4 are cognitive, metacognitive, and affective thought processes (Figure 40).

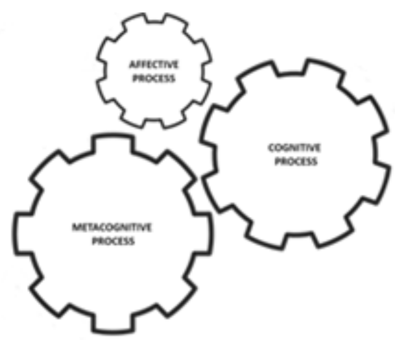

Figure 40. A schematic model of thought processes for a reflective design process

The cognitive process is mainly concerned with the direct action of the design tasks, where the metacognitive process is mainly concerned with the process that is used, and affective process is mainly concerned with students' emotional state while engaged with the learning-task. Tasks in this regard, like monitoring and regulation of the problem-solving process, are considered metacognitive, while tasks like taking notes, sketching, and making models, and using these items to solve current tasks are considered cognitive. The affective thought processing category includes positive, neutral, and negative feelings which could help or hinder the problem-solving process. These thought processes and their subcategories are in constant interaction with each other. These interactions are both between and within each of the thought processes. These interactions can be described as complex and nonlinear. The complexity of the interactions refers to the fact that the switching that occurs between or within each thought processing category happens with no apparent pattern. The nonlinearity refers to the fact these interactions do not always lead to advancements; and the direction can be either forward or backward.

It is feasible to arrive at a successful result in a design process when all of these three aspects work well together. However, due to the focus of the study, the conclusion elaborates the metacognitive process, as illustrated in Figure 30 in detail.

According to the complex and nonlinear nature of the design process, students move through different variations of this method based on their distinctive backgrounds, levels of experience, and personalities, to a point where it can be said that there are as many design processes as there are designers. However, the whole process of metacognitive thinking happens in three realms (automated, personal awareness, and communal), as well as providing a general framework (Figure 41). Each level ends with the cognition thought process as the outcome of that level.

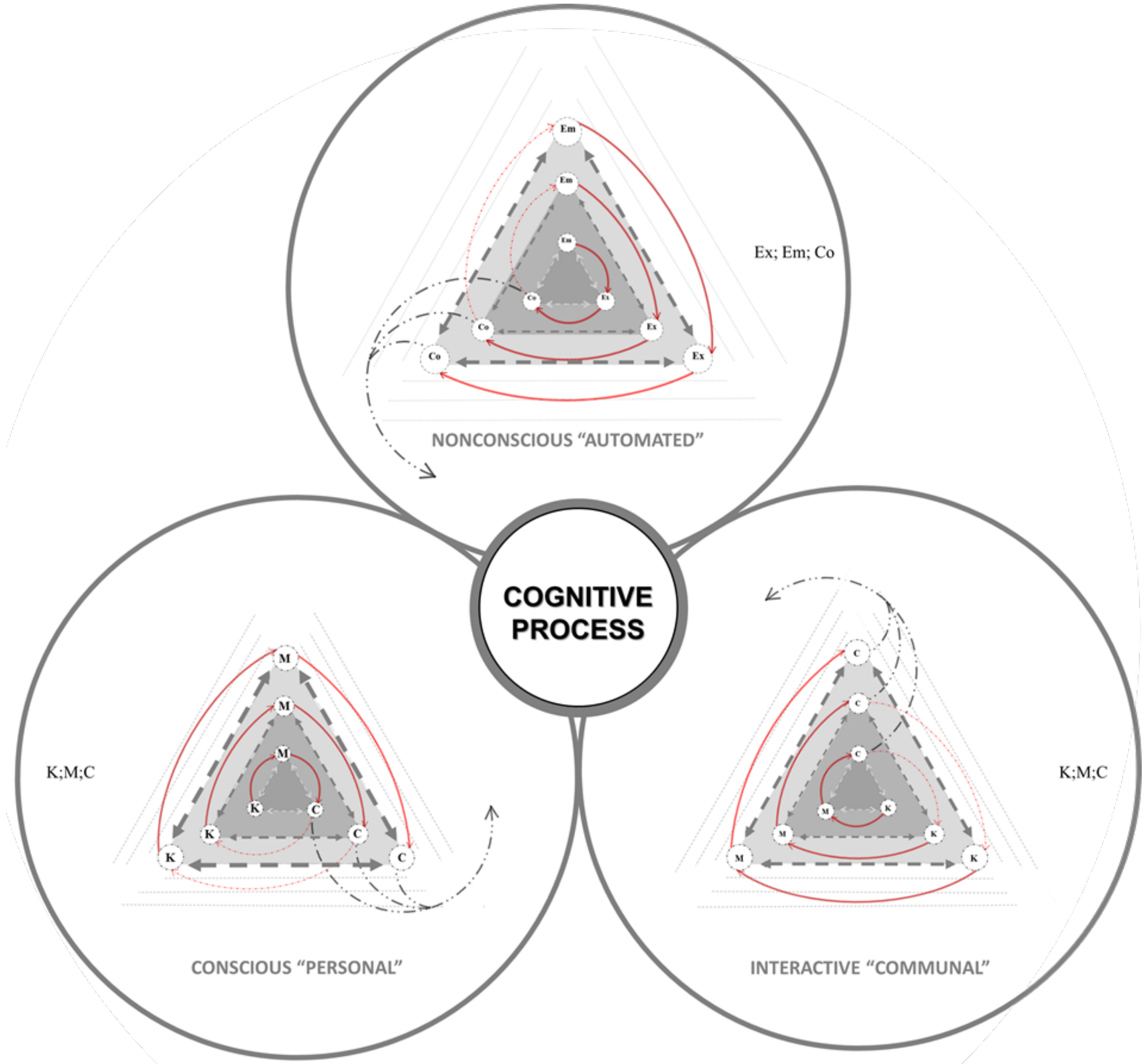

Figure 41. Cognitive process -three realms of the metacognitive thought processes contributing to the reflective design process. The outermost dashed triangles represent the continuous process of reflective process.

Note. M = Reflective Process Monitoring; C = Reflective Process Control; K = Reflective Process Knowledge;
Co = Cognitive Process Ex = Experience Em = Emotion

In the “automated,” realm (Figure 42) students perform the prescribed tasks with minimal conscious thinking; the dominant thought process in this realm is cognition, which is mostly affected by experience and emotion. Any control or monitoring that occurs at this realm is most likely automated and non-conscious. Experience plays a vital role in this realm as cognition and emotions could be impacted by the lessons learned before. However, the final cognition of this level transforms to new experience for next times. As shown by the red curved dotted arrows in the diagram, the cognition resulting from this level does not necessarily happen once, and could occur repeatedly. Due to the low experience of foundation students, mostly the decisions in this level come from emotions. As students become aware of these processes and try to think of ways to improve them, they move from the non-conscious, to the conscious, personal realms.

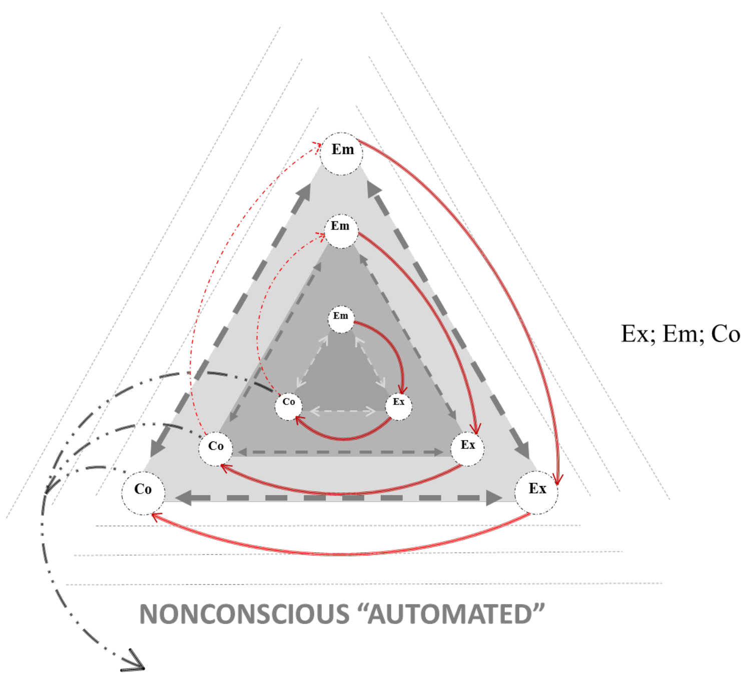

Figure 42. Nonconscious automated. The first realm of metacognitive thinking

Note. Ex = Experience; Em = Emotion; Co = Cognitive Process

The "personal-awareness" realm is the main level, which can be trained and improved, if students learn to manage it successfully. It is a multi-cyclical process, where the fundamental components are: *Reflective process knowledge*, (K) *reflective process monitoring*, (M) and *reflective process control* (C) to weight, sort, and arrange the possibilities and select the best decision to pursue (Figure 43). Each cycle of (K-M-C) can result in a directed action (as shown by black curved dotted arrows toward *cognitive process*), or continue on, followed by another cycle to improve and correct the previous decision (as shown by red curved dotted arrows). These cycles grow in a spiral way; the complexity of the thought processes increases with respect to the previous cycle. It should be noted that throughout the whole process, not all the cycles happen completely and it is possible that a cycle only includes one or two components. For example, in a new cycle the knowledge component could be unchanged from the previous cycle, and the new cycle may only include reflective process monitoring and/or reflective process control components. The spiral design processes can help students proceed beyond their automated thought process to accomplish an effective and responsive design. What makes design processes unique is that design is an ongoing process, along with these cycles that continue on. This concept can be better explained using a hypothetical example.

Let's assume that the cycle starts with reflective process monitoring, i.e. *idea generation*; the next step could be reflective process control, making a decision on how to develop the idea, the result from these two metacognitive steps could be a cognitive act like sketching. This cycle only included two of the components of metacognition. The next cycle could start with metacognitive knowledge, i.e. task analysis, to evaluate the requirements of the learning-task. The next step in this cycle could be monitoring the closeness of the generated idea in the previous step to the task requirements, and after that metacognitive control which may lead to changing parts of the sketch.

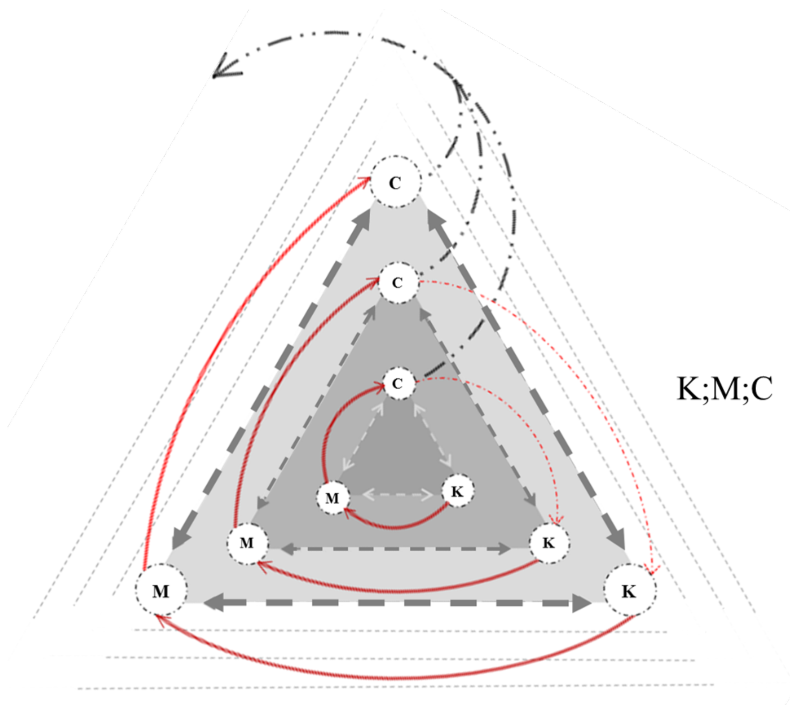

Figure 43. personal-awareness/ communal realm. The second and third levels of metacognitive thinking

Note. K = Reflective Process Knowledge; M = Reflective Process Monitoring; C = Reflective Process Control

The "communal" realm (Figure 43) is the final level that is of importance to the design field. The thought process and its components in this level are similar to the personal-awareness level (Figure 43), where the main difference is due to the external factors which influence the process. The framework that came from this research shows the importance of both personal and communal realms. The significance of the communal realm in the design field is not limited to group design tasks, but goes beyond the group partners, and even students in same class or level. The results showed the notable role of the interactive environment in Design Labs, where students are significantly influenced and affected by the environment, along with either lecturers or other students. Therefore, the emphasis on the effective environment with successfully defined social interactions is critical for design students and the elevation of their metacognitive thinking process. The process that is illustrated in Figure 40 describes how various parts of thought processes interact with each other.

The final model upholds the concept of iteration in the Foundation Design Lab, where one of the main purposes is training students to use and understand the contribution of such a cyclical process in their designs. According to the proposed model, iteration is not merely described as repetition, because each cycle draws upon metacognitive thinking. This differs from trial and error as a repetitive process that only involves cognition, without metacognition. Results show that the final spiral model that came out from this study better explains metacognitive thinking, especially related to design students, as compared with previously proposed models-Dunlosky and Metcalfe (2009); Pintrich, Wolters, and Baxter (2000) and Paris and Winograd (1990).

6.2. Effective Conditions in Metacognitive Design Problem-Solving

In order to answer the question of "what are the effective conditions in metacognitive design problem-solving?" the researcher analyzed the results extracted earlier from student responses to the questionnaire (see Section 5.3 for more details). Similarly, the discussions have been divided into factors indicating student judgment and factors indicating their ability.

With regard to the factors that affect student judgment, a significant percentage (84.5%) of students answered "yes" to the question: *having ability to complete the task*. This question addresses student understanding of *self-awareness* and *self-reliance* in combination with the fact that only 37.5% of students answered "yes" to the *requiring more knowledge and skill* question. This shows that the experience students have gained from working on design learning-tasks during the semester has positively influenced their *self-reliance*. This is important due to the fact that if students think that the completion of the task is outside their cognitive abilities, it negatively influences their performance.

The results regarding the question, *successfully adopting new strategies*, shows that students are employing metacognitive thinking during their design process. In order to successfully adopt a new strategy, students must first engage in metacognitive monitoring to identify the shortcomings of their previous strategy. Once these shortcomings are identified, students need to engage in metacognitive knowledge, if they think their current knowledge is not sufficient, and metacognitive control to make the necessary decisions and implement the changes. It should be also noted that students might falsely think that they have been successful in implementing the new strategy, in some instances, because of their lack of metacognitive knowledge, the new strategy might have negatively influenced performance.

Student responses to the question, *having an incorrect impression of task difficulty*, have the lowest percentage of all the factors. This can be attributed to the fact that the third learning-task was given to the students at the end of their first year. At this point, students had completed numerous design tasks. The experience gained from the previous learning-tasks gave students the ability to accurately judge the difficulty level of the task. Similar to the previous factor, this could also be simply an incorrect judgment, where students think they have a correct impression of the difficulty level of the task but in reality their judgment is not accurate. The initial judgment of task difficulty is an important factor. Misjudgment regarding task difficulty can negatively impact student performance.

In regards to the factors that affect student ability, *searching for alternative solutions*, *enhancing/developing the design approach*, and *receiving suggestions from others in the school* have the highest influence. As students proceed through the first year, they acquire different strategies regarding how to approach learning-tasks. The combination of *searching for alternative solutions*, *enhancing/developing the design approach* shows that students are consciously engaging solutions related to the learning-task and using the strategies that they have learned to accomplish the task.

The lab environment is designed to promote student interaction with each other and with the faculty members. Conclusions based on student responses to the question *receiving suggestions from others in the school* show that students are using the collaborative environment to their advantage.

Because of the experience that students have gained during their first year, some of the factors like *having over-confidence at the beginning of the project*, *significantly changing the initial design*, and *strongly relying on one solution to focus the project* have the lowest influence on the students' ability in their design problem-solving. This demonstrates students, through conscious or non-conscious metacognitive thinking, have identified the strategies that hinder their creative thinking and as a result avoid these situations. Another reason as to why these factors are low, may be because of their negative connotation. The question posed might suggest a mistake or a misjudgment, which is oftentimes not easily admitted.

As a final conclusion in this section, the diverse factors influenced the design students' metacognitive thinking development could be categorized in three areas; learning-task, student, and dynamic process of designing.

In terms of the learning-task, it can be concluded that students tend to engage in metacognitive thinking when they think that the task difficulty is within their abilities and they have the knowledge to accomplish the task. However, the defined task in the Design Lab should be challenging enough not to fall within students' automated process and engage them by offering new challenges. This emphasizes the importance of the learning-tasks, and the role of the professor in a Design Lab extended into the Design Lab environment. Contrary to rational problem-solving tasks (Simon, 1969), the learning-task is not offered as a fully defined task. It should invite the designer's interpretation. The open-endedness of the design learning-task can promote metacognitive thinking for students in higher levels. In an open-ended situation, students usually engage in discussions with other students or the professor to clarify the situation and more importantly their positions. It is necessary to provide this interactive environment in which students explain their interpretations and the logic behind them, and listen to their peers, which inherently enhances metacognitive thinking.

The other important piece of this puzzle is the student him/herself, whose knowledge and ability is effective in the metacognitive thinking process. Based on the analyzed factors, there are a few ways to help students to become metacognitive thinkers such as the assessment method. In the design field, it is vital to educate students to nurture their creativity and think out of box rather than following the usual procedure to arrive at a good outcome. The longitudinal assessment of students was based on their designs in a semester and probable improvements/retrogression, rather than focusing on a single outcome. The syllabus is directed to the whole person becoming more educated, as the real outcome of the educational effort, not the design task. Moreover, this type of longitudinal assessment helps students to comprehend their strengths and weaknesses better and avoid misunderstanding their abilities. Even though it is believed that each student's reflection is based on his/her comprehension of the learning-task, it seems that a shallow interpretation of design objectives could mislead metacognitive thinking. Therefore, one of the fundamental steps in enhancing metacognitive thinking is emphasis on task comprehension and its objectives.

Finally, the dynamic process of design is the final core for the desired metacognitive thinking in the design field where there is no defined approach or strategy to reach the final result. The concept of iteration in the Foundation Design Lab is meaningful in that understanding this dynamic when different approaches, strategies, or even interpretations could result in a new process and outcome, iteration gathers greater understanding on the part of the student; such offerings in an open setting enlarge the group's understanding. The significance of the dynamic design process is a highlighted in the interactive environment of Design Lab where the communal realm of metacognitive thinking is activated. In this way, Design Lab emphasizes iteration, in which a cycle that does not end with the desired result, will be followed by the next cycle based on and enhanced by the mistakes or shortcomings of the previous ones. It is important to note the differences of iteration with common trial and error strategies; in iteration, design-thinking cycles call upon metacognition. In this regard, students can benefit even from their mistakes in deficient metacognitive cycles. Therefore, in disregarding the final outcomes as final, students are required to reflect individually on their mistakes or deficiencies in the whole process of design thinking and learn from their experiences as a positive outcome.

6.3. The Difference in the Metacognitive Thinking Process of High-Performance and Low-Performance Students

To answer the question of "how do metacognitive thinking and actions influence students' design learning?" the researcher analyzed the results presented in Chapter 5 for all three learning-tasks to identify the difference between the thinking processes of high-performing students and low-performing students. The results of this analysis are discussed in this section.

In the following sections, each of the influential factors are analyzed across three design learning-tasks students completed for the purpose of this research. This section is organized based on the main thought processing categories -- cognition and metacognition. It should also be noted that student thought processes are all interconnected, with no single category or subcategory that can be singled out as the main reason for student success or failure.

6.3.1. **Cognitive process**

In general, cognitive processes include activities that students perform in the course of their design learning-tasks that result in building knowledge. In Chapter 5, several trends were identified that showed the difference between HP and LP students. In this section these trends are discussed in more detail.

In general, it was shown that LP students spend more time and rely more on *cognitive processes* compared to HP students. As mentioned earlier, cognition includes tasks like sketching, and making models. LP students dedicate more time to activities that relate directly to the learning-task. One of the reasons that LP students do not produce successful designs in spite of this, might be that the cognitive skills required for the learning-tasks in the Foundation Design Lab is not very high. Hence, metacognition plays a more prominent role in student design performance. This is why students who engage more with thinking about how to do the task (metacognition) had better performance. LP Students believe the design task is all-encompassing and as a result do not find as much success as students in design. They are students of the task at hand only. As students of design, HP students are ever-open to what is happening, especially with regard to products, by-products, accidents and the educational environment all together.

LP students not only more fully rely on cognitive processes, but also the analysis of the sequence of their thought process, which suggested that in most cases their *cognitive process* was followed by unrelated behavior. This may be due to the fact that LP students jump from one idea to the next without analyzing its shortcomings, or reading shortcomings as an opportunity to more complex action. For them when change does not yield better outcomes. They may become frustrated and engage in unrelated behaviors like leaving their desks. HP students in most cases engaged in cognition follow-up with monitoring.

6.3.2. **Metacognitive process**

Runco, (1994) emphasizes the role of metacognition in problem-solving and the correlations that exist between problem-solving performance and the number of metacognitive statements. What makes metacognition important, especially in open-ended problem-solving, is that it gives learners the ability to assess the closeness of their solution to what is required and what is required is more complexly tuned or defined by their consideration and openness to other questions. Once this kind of assessment is realized, students can advance their work with more critical choices, making decisions more complex regarding their next step.

The wide range of solutions that students create for the same problem is due to the difference between the metacognitive thinking processes that students use to develop their solutions. As a result, students' failure or success can also be attributed to the metacognitive process that they choose for their problem-solving (Runco, 1994). The main goal of this research is to further the understanding of the metacognitive processes that occur for design students. This can then be used to identify those patterns that result in high/low quality solutions; professors may then use this information to direct students towards patterns that will lead to high quality investigations and design results.

To be creative and successful, as supported by the protocol studies of Cross (2003), designers need to draw widely on information and knowledge gained from previous design projects. Lower knowledge monitoring levels in low-performing students suggests that these students limit the use of their previous experiences by rushing into the embodiment of their idea.

In the following sections, the thought process for each of the subcategories of *metacognitive process* are discussed to show the differences between LP and HP students.

6.3.2.1. **Reflective process knowledge**

Reflective process knowledge deals with learner's knowledge and understanding of how to learn, influencing the process of learning. As shown in section 4.2.1.1 *reflective process knowledge* has three subcategories of *cognitive strategy knowledge*, *self-awareness* and *task-awareness*. The factors extracted from the questionnaire that students filled out at the end of the third learning-task has several questions that can be attributed to *reflective process knowledge*. In this section, all the data presented in Chapter 5 as they relate *reflective process knowledge* are combined. This helped the researcher to develop an overall conclusion regarding the influence of *reflective process knowledge* in student design learning performance.

The results presented in Section 5.1.2.1 demonstrated that High-performing students have a higher *task-awareness* relative to low-performing students. Similar results were also demonstrated in Section 5.3, where the percentage of leaders who answered "yes" to this question *Not fully understanding the project directives/objectives at the beginning* was significantly lower when compared to the rest of the students. It can be concluded from these results, that High-performing students invite a greater field of knowledge to the scope of understanding surrounding the learning-task and its requirements before doing the task. On the other hand, low-performing students are comfortable deploying their cognitive ability without a comprehensive analysis, which in turn limits their creative design space.

As mentioned previously, to invoke student creativity, the design tasks that students are required to undertake in the Foundation Design Lab intentionally direct action but may be read as ambiguous and open-ended, which prompts students to begin to realize what metacognitive process is in the design process. To improve student design outcomes, professors can help students to analyse the objectives of the task, especially as they begin the year.

The results for the first and second learning-tasks presented in Chapter 5, *self-awareness* and *cognitive strategy knowledge*, did not have a significant influence on student design learning processes. But, based on the results acquired from student responses to the questionnaire (the third learning-task), the following conclusions can be made regarding how *self-awareness*, and *cognitive strategy knowledge* affects students' design learning processes.

Self-awareness can improve student design outcomes, but if student knowledge is inaccurate it can adversely influence performance. Factors extracted from the questionnaire suggested that when students become over/under confident, *having over-confidence at the beginning of the project or Underestimating his/her ability*, or set unrealistic expectations *fear of failing* or *not being able to satisfy self-expectations*, can negatively influence their performance. Professors should be aware of these phenomena and remind students that in order for them to produce successful designs, it is important to engage in the task regardless of their perception of the difficulty level of the task. Also, in order for students not to over/underestimate their abilities, it is important for professors to include elements in the curriculum that provide students with a better sense of their abilities. To reduce students' unrealistic self-expectations, instructors may highlight the strengths of each students' design since all designs contain ideas and examples of these ideas can be readily found.

Based on the results presented in Section 5.1.2.1, *cognitive strategy knowledge* shows a low percentage from all students and indicates no particular trends that differentiate HP students and LP students. Students have also suggested that they need more knowledge in their responses to the question, *thinking you needed to have more knowledge before taking a design action*. This is mainly due to the fact that first-year design students have less exposure to design problems and may not be able to develop accurate knowledge regarding various cognitive strategies and the design situations where each could be used successfully. Results suggest the importance of *cognitive strategy knowledge* on design student success. Therefore, it is important for professors to ensure that students' *cognitive strategy knowledge* is improving as they are exposed to various design learning-tasks.

At the beginning of the first learning-task, students were asked to describe their previous experience with similar learning-tasks. Based on their responses, it can be seen that high-performing students not only have prior exposure to similar tasks, they were also able to correctly identify the task requirements. Low-performing students, on the other hand, in many cases couldn't think of any similar tasks, or they identified the task requirements incorrectly, which was clear from the past experiences they relate as similar to this experience. This further confirms the results from the retrospective verbalization where it was shown that low-performing students have less task familiarity (a subcategory of *task-awareness*) than high-performing students.

6.3.2.2. ***Reflective process Monitoring***

Reflective process monitoring deals with judgments made by learners regarding the status of learning (how learning is progressing, how learning should progress). In this section results presented in sections 5.1.2.2, and 5.2.1.1 for *reflective process monitoring* and its subcategories, *situational action monitoring*, *personal feeling monitoring* along with the results from the questionnaire, are discussed. In section 5.1.2.2 it was stated that *reflective process monitoring* is the most popular subcategory of metacognitive thought process, and that HP students monitor their design learning process more than LP students (both in terms of number of statements and time spent). Student responses to the questionnaire confirmed the results. The questions that can be categorized as *reflective process monitoring* like *searching for alternative solutions,* had the highest number of positive responses in the questionnaire and were also more popular among effective students.

It should be noted that having a high percentage of *reflective process monitoring* does not necessarily result in successful designs. In some instances, students made incorrect judgments regarding how to improve their designs. It was shown in the questionnaire that some students made the judgment of *significantly changing the initial design,* which may have made a significant contribution to lower quality designs outcome rather than bringing focus to iterative refinements that substantiate their idea. This further emphasizes the previous point regarding increasing student *cognitive strategy knowledge*. Therefore, when students make the judgment that they need to modify their design process, they have the necessary knowledge to make decisions that will lead to improving the outcome of their design.

Another common phenomenon was that students were *working to satisfy the professor's expectations*, instead of working to better understand the design process, which negatively influences students' learning. Although, in Virginia Tech's Foundation Design Lab, to promote a mastery of larger educational goals instead of performance goals, the common practice is not to grade individual students projects; ;instead grades are given based on student progress and engagement (see syllabus) over the semesters. This phenomenon is still influencing student performance (Kavousi & Miller, 2014). Midgley, Anderman and Hicks (1995) claim that this can also be accomplished by focusing on increasing one's current level of performance and rewarding increased effort and persistence instead of placing a strong emphasis on performance. Unfortunately for some students, the habits of high school learning where performance is the premium, persist beyond the first year. While it remains difficult for these students to realize the opportunity given in the design lab, when they witness for themselves the change in other students and their work, new modes of thinking can be realized. Results from the questionnaire also suggest that leaders are more focused on mastery goals relative to the rest of the students, which is in agreement with what is provided in the literature. Ames and Archer (1988) claim that mastery students are more successful overall because they experience less anxiety, use more strategies, and attribute their success to controllable causes.

In conclusion, consistent to what has been suggested by the literature, educators should challenge and explicitly assist students in acquiring metacognitive knowledge to design their problem-solving efforts and design their educational path, how to set goals and sub-goals for their efforts, and how to monitor their progress toward their goals (Hargrove, 2008; Jausovec, 1994).

6.3.2.3. ***Reflective process control***

Reflective process control deals with decisions made or actions taken by learners that influence progress in learning. This section discusses results in Chapter 5 regarding *reflective* *process control*. The main outcome previously presented, showed that low-performing students had more instances of *reflective process control*. In this section, more discussion is provided regarding the underlying reasons for this phenomenon.

Student responses to the question *focusing on smaller details of the project* in the questionnaire suggest that leaders bring focus to the project as a whole, which helps produce more successful designs (leaders: 41.18%; rest of students: 58%, See Table 30). It can be challenging for students to manage their focus. Instructors can help students move away from the specifics of projects to look at their work and see it with new vision of coherence, how the parts and the whole are together actually, to be brought in concert.

Reflective process control can be the most effective when students have a strong strategy. Successful students are cognizant of when they behave strategically and when they do not (Eggen & Kauchak, 2001; Ozsoy, 2011), emphasizing the fact that learning can be effective in cases where it occurs consciously. This is drawn from the fact that the percentage of leaders who answered the question *strategizing in response to changing conditions*, the project posed was higher than the rest of the students. As mentioned in Section 3.2.1.3, the "ordering" of design learning-task types helps students experience how to strategize as the conditions of the project change.

Student responses to the question, *enhancing/developing the design approach*, reveal two things. First, the overall number of students who answered "yes" is high, which shows the design learning-task has been effective in improving student design strategies. Secondly, since the percentage of leaders who responded "yes" is higher, it reaffirms the importance of the students' *cognitive strategy knowledge* in producing high-quality designs. Similarly, Ozsoy (2011) claims that metacognitive control is the ability to use metacognitive knowledge. Although, LP students have a higher number of control instances, the decisions they make do not lead to improvements because of their lower breadth of knowledge. One of the main reasons that LP students have more instances of control is that they used a trial and error strategy more often. This is evident throughout the data collected, across the three learning-tasks. While as mentioned in Section 3.2.2.3, iteration is part of the design methodology and is promoted in design learning, trial and error has the reverse effect. In this study trial and error is defined as the strategy where students terminate the design process and start on a new design without reflecting on why the current design failed. Error for them is a conclusion not a beginning. This happens mainly because low-performing students do not have a clear strategy (low cognitive strategy knowledge) for approaching the learning-task. Instead they think if they spend a lot of time and make numerous designs they should be able to come up with a complete solution.

Based on student responses to the question: *discovering a focus in the design process*, it can be concluded that discovering the focus of the design task positively influences the students' outcome. One possible explanation is that finding the focus of the design task increases student intrinsic motivation in doing the task. This also increases the student's satisfaction with the outcome of the task, another question in the questionnaire.

6.4. Implications for Future Direction and Practice

Although when it comes to design there is no magic formula that if implemented causes every student to become a star designer, and this was never the intention of the researcher. There are techniques that this research suggests that will improve students' learning experience. Therefore, the implications of this research are presented as series of suggestions for lab instructors or architecture education policy makers on how to encourage students to engage in metacognitive thinking.

Needless to say, situated learning-task is the most important factor in design learning. The main advice in this regard is that lab instructors should realize the difficulty of designing a course or a learning-task. The distinctive nature of design learning-tasks is that there are no beginnings or ends to them. Instructors should take advantage of this, by fine-tuning the learning-tasks as students are engaged with them. The researcher cannot suggest a series of learning-tasks that instructors can give to design students in every studio in every design program and would make all of them successful designers. What the researcher has done, besides characterizing the already existing learning-tasks in Foundation Design Lab, is to provide the reader with features that if correctly implemented in a learning-task will help students achieve their optimum intellectual development. The learning-task should be open-ended, where students constantly need to monitor the progress of their designs. When first year learning occurs where the whole of the school is curious about education, first year is not a preliminary year for beginners but a place of design thinking. Here students are given a lens in which to perceive outcomes of strategic thinking and acting in a continuum. The learning-tasks could also ask students to reflect on their own and their classmates' designs and record each design's strengths and weaknesses. Reflection inherently forces students to use metacognition and to understand and make sense of what they have learned. Professors should ask students to reflect on their decisions at every possible situation. For example, if a student is making significant changes to his/her design the professor could ask them to elaborate on how a design progresses and reasons why the other design direction ~~d~~id not progress and what lessons have been learned from this experience that can be helpful in the next iteration.

Interaction with others in the lab is another feature that can cause students to think about what, why, and how they have accomplished a learning-task at a high level or what they think is the reason for failure in accomplishing the objectives of the task. This can be achieved through group learning-tasks where students engage in conversation with their cohort(s). As students describe their thought processes and assumptions to each other, they are engaging in monitoring and evaluation activities. Another attribute that adds to the difficulty of designing a course or a learning-task is situating the learning-tasks and the discussion surrounding the learning-task. If the learning-tasks are not challenging enough, students do not bring thinking into action to come up with the solution. On the other hand, if they are too challenging they will be thinking too much, will hinder progress and negatively influence design outcomes. Finding the optimum structure of a learning-task is a reading a professor makes to draw out the capabilities of students that are both available and can be learned, which makes developing the optimum learning-task a challenging endeavour. As students move through these learning-tasks, their metacognitive knowledge increases and metacognitive thought processes like monitoring and control would become a habitual part of their practice.

In the researcher’s view, metacognition works best when it is embedded in the pedagogy. If we teach students to consciously reflect on each thought and then monitor and control their thoughts, not only we have not improved their learning experience and made them more creative but these interruptions have the exact opposite effect. This does not mean that the researcher believes that exclusive metacognition training is not an effective method of exposing students to the concept. As part of the Foundation Design discussions, professors should familiarize students with metacognition and how it can be called upon in the design learning process. This will help students understand how to call upon learning occurring as a conscious act rather than through non-conscious automated action, resulting in achieving a more genuine relationship with their work. Pointing all this out as a more normative facet of the design lab will enable students to gain more authentically from their education. Instructors individually should direct their teaching toward the improvement of student metacognitive thinking abilities, which can be achieved by implementing some of the features previously mentioned, in learning-tasks.

Professors should also explain to students that the learning-tasks are intentionally open-ended, which students may even perceive as ambiguous, to encourage them to think about the learning-task and its requirements. Students should be encouraged to redefine the task requirements before engaging in actions. Hence, professors should be on the lookout for students who start building their models (cognitive activity) right away, as it suggests that they have not carefully analyzed the task. Students should also be encouraged to discuss the learning-task and their interpretation of its requirements with classmates and ask others for their interpretations.

Educators should be mindful of the fact that some students tend to focus on small details of the learning-task and often miss the bigger picture, negatively affecting their performance. To advance these situations as an educational opportunity instead of a liability for the student, professors can help students relate and show through examples how a detail speaks about the relations of a whole and how this development can occur. The professor and the educational environment of the school can orient students so that they can see how various blind spots open doors to a wider range of possibilities.

A common practice among Virginia Tech's Foundation Design Lab instructors is to answer students' questions with questions that evoke thinking. This study also supports not providing students with specific instructions on how to proceed. Instructors can promote metacognitive thinking in students by answering their questions with phrases like "what did you discover?", or "why do you think this material contributes to the learning-task?". These types of questions encourage students to revisit some of the decisions they made in early stages of the design process.

The main suggestion that the researcher has for design program policy makers is the importance of the environment in which design learning is taking place. This study has shown the positive relationship between student interactions and metacognitive thinking; hence, it is important that the space allocated for labs promote such behaviors. The design environment has to allow students to move freely to interact with others, not only with their peers but also with students in different levels. The space should also allow students to display their previous designs. This will cause the creator of the model/sketch to reflect on their previous experience and could also be a source of inspiration for others.

6.4.1. **Implications for other scholars**

Although this research is mainly directed toward design instructors and design policy makers, it can also be beneficial for other groups of scholars not directly working in design environments. The researcher had identified the following groups:

- Metacognition/education researchers
- Educators

In the following sections the researcher describes the takeaways of each group from this research and that can utilize this document to further their agenda.

6.4.1.1. ***Metacognition/education researchers***

This group of scholars can use several parts (literature review, methodology, data acquisition, data analysis, conclusions) of this research to further their understanding of metacognition and how it can be used to improve the education system in other disciplines, and also to design and execute their own research.

The researcher has provided an extensive review of the literature on metacognition that provides valuable information for other researchers in this area, which they can use as the starting point for their research. The researcher also makes the case for using grounded theory for conducting research in the area of metacognition, which can assist other researchers in their choice of methodology.

Although the learning-tasks that the researcher used for the purpose of this research cannot be directly used in other disciplines, the types of data collection scenarios that the researcher used can be used. Researchers can gain a better understanding of the advantages and disadvantages of each type of data collection (individual learning-tasks, group learning-tasks) and make decisions regarding the most appropriate type for the research that they are doing.

The process by which the researcher analyzed the data collected is independent of design-learning and can be directly used for data collected in other disciplines.

Although the framework developed by the researcher was based on the data acquired from Foundation Design Lab (first year) students at Virginia Tech, the framework may be applicable at higher years, as well. Metacognition researchers can use this framework (see Figure 30) as the basis for their research but may need to make some modifications based on the specific discipline that they are researching.

6.4.1.2. ***Educators***

Educators can be further divided into two categories: design educators in environments that are different from the education environment of Virginia Tech, and educators in other disciplines like engineering or language learning.

As mentioned earlier, in the context of this research, Virginia Tech's pedagogy is different from many other design schools, and in some cases goes against the accepted practices. This makes it more challenging for instructors in other schools to implement some of the findings of this research, but the majority of findings that effect student behaviors and result in improved learning can be directly applied.

The researcher indicated the importance of environment in the learning experience of students. The environment is more than just the physical environment. Here it also includes the shared body of knowledge among the faculty members at Virginia Tech who view the construction of a school beyond the curriculum a pursuit to attend to daily, while simultaneously reaching beyond the bounds of the Architecture School. The researcher does not claim that the environment at Virginia Tech is the only way of engaging students in metacognitive thinking. This research selected the Virginia Tech Foundation Lab as a specific case example, because of a rich pedagogical approach to design education, rather than as a typical program that would serve as a prescription for other schools to adopt. The body of knowledge shared by the faculty demonstrate in this case study an example of the *external source* subcategory of *idea generation monitoring*. This also reveals the relationship between the school and the syllabus, or how much of the syllabus gains from the fostered in the school. Recognizing this relationship, allows the faculty of the school in the Architecture School at Virginia Tech to improvise as the teach, so that this shared body of knowledge or understanding is constantly being addressed as the faculty become more a tuned to the student's engagement while also passing on this understanding to-new members who may join the team.

At Virginia Tech, the design lab environment creates opportunities where students may engage with students in other labs and even other levels. In design schools where this is not occurring, instructors should encourage students to engage with other students, for instance, by having exercises that ask students to work with students at other levels. This increases students' situational action monitoring and control. The researcher also illustrated the benefits of mastery goals as opposed to performance goals. In this case, mastery are promoted by longitudinal assessment of student performance and by evaluating students based on their design process, as opposed to singular design products. In other design programs, where instructors are often required to have a certain number of learning-tasks and evaluate each learning-task~~s~~ independently, instructors might advance a different protocol to also assign a portion of the student's grade for process. This would encourage recognition of a greater breadth of design activities and would promote a more open and thoughtful response to given design assignments, enhancing opportunities for metacognition. With this, fear of design failure would be lessened and more design pathways could be identified to producing a richer, more complex educational setting.

The researcher in providing a typology of the learning-tasks at Virginia Tech seeks to illustrate the importance of tasks that are not deterministic or reductionist in engaging students in metacognitive thinking and suggests instructors at other schools can take advantage of this information to also develop learning-tasks that encourage more open-ended thinking in their educational setting. This researcher believes that the design task should disappear in the work of student, and this can be achieved best by design tasks that are purposely vague in the design requirements, as opposed to prescriptive or pragmatic design tasks.

Although this research is directed toward learning in the design environment and specifically Foundation or First Year Design, instructors from other disciplines can implement parts of the framework for their classrooms. The researcher has sought to illustrate the power of reflection in encouraging metacognitive thinking for students engaged complex learning-tasks. Here, thinking in the context of design learning was active and associated with behaviors like reflecting on their roll or sketchbook. Although these behaviors may seem-unlikely for students from other disciplines, recording, in some form, is oftentimes fruitful. Instructors promoting reflection in some form as a means of encouraging students to engage in metacognitive thinking may find a true benefit with authentic student engagement resulting.

6.5. Contributions

The contributions stemming from this research are four-fold. First, this study supported the development of a new theoretical framework and nomenclature for understanding metacognition in design learning. Second, from the wide range of available data collection methods, the researcher selected the ones most appropriate (i.e. least interfering with students' design and thought process) for a first year design lab-based learning environment, where students work in their dedicated work spaces, and customize them based on the unique needs in this environment Retrospective and concurrent verbalization strategies, as well as observational methods were modified and deployed to reveal students metacognitive thinking in the Foundation Design Lab. Third, the researcher identified and categorized the various types of design learning-tasks in Foundation Design lab at Virginia Tech -- beyond the program's original articulation, which only emphasized ambiguity. Fourth, this research can provide further support for work in metacognition, while providing a previously undiscovered picture of metacognitive thinking in a design context. Therefore, this work can be used as a starting point for developing tasks, curricula and pedagogy to nurture and support metacognitive thinking, skills, and behavior.

6.6. Future study

In this study, the researcher developed the fundamental components and the configuration of a coherent model of metacognition in the first year foundation design lab. In the model that was developed, individual differences were only attributed to the differences in the metacognitive thought processes that each student used in the development of their designs, without noting the influence of gender, cultural background, and personal characters. Future researchers could extend this research by studying these factors and their influence on student metacognitive thinking process and performance. The future work may be able to use structural equation modeling to provide a platform showing the causation of the identified factors as well as the significant level of each one.

Through the data collection and analysis process the researcher was able to extract the thought processing components and thinking patterns that positively influence student design learning. Based on these findings, the researcher encourages future researchers to continue this study by creating learning environments where teachers could encourage design students to employ similar thinking patterns in their design process. The results from this group of students could be compared with a control group that were only exposed to other first year educational systems, such an education system based on the Beaux Arts' education system.

As part of the implications of this study, the researcher suggested including exclusive metacognition training as part of the Foundation Design Lab curriculum. Opportunities for a future researcher would include developing methods of teaching metacognitive thinking to design students in tandem with their influence on student performance. This research studied the influence of student metacognitive thinking on their performance. Future researchers could focus upon bringing in lecturers' voices to better understand how design professors use metacognitive thinking in teaching design to students, and how this influences students' performance.

Finally, the researcher recommends pursuing a longitudinal study of the metacognitive thinking in design field to better understand the metacognition progress over time and during different years of study. Such works will provide information useful in particularly developing interventions for design students in each year, with the intent of strengthening their metacognitive skill for the whole period of their study.

6.7. Closing Thoughts

The main objective of this study was to further the understanding of metacognitive thinking and its influence on design student performance in the Foundation Design Lab. The goal of developing theories similar to the one proposed by the researcher is to facilitate the development of pedagogy, curricula, and environments that improve learners' metacognition. While metacognitive thinking improves student performance, implementing teaching strategies that enhance metacognitive thinking will not result in every student becoming a star as a designer. Similar to other educational researchers, the ultimate goal here is to help students reach their full potential and as suggested by the outcomes of this study, metacognition could be a useful tool in this regard.

This research can also be used in the wider context of educational theories. The results of this research suggest the importance of student interactions, as in this case study, student centered educational environment supports communities of active learners, rather than lecture-based or prompted learning. Philosopher, educator, Paolo Freire calls upon an understanding of critical pedagogy in viewing teacher-centered methods referencing this as a "banking concept of education." In this reference, he likens information equated to money that the teacher has deposited with students to store and goes on further to claim this teacher-centered method inhibits students' critical consciousness by removing students from the action. According to Freire, for learning that arrives at a critical consciousness is the result of "intervention in the world as transformers of that world." (Freire, 2000, p.22)

Similarly, (Baxter Magolda, 2007) emphasizes the importance of Learning Communities where she calls upon the Learning Partnership Model (LPM), to orient college students towards the realm of self-authorship and away from the high school kind of environment that tends to leave students to following formulas for success. The importance of combining the existing knowledge regarding learning, development, instruction and assessment to develop new educational practices has been emphasized by other researchers as well (Baxter Magolda, 2007). This researcher has sought to describe each of these aforementioned components in the context of the first-year design lab education that is the focus of this study.

My future plan is to devote my professional life to improving design students' experience, specifically in the setting of a foundation design lab or first-year lab. I believe that the first-year learning experience is significant, pivotal in situating and greatly influencing the rest of students' academic and lifelong learning. Through this platform, I intend to further investigate methods that would help design students better utilize the power of metacognition.

7. References

Afflerbach, P. (2000). Verbal reports and protocol analysis. In M. L. Kamil, P. B. Mosenthal, P. D. Pearson, & R. Barr (Eds.), *Handbook of reading research* (pp. 163–179). Mahwah, NH: Erlbaum.

Anthony, K. H. (1991). *Design juries on trial: The renaissance of the design studio*. New York: Van Nostrand Reinhold.

Artzt, A. F., & Armour-Thomas, E. (1992). Development of a cognitive metacognitive framework for protocol analysis of mathematical problem solving in small groups. *Cognition and Instruction*, *9*, 137–175.

Azevedo, R., & Aleven, V. (2013). *International Handbook of Metacognition and Learning Technologies.* New York: Springer.

Bahari, S. F. (2010). Qualitative versus quantitative research strategies: contrasting epistemological and ontological assumptions. *Jurnal Teknologi (Sains Sosial)*, *52*, 17–28.

Bandura, A. (1977). *Social learning theory.* Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. (1986). *Social fourtdatiorts of thought and action: a social cognitive theory*. New Jersy: Prentice Hall.

Boekaerts, M. (1999). Self-regulated learning: Where we are today. *International Journal of Educational Research*, *31*, 445–457.

Boyer, E. L., & Mitgang, L. D. (1996). *Building community: A new future for architecture education and practice : a special report*. Princeton, N.J: Carnegie Foundation for the Advancement of Teaching.

Bransford, J., Brown, J., & Cocking, R. (2000). *How people learn: Brain, mind, experience, and school* (National A.). Washington DC.

Bransford, J. D., Burns, M. S., Delclos, V. R., & Vye, N. J. (1986). Teaching Thinking: Evaluating Evaluations and Broadening the Data Base. *Educational Leadership*, *44*(2), 68–70.

Broadbent, G. (1995). Architectural education. In M. Pearce & M. Toy (Eds.), *Educating architects* (pp. 10–23). London: Academy Editions.

Brown, A. (1978). Knowing when, where, and how to remember: A problem of metacognition. In A. Glaser (Ed.), *Advances in instructional psychology* . Hillsdale, NJ: Lawrence Erlbaum Associates.

Brown, A. (1987). Metacognition, Executive Control, Self Regulation and Mysterious Mechanisms. In W. and Klume (Ed.), *Metacognition, Motivation and Understanding.* (pp. 65–117). New Jersey: Erlbaum Hillsdale.

Bruner, J. S. (1996). *The culture of education*. Cambridge, Mass: Harvard University Press.

Bryant, A. (2002). Re-grounding grounded theory. *Journal of Information Technology Theory and Application*, *4*(1), 25–42.

Bryant, A. (2003). A constructivist response to {Glaser}. *Forum. ' Qualitative Social Research*, *4*(1). Retrieved from http://www.qualitative-research.net/index.php/fqs/article/view/757/1642

Bryman, A. (2004). Integrating quantitative and qualitative research: how is it done? *Qualitative Research*, *6*(1), 97–113.

Burchard, C. (1959). Gropius at Harvard; ACSA-AIA Seminar: The Teaching of Architecture. *Journal of Architectural Education*, *14*(2), 23–25.

Burchard, C. (1965). Blue Book, a pedagogical document on the proposed changes to the curriculum. Blacksburg, VA: Special Collection, MS 1991-048.

Burchard, C. (1965). *Blue Book, a pedagogical document on the proposed changes to the curriculum*. Blacksburg, VA.

Burchard, C. (1967). A Curriculum Geared to the times. *AIA Journal*, *47*(5), 101–106.

Burchard, C. (1969). The VPI Inner Collage for Environmental Design, Dialogue and Discovery. *AIA Journal*, *51*(1), 45–49.

Burchard, C. (1972). The continuing experiment for environmental design at Virginia Polytechnic & State University, , Virginia, USA. *Environmental Design Perspectives: Viewpoint on the Profession, Education, Research*. Christiansburg printing.

Burchard, C. (1973). AIA Journal. *The Next Horizon*, *60*(4), 46–47.

Candy, P. C. (1991). *Self-direction for lifelong learning: A comprehensive guide to theory and practice.* San Francisco, CA: Jossey Bass.

Carlhian, J. P. (1979). The Ecole des Beaux-Arts. *Journal of Architectural Education*, *33*(2), 7–17.

Carson, L. J. (2012). *An exploration of metacognition and its interplay with other forms of conscious thought processing in independent learning at tertiary level*. Doctoral dissertation, Dublin City University. Retrieved from http://doras.dcu.ie/17464/

Carver, C. S. (2003). Pleasure as a sign you can attend to something else: Placing positive feelings within a general model of affect. *Cognition and Emotion*, *17*, 241–261.

Carver, C. S., & Scheier, M. F. (1998). *On the self-regulation of behaviour.* NY: Cambridge: University Press.

Case, L., P., Harris, K. R., & Graham, S. (1992). Improving the mathematical problem solving skills of students with learning disabilities: Self-regulated strategy development. *The Journal of Special Education*, *26*(1), 1–19.

Caviola, S., Mammarella, I. C., Comoldi, C., & Lucangeli, D. (2009). A metacognitive visupatial working memory training for children. *International Electronic Journal of Elementary Education*, *2*(1), 123–136.

Chambres, P., Bonin, D., Izaute, M., & Marescaux, P. J. (2002). Metacognition triggered by social aspect of expertise. In P. Chambres, M. Izaute, & P. J. Marescaux (Eds.), *Metacognition process, function and use (pp. 153–168). Norwell*. MA: Kluwer.

Chan, L. K. S., & Moore, P. J. (2006). Development of attributional beliefs and strategic knowledge in years 5 to 9: A longitudinal analysis. *Educational Psychology*, *26,*(2), 161–185.

Charmaz, K. (2002). Tenets of terror. *Qualitative Inquiry*, *8*, 189–190.

Charmaz, K. (2006). *Constructing grounded theory A practical guide through qualitative analysis*. London, UK: Sage.

Child, D. (1995). *Psychology and the teacher* (5th ed.). New York, NY: Holt, Rinehart & Winston.

Cho, J. (2011). *Pedagogy of aesthetic: A study of three architectural design studios.*

Clark, R. C. (1988). Metacognition and human performance improvement. *Performance Improvement Quarterly*, *1*, 33–45.

Clark, R. C. (2002). Applying cognitive strategies to instructional design. *Performance Improvement*, *41*(7), 8–14.

Clarke, A. E. (2003). Situational analyses: grounded theory mapping after the postmodern turn. *Symbolic Interaction*, *26*(4), 553–576.

Clarke, A. E. (2005). *Situational analysis: grounded theory after the postmodern turn*. Thousand Oaks, CA: Sage.

Corno, L. (1993). The best-laid plans: Modern conceptions of volition and educational research. *Educational Researcher*, *22*, 14–22.

Corno, L., & Mandinach, E. (1983). The role of cognitive engagement in classroom learning and motivation. *Educational Psychologist*, *18*, 88–100.

Cotterall, S., & Murray, G. (2009). Enhancing metacognitive knowledge: Structure, affordances and self. *Science Direct*, *37*, 34–45.

Creswell, J. W. (1998). *Qualitative Inquiry and Research Design*. Thousand Oaks,CA: Sage.

Creswell, J. W. (2009). *Research Design. Qualitative, Quantitative and Mixed Methods Approaches* (3rd ed.). Thousand Oaks, CA: Sage.

Creswell, J. W. (2014). *Research design: qualitative, quantitative, and mixed methods approaches* (2nd ed.). Thousand Oaks, CA: Sage.

Creswell, J. W., & Plano Clark, V. L. (2007). *Designing and Conductiong Mixed Methods*. Thousand Oaks, CA: Sage.

Cross, A. (1983). The Educational Background to the Bauhaus. *Design Studies*, *4*(1), 43–52.

Cross, N. (2011). *Design Thinking: Understanding how designers think and work*. Oxford: Berg/Bloomsbury.

Crotty, M. (2003). *The foundations of social research: Meaning and perspective in the research process* (3rd ed.). London, UK: Sage.

Cubukcu, F. (2009). Metacognition in the classroom. *Procedia Social and Behavioral Sciences*, *1*, 1559–1563.

D, G. M., Borg, W. R., & Gall, J. P. (2003). *Educational research: An introduction*. (B. D, W. R., & J. P. (2003). E. research: A. introduction (7th Gall, Eds.). White Plains, NY: Longman Publisher.

Demirbas, O. O. (2001). *The relation of learning styles and performance scores of the students in interior architecture education*. Unpublished Ph.D. dissertation, Bilkent University, Ankara.

Demirbas, O. O., & Demirkan, H. (2003). Focus on architectural design process through learning styles. *Design Studies, 24, 24*, 437–456.

Dempsey, A. (2002). *Art in the Modern Era: A Guide to Styles, Schools and Movements 1860 to the Present*. New York City, NY: Harry N. Abrams.

Denzin, N. K. (1971). The logic of naturalistic inquiry. *Social Forces*, *50*, 166–182.

Desoeae, A., & Roeyers, H. (2002). Offline metacognition-a domain-specific retardation in young children with learning disabilities. *Learning Disability Quarterly*, *25*, 123–139.

Desoete, A. (2008). Multi-method assessment of metacognitive skills in elementary school children: How you test is what you get. *Metacognition and Learning*, *3*(3), 189–206.

Desoete, A., & Ozsoy, G. (2009). Introduction: Metacognition, more than the lognes monster? *International Electronic Journal of Elementary Education*, *2*(1), 1–6.

Desoete, A., Roeyers, H., & Buysse, A. (2001). Metacognition and mathematical problem solving in grade 3. *Journal of Learning Disabilities*, *34*, 435–449.

Desoete, A., Roeyers, H., & De Clerq, A. (2001). Dynamic assessment of metacognitive skills in young children with mathematics –learning disabilities. In J. Carlson (Ed.), *Potential Assessment and Cognitive Training: Actual research and Perspectives in Theorybuilding and Methodology*. England: JAI Press Inc/Elsevier, in press.

Dewey, J. (1933). *How We Think*. Boston: Heath & Co.

Dina, F., & Efklides, A. (2009). Metacognitive experiences as the link between situational characteristics, motivation, and affect in self-regulated learning. In M. Wosnitza, S. A. Karabenick, A. Efklides, & P. Nenniger (Eds.), *Contemporary motivation research: From global to local perspectives (pp. 117–146).* Goettingen, Germany: Hogrefe & Hube.

Dinsmore, D. L., Alexander, P. A., & Loughlin, S. M. (2008). Focusing the Conceptual Lens on Metacognition, Self-regulation, and Self-regulated Learning. *Educational Psychology Review*, *20*, 391–409.

Doerner, D. (1974). *Die kognitive Organisation beim Problemloesen*. Bern: Huber.

Dorst, K. (1997). *Describing design: a comparison of paradigms*. Unpublished PhD Dissertation, Delft University of Technology, Delft, Netherlands.

Dorst, K., & Dijkhuis, J. (1996). Comparing paradigms for describing design activity. *Design Studies*, *16*, 261–274.

Driscoll. (2005). Psychology of Learning for Instruction. In *Ch. 11 – Constructivism* (Vol. 11, pp. 384–407;). Toronto, ON: Pearson.

Dunlosky, J. (1998). Epilogue. Linking metacognitive theories to education. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice (pp. 367–381).* Mahwah: Erlbaum.

Dunlosky, J., & Metcalfe, J. (2009). *Metacognition*. Thousand Oaks, CA: Sage.

Efklides, A. (2001). Metacognitive experiences in problem solving: Metacognition, motivation, and self-regulation. In A. Efklides, J. Kuhl, & R. M. Sorrentino (Eds.), *Trends and prospects in motivation research (pp. 297–323).* Dordrecht, The Netherlands: Kluwer.

Efklides, A. (2002). Feelings as subjective evaluations of cognitive processing: How reliable are they? *Psychology: The Journal of the Hellenic Psychological Society*, *9*, 163–184.

Efklides, A. (2006). Metacognitive Experiences: The Missing Link in the Self-Regulated Learning Process. A Rejoinder to Ainley and Patrick. *Educational Psychology*, *18*, 287–291.

Efklides, A. (2008). Metacognition. Defining its facets and levels of functioning in relation to self-regulation and co-regulation. *European Psychologist*, *13*(4), 277–287.

Efklides, A. (2011). Interactions of Metacognition With Motivation and Affect in Self-Regulated Learning: The MASRL Model. *Educational Psychologist*, *46*(1), 6–25.

Efklides, A., Kourkoulou, A., Mitsiou, F., & Ziliaskopoulou, D. (2006). Effort regulation, effort perceptions, mood, and metacognitive experiences: What determines the estimate of effort expenditure? *Metacognition and Learning*, *1*, 33–49.

Efklides, A., & Misailidi, P. (2010). ntroduction: The present and future in metacognition. In A. Efklides and P. Misailidi (Ed.), *Trends and prospects in Metacognition Research* (pp. 1–20). New York: Springer.

Efklides, A., & Sideridis, G. D. (2009). Assessing cognitive failures. *European Journal of Psychological Assessment*, *25*, 69–72.

Efklides, A., & Tsiora, A. (2002). Metacognitive experiences, self-concept, and self-regulation. *Psychologia: An International Journal of Psychology in the Orient*, *45*, 222–236.

Eggen, P., & Kauchak, D. (2001). *Educational Psychology*. New Jersey, NJ: Merrill Prentice Hall.

Eisner, E. W. (1981). On the differences between scientific and artistic approaches to qualitative research. *Educational Research*, *10*(4), 5–9.

Ellen, R. F. (Ed.). (1984). *Ethnographic research: A guide to general conduct*. London,UK: Academic Press.

Ericsson, K., & Simon, H. (1980). Verbal reports as data. *Psychological Review*, *87*(3), 215–251.

Ericsson, K., & Simon, H. (1993). *Protocol analysis: Verbal reports as data*. Cambridge, MA: Bradford Books/ MIT Press.

Fabricius, W. V., & Schwanenflugel, P. J. (1994). The older child's theory of mind. In A. D. & A. Efklides (Ed.), *Intelligence, mind, and reasoning: Structure and development (pp. 111–132).* Amsterdam: Elsevier.

Field, R., Duffy, J., & Huggins, A. (2014). Independent learning skills, Self-determination theory and psychological well-being: Strategies for supporting the first year university experience. July 6-9, 2014, Darwin.: Paper presented at the International First Year in Higher Education Conference.

Fincham, F., & Cain, K. (1986). Learned helplessness in humans: A developmental analysis. *Developmental Review*, *6*, 25–86.

Firestone, W. A. (1987). Meaning in method: The rhetoric of quantitative and qualitative research. *Educational Researcher*, *16*(7), 16–21.

Fjeld, P. O. (2005). Teaching Architecture: A revitalization of architectural consciousness. *Transaction on Architectural Education in European Association for Architectural Education*, 11–16.

Flavell, J. (1981). Monitoring social cognitive enterprises: Something else that may develop in the area of social cognition. In J. Flavell & L. Ross (Eds.), *Social cognitive development (pp. 272–287).* New York City, NY: Cambridge University Press.

Flavell, J. H. (1976). Metacognitive aspects of problem solving. In L. B. Resnick (Ed.), *The nature of intelligence* (pp. 231–236). Hillsdale, NJ: Erlbaum.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry. *American Psychologist*, *34*, 906–911.

Flavell, J. H. (1985). *Cognitive development Englewood Cliffs* (2nd ed.). NJ: Prentice-Hall.

Flavell, J., Miller, P. H., & Miller, S. A. (2002). *Cognitive Development* (fourth.). Toronto: Pearson Education.

Ford, J. K., Smith, E. M., Weissbein, D. A., Gully, S. M., & Salas, E. (1998). Relationships of goal orientation, metacognitive activity, and practice strategies with learning outcomes and transfer. *Journal of Applied Psychology*, *83*, 218–233.

Fowler, F. J. J. (1984). *Survey research methods*. Thousand Oaks, CA: Sage.

Fox, E., & Riconscente, M. (2008). Metacognition and self-regulation in James, Piaget, and Vygotsky. *Educational Psychology Review*, *20,* 373–389.

Freire, P. (2000). *Pedagogy of the oppressed*. New York, NY: Continuum.

Gall, M., Gall, J, Jacobsen, D., & Bullock, T. L. (1990). *Tools for Learning: A Guide to Teaching Study Skills. Alexandria, VA: Association for Supervision and Curriculum Development; 1990.*

Garner, R. (1988). *Metacognition and reading comprehension.* Norwood, NJ: Ablex.

Garofalo, J., & Lester, F. K. (1985). Metacognition, cognitive monitoring, and mathematical performance. *Journal for Research in Mathematics Education*, *16*(3), 163–176.

Georghiades, P. (2004). From the general to the situated: three decades of metacognition. *International Journal of Science Education*, *26*(3), 365–385.

Glaser, B. G. (1978). *Theoretical Sensitivity advances in the methodology of grounded theory.* Thousand Oaks, CA: Sociology Press.

Glaser, B. G. (2012). Constructivist Grounded Theory. *The Grounded Theory Review*, *11*(1), 28–38.

Glaser, B. G., & Strauss, A. (1967). *The discovery of grounded theory*. Hawthorne, NY: Aldine De Gruyter.

Goldschmidt, G. (1991). The Dialectics of sketching creativity. *Research Journal*, *4*(2), 123–143.

Goos, M., & Galbraith, P. (1996). Do it this way! Metacognitive strategies in collaborative mathematical problem solving. *Educational Studies in Mathematics, 30*, 229–260.

Graves, D. H. (1983). *Writing: Teachers and children at work.* Portsmouth, NH: Heinemann Educational Books.

Greene, J. A., & Azevedo, R. (2007). A theoretical review of Winne and Hardwin's model of self-regulated learning: New perspectives and directions. *Review of Educational Research*, *77*, 334–372.

Groat, L. N., & Wang, D. (2013). *Architectural research methods* (2nd ed.). New Jersey, NJ: John Wiley & Sons.

Gropius, W. (1967). Correspondence from Walter Gropius to Charles Burchard. Blacksburg: Walter Gropius/G. Preston Frazer Papers, Ms1992-052, Special Collections, Virginia Tech.

Guba, E. (1987). What have we learned about naturalistic evaluation? *Evaluation Practice*, *8*(1), 23–43.

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N. K. D. and Y. S. Lincoln (Ed.), *in Handbook of Qualitative Research,* (pp. 105–117). Thousand Oaks, CA: Sage.

Guba, E., & Lincoln, Y. (1981). *Effective evaluation*. San Francisco, CA: Jossey-Bass.

Hargrove, R. (2008). *Creating creativity in the design studio: Assessing the impact of metacognitive skill development on creative abilities*. Doctoral dissertation, Doctoral dissertation, North Carolina State University. Retrieved from http://www.lib.ncsu.edu/resolver/1840.16/3048

Hargrove, R. (2013). Assessing the long-term impact of a metacognitive approach to creative skill development. *International Journal of Technology and Design Education*, *23*(3), 489–517.

Hartman, H. (2001). *Metacognition in learning and Instruction*. Dordrecht, Netherlands: Kluwer.

Hathaway, R. S. (1995). Assumptions Underlying Quantitative and Qualitative Research: Implications for Institutional Research. *Research in Higher Education*, *36*(5), 535–562.

Hergenhahn, B. R., & Olson, M. H. (2001). *An Introduction to Theories of Learning* (6th ed.). New Jersey: Prentice-Hall.

Hesse-Biber, S., & Leavy, P. (2011). *The practice of qualitative research* (2nd ed.). Thousand Oaks, CA: Sage.

Hitchcock, G., & Hughes, D. (1995). *Research and the teacher: A qualitative introduction to school-based research* (2nd ed.). New York, NY: Routledge.

Horst, S. (2016). *Cognitive pluralism* (1st ed.). London, England: MIT Press.

Hunter-Blanks, P., Ghatala, E. S., Pressley, M., & Levin, J. (1990). Comparison of moni- toring during study and during testing on a sentence-learning task. *Journut of Educational Psychology, 80*, 279–283.

Jacob, E. (1988). Clarifying qualitative research: A focus on traditions. *Educational Researcher*, *17*(1), 16–24.

Jausovec, N. (1994). Metacognition in creative problem solving. In M. Runco (Ed.), *Problem Finding, Problem Solving and Creativity*. Norwood, NJ: Ablex Publishing.

Jonassen, D., Strobel, J., & Lee, C. B. (2006). Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education*, *95*(2), 139– 151.

Jonassen, D. H. (1991). Objectivism versus constructivism: Do we need a new philosophical paradigm? *Educational Technology Research and Development*, *39*(3), 5–14. Retrieved from http://link.springer.com/10.1007/BF02296434

Jonassen, D. H. (1998). Designing constructivist learning environments. In C. M. Reigeluth (Ed.), *Instructional theories and models* (2nd ed.). New Jersey, NJ: Erlbaum.

Jonassen, D. H., & Easter, M. A. (2012). Conceptual Change and Student-Centered Learning Environments. In D. J. & S. Land (Ed.), *Theoretical Foundations of Learning Environments* (2nd ed.). New York: Routledge.

Kahneman, D. (2003). A perspective on judgment and choice. American Psychologist, *58*, 697–720.

Kavousi, S., & Miller, P. A. (2014). The community of practice: Teaching Pedagogy in the Architecture Foundation Design Lab. In *EDULEARN14 Proceedings, IATED: 2548-2557*.

Kinnunen, R., & Vauras, M. (1995). Comprehension monitoring and the level of comprehension in high- and low-achieving primary school children's reading. *Learning and Instruction*, *5*, 143–165.

Kirby, J. R., & Ashman, A, F. (1984). Planning skills and mathematics achievement: Implications regarding learning disability. *Journal of Psycho Educational Assessment*, *2*, 9–22.

Koch, T. (2006). Establishing rigour in qualitative research: the decision trail. *Journal of Advanced Nursing*, *53*(1), 91–100.

Koriat, A. (1993). How do we know that we know? The accessibility model of the feeling of knowing. *Psychological Review*, *100*, 609–639.

Koriat, A. (2000). The feeling of knowing: Some Metatheoretical Implications for Consciousness and control. *Consciousness and Cognition*, *9*(2), 149–171.

Koriat, A. (2007). Metacognition and consciousness. In P. D. Zelazo, M. Moscovitch, & E. Thompson (Eds.), *The Cambridge handbook of consciousness (pp. 289-325).* New York: Cambridge University Press.

Koriat, A., & Levy-Sadot, R. (1999). Processes underlying metacognitive judgments: Information-based and experience-based monitoring of one's own knowledge. In S. Chaiken, S., Trope (Ed.), *Dual process theories in social psychology (pp. 483-502).* New York: Guilford Press.

Kruger, J., & Dunning, D. (2009). Unskilled and unaware of it: How difficulties in recognizing one's own incompetencies lead to inflated self-assessments. *Journal of Psychology*, *1*, 30–46.

Ku, S., & Morgan, M. (2006). Technology from a metacognitive perspective in studio settings in the higher education sector (pp. 208–216). 7th International Conference on Information Technology Based Higher Education and Training, 10 July 2006 to 13 July 2006, University of Technology Sydney, Sydney NSW Australia.

Kuhl, J. (1985). Volitional mediators of cognition-behavior consistency: Self-regulatory processes and action versus state orientation. In J. Kuhl & J. Beckman (Eds.), *Action control: From cognition to behavior* (pp. 101–128). Berlin, Germany: Springer-Verlag.

Kuhl, J. (1992). A theory of self-regulation: action versus state orientation, self-discrimination, and some applications. *Applied Psychology. An International Review*, *41*, 97–129.

Kuhl, J., & Fuhrmann, A. (1998). Decomposing self-regulation and self-control: The volitional components checklist. In J. Heckhausen & C. Dweck (Eds.), *Life span perspectives on motivation and control (pp. 15–49).* Mahwah, NJ: Erlbaum.

Kung, W. R. L., & Pui-yuen, V. L. (2008). On Design Thinking: Studying the Hybrid Process of ManagingCreative Thinking and Design Planning in Design Education. *Journal of Design Principlesand Practices*, *2*(1), 99–104.

Land, S., Hannafin, M. J., & Oliver, K. (2012). Student-centered learning environments. In *Theoretical Foundations of Learning Environments* (2nd ed., pp. 3–26). London, UK: Routledge.

Lang, J. (1987). *Creating Architectural Theory: The Role of the Behavioral Sciences in Environmental Design*. New York City, NY.

Lawanto, O. (2008). *Self -appraisal and self -management of cognition and problem difficulty: Relationship and metacognitive changes during an engineering design project*. Dissertation Abstracts International Section A: Humanities and Social Sciences.

Lawanto, O. (2010). Students' metacognition during an engineering design project. *Performance Improvement Quarterly*, *23*(2), 115–134.

Lawanto, O., Butler, D., Cartier, S., Santoso, H. B., & Goodridge, W. (2013). Task Interpretation, Cognitive, and Metacognitive Strategies of Higher and Lower Performers in an Engineering Design Project: An Exploratory Study of College Freshmen. *International Journal of Engineering Education*, *29*(2), 459–475.

Lawson, B. (1994). *Design in mind*. Oxford, UK: Butterworth-Heinemann.

Lawson, B. (2006). *How Designers Think: The Designing Process Demystified*. London, UK: Architectural Press.

Lee, J., & Shute, V. J. (2010). Personal and social-contextual factors in k-12 academic performance: An integrative perspective on student learning. *Educational Psychologist*, *45*(3), 185–202.

Lester, F. K., Garofalo, J., Kroll, D. (1989). *The role of metacognition in mathematical problem solving: A study of two grade seven classes.* Final report to the National Science Foundation of NSF project MDR 85-50346.

Li, S., & Munby, H. (1996). Metacognitive strategies in second language academic reading: A qualitative investigation. *English for Specific Purposes*, *15*(3), 199–216.

Lloyd, P., Lawson, B., & Scott, P. (1995). Can concurrent verbalization reveal design cognition? *Design Studies*, *2*(16), 237–259.

Mahmoodi, A. S. (2001). *The Design Process in Architecture: A pedegogive approach using Interactive Thinking*. Ph.D Thesis, University of Leads, U.K.

Marchant, G. J. (1989). Meta-teaching: A metaphor for reflective teaching. *Education*, *109*(4), 487–489.

Martinez, M. E. (2006). What is metacognition? *Phi Delta Kappan*, *87*(9), 696–699.

Mason, J. (1996). *Qualitative researching*. London,UK: Sage.

Matanzo, J. B., & Harris, D. L. (1999). Developing metacognitive awareness in preservice courses. In Advancing the World of Literacy: The 21st College Reading Association Yearbook (pp. 201- 225). Carrollton, GA: College Reading Association. In *Advancing the World of Literacy: The 21st College Reading Association Yearbook* (College Re., pp. 201–225). Carrollton, GA: Florida: Florida Atlantic University.

McCracken, D. G. (1988). *The Long Interview (Qualitative Research Methods, Vol (13).* Newbury Park, CA: Sage.

Metallidou, P., & Efklides, A. (2001). The effects of general success-related beliefs and specific metacognitive experiences on causal attributions. In A. Efklides, J. Kuhl, & R. M. Sorrentino (Eds.), *Trends and prospects in motivation research (pp. 325–347).* Dordrecht, Netherlands: Kluwer.

Metcalfe, J., & Shimamura, A. P. (1994). *Metacognition: knowing about knowing*. London, UK: The MIT Press.

Meyer, B., Haywood, N., Sachdev, D & Faraday, S. (2008). *Independent Learning Literature Review*. Research Report DCSF-RR051 (Department for Children Schools and Families).

Miles, M., & Huberman, A. M. (1984). Drawing valid meaning from qualitative data: Towards a shared craft. *Educational Researcher*, *13*, 20–30.

Miller, P. H., Kessel, F. S., & Flavell, J. H. (1970). Thinking about people thinking about people thinking about...: A study of social–cognitive development. *Child Development*, *41*, 613–623.

Miller, G. (1956). The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information. *Psychological Review*, *101*, 343–352.

Mills, J., Bonner, A., & Francis, K. (2006). The development of constructivist grounded theory. *Internationa/Journa/ of Qualitative Methods*, *5*(1), 1–10.

Montague, M. (1998). Research on metacognition in special education. In T. E. Scruggs & M. A. Mastropieri (Eds.), *Advances in learning and behavioural disabilities* (p. 151). San Diego, CA: Academic.

Morgan, D. L. (2013). *Integrating Qualitative and Quantitative Methods: A Pragmatic Approach*. Thousand Oaks, CA: Sage.

Motloch, J. L. (2001). *Introduction to Landscape Design* (2ed ed.). New York City, NY: John Wiley and Sons.

Murphy, E., & Dingwall, R. (2003). *Qualitative Methods and Health Policy Research*. New York, NY: Aldine deGruyter.

Negretti, R. (2012). Metacognition in Student Academic Writing: A Longitudinal Study of Metacognitive Awareness and Its Relation to Task Perception, Self-Regulation, and Evaluation of Performance. *Sage*, *29*(2), 142–179.

Nelson, T. (1996). Consciousness and metacognition. *American Psychologist*, *51*, 102–116.

Nelson, T. O. (1999). Cognition versus metacognition. In Sternberg R. J. (Ed.), *The Nature of Cognition* (pp. 625–641). Cambridge, MA: The MIT Press.

Nelson, T. O., & Narens, L. (1990). Metamemory: A theoretical framework and new findings. In G. H. Bower (Ed.), *The psychology of learning and motivation,* (p. vol. 26, pp. 125–173). New York, NY: Academic Press.

Nelson, T. O., & Narens, L. (1994). Why investigate metacognition? In J. Metcalfe & A. Shimamura (Eds.), *Metacognition: Knowing about knowing (pp. 1–25).* Cambridge, MA: MIT Press.

Nietfeld, J. L., & Schraw, G. (2002). The effect of knowledge and strategy explanation on monitoring accuracy. *Journal of Educational Research*, *95*, 131–142.

Nuckles, M., Hubner, S., & Renkl, A. (2009). Enhancing self-regulated learning by writing learning protocols. *Learning and Instruction*, *19*(1), 259–271.

Onions, P. E. W. (2006). Grounded theory applications in reviewing knowledge management literature. Leeds: paper presented in Leeds Metropolitan University Innovation North Research Conference. Retrieved from http://ijds.org/Volume6/IJDSv6p095-114Jones322.pdf

Ormrod, J. E. (2012). *Human learning* (6th ed.). Boston, MA: Pearson.

Oxford, R. L. (1997). Constructivism: Shape-Shifting, Substance, and Teacher Education Applications. *Peabody Journal of Education*, *72*(1), 35–66.

Ozsoy, G. (2008). Ustbilis [Metacognition]. *Turk Egitim Bilimleri Dergisi*, *6*(4), 713–740.

Ozsoy, G. (2011). An investigation of the relationship between metacognition and mathematics achievement. *Asia Pacific Education*, *12*, 227–23.

Panaoura, A. (2004). *Young pupils' metacognitive ability in maths*. Cyprus: Master's thesis, Department of Education, University of Cyprus.

Pandit, N. R. (1996). The creation of theory: A recent application of the grounded theory methodology. *The Qualitative Report*, *2*(4).

Paris, S., Cross, D. R., Lipson, M. Y. (1984). Informed strategies for learning: A program to improve children's reading awareness and comprehension. *Journal of Educational Psychology*, *76*(6), 1239–1252.

Paris, S., Lipson, M., Wixson, K. (1983). Becoming a strategic reader. *Contemporary Educational Psychology*, *8*(1), 293–316.

Paris, S. G., & Winograd, P. (1990). How metacognition can promote academic learning and instruction. In B. F. Jones & L. Idol (Eds.), *Dimensions of thinking and cognitive instruction* (pp. 15–51). Hillsdale, NJ: Lawrence Erlbaum.

Peirce, W. (2003). *Metacognition: Study Strategies, Monitoring and Motivation*. A greatly expanded text version of a workshop presented November 17, 2004, at Prince George's Community College. Retrieved from http://academic.pgcc.edu/\~wpeirce/MCCCTR/

Perkins, D. N. (1992). Technology Meets Constructivism: Do They Make a Marriage? In D. Duffy, T.M. & Jonassen (Ed.), *Constructivism and the Technology of Instruction: A Conversation* (pp. 45–55). Hillsdale, NJ: Lawrence Erlbaum.

Pesut, D. J. (1984a). *Doctoral dissertation. Metacognition: The self-regulation of creative thought in nursing.* Ann Arbor: The University of Michigan.

Pesut, D. J. (1984b). *Metacognition: The Self-Regulation of Creative Thought in Nursing*. Doctoral Dissertation.Ann Arbor: The University of Michigan.

Pintrich, P. R., Wolters, C. A., & Baxter, G. P. (2000). 2. Assessing Metacognition and Self-Regulated Learning. In *Issues in the Measurement of Metacognition* (pp. 43–97).

Pintrich, P. R. (2000). Multiple goals, multiple pathways: The role of goal orientation in learning and achievement. *Journal of Educational Psychology*, *92*, 544–555.

Pintrich, P. R., & DeGroot, E. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, *82*(1), 33–40.

Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W. J. (1991). *A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ).* Ann Arbor: University of Michigan, National Center for Research to Improve Postsecondary Teaching and Learning.

Powers, M. N. (2017). *Self-Regulated Design Learning: A Foundation and Framework for Teaching and Learning Design*. London: Routledge.

Pressley, M., & Afflerbach, P. (1995). *Verbal protocols of reading: The nature of constructively responsive reading.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Pressley, M. (2000). Comprehension instruction: What makes sense now, what might make sense soon. In P. Mosenthal, P. D. Pearson, & R. Barr (Eds.), *Handbook of Reading Research: Volume III.* (Vol. III). New York, NY: Longman.

Pressley, M., Etten, V., S., Y., L., F., G., Meter, V., & P. (1998). The metacognition of college studentship: {A} grouped theory approach. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 347–366). Mahwah, NJ: Erlbaum.

Prince, G. M. (1970). *The Practice of Creativity*. New York, NY: Harper and Row.

Rahman, F., & Masrur, R. (2011). Is metacognition a single variable? *International Journal of Business and Social Science*, *2*(5), 135–141.

Reid, J. (1990). The dirty laundry of ESL survey research. *TESOL Ouarterly*, *24*, 323–338.

Reingold, R., Rimor, R., & Kalay, A. (2008). Instructor's scaffolding in support of student's metacognition through a teacher education online course: A case study. *Journal of Interactive Online Learning*, *7*(2), 139–151.

Reswick, J. (1965). *Protspectus for an Engineering Design Center*. Cleveland, OH: Case Institute Of Technology.

Ross, M. E., Green, S. B., Salisbury-Glennon, J. D., & Tollefson, N. (2006). College students' study strategies as a function of testing: An investigation into metacognitive self-regulation. *Innovative Higher Education*, *30*(5), 361–375.

Ruffman, T., Slade, L., & Crowe, E. (2002). The relation between children's and mothers' mental state language and theory-of mind understanding. *Child Development*, *73*, 734–751.

Salama, A. (1995). *New Trends in Architectural Education: Designing the Design Studio*. Raleigh, NC: Tailored Text and Unlimited Potential Publishers.

Samek, R. (1981). *The meta phenomenon*. New York, NY: Philosophical Library.

Santoso, H. B., Boyles, R., Lawanto, O., & Goodridge, W. (2011). A preliminary study of conducting semi-structured interview as metacognitive assessment in engineering design: Issues and challenges. In *American Society of Engineering Education (ASEE) Annual Conference.* Vancouver, Canada.

Saunders, M., Lewis, P., & Thornhill, A. (2007). *Research Methods for Business Students* (4th ed.). London, UK: Prentice Hall.

Sawyer, R. K. (2006). *The Cambridge Handbook of the Learning Sciences*. New York, NY: Cambridge University Press.

Schoenfeld, A. (1992). Learning to think mathematically: Problem solving, metacognition and sense making in mathematics. In D. Grouws (Ed.), *Handbook of research on mathematics teaching and learning (pp. 189-215).* New York, NY: Macmillan.

Schoenfeld, A. H. (1983). Beyond the purely cognitive: Belief systems, social cognitions, and metacognitions as driving forces in intellectual performance. *Cognitive Science*, *7*(4), 329–363.

Schön, D. A. (1963). *Displacement of Concepts*. London, England: Routledge.

Schön, D. A. (1983). *The reflective practitioner*. London, UK: Temple-Smith.

Schön, D. A. (1984). The architectural studio as an exemplar of education for reflection in action. *Journal of Architectural Education*, *38*(1), 2–9.

Schön, D. A. (1987). *Educating the reflective practitioner*. San Francisco, CA: Jossey-Bass.

Schön, D. A. (1992). Designing as reflective conversation with the materials of a design situation. *Knowledge-Based Systems*, *5*(1), 3–14.

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review*, *7*, 351–373.

Schraw, G. (1998). Promoting general metacognitive awareness, Instructional Science. *26*, 113–125.

Schraw, G. (2000). Assessing metacognition: Implications of the Buros symposium. In G. Schraw & J. C. Impara (Eds.), *Issues in the measurement of metacognition* (pp. 297–321). Lincoln, NE: Buros Institute of Mental Measurements.

Schraw, G., & Dennison, R. S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology*, *19*, 460–475.

Schraw, G., & Impala, J. C. (2000). *Issues in the measurement of metacognition*. Lincoln, NE: Buros Institute of Mental Measurements. University Of Nebraska-Lincoln.

Schunk, D. H. (2004). *Learning theories: An educational perspective. Upper Saddle River*. NJ: Pearson.

Schunk, D. H. (2008). Metacognition, self-regulation, and self-regulated learning: Research recommendations. *Educational Psychology Review*, *20*(4), 463–467.

Schunk, D. H., & Zimmerman, B. J. (1998). *Self-regulated learning: from teaching to self-reflective practice.* New York, NY: Guilford Press.

Sheppard, S.D., Macatangay, K., Colby, A., & Sullivan, W. M. (2009). *Educating engineers: Designing for the future of the field.* San Francisco, CA: Jossey-Bass.

Shimamura, A. P. (2000). Toward a Cognitive Neuroscience of Metacognition. *Consciousness and Cognition*, *9*, 9, 313–323.

Silverman, D. (2010). *Doing qualitative research* (3rd ed.). Thousand Oaks, CA: Sage.

Simon, H. A. (1969). *The Sciences of Artificial* (3rd ed.). Cambridge, MA: MIT Press.

Smith, T. E., Knapp, C., & E. C. (2011). *Sourcebook of experiential education* (Routledge.). New York City, NY. Retrieved from http://ebookcentral.proquest.com

Smith, J. (1983a). Quantitative versus interpretive: The problem of conducting social inquiry. In E. House (Ed.), *Philosophy of Evaluation* (pp. 27–52). San Francisco, CA: Jossey-Bass Publishers.

Smith, J. (1983b). Quantitative versus qualitative research: An attempt to clarify the issue. *Educational Researcher. 12(3)*, *12*(3), 6–13.

Smith, J. (1984). The problem of criteria for judging interpretive inquiry. *Educational Evaluation and Policy Analysis*, *6*(4), 379–391.

Smith, J., Shields, W., & Washaburn, D. (2003). *Intentional conceptual change*. New Jersey, NJ: Lawrence Erlbaum.

Smith, S. M. (1994). Frustrated feelings of imminent recall: On the tip-of-the tongue. Metacognition: Knowing about knowing (pp. 27–46). In A. P. Metcalfe, J. & Shimamura (Ed.), . Cambridge, UK: MIT.

Son, L. K., & Schwartz, B. L. (2002). The relation between metacognitive monitoring and control. In T. J. Perfect & B. S. Schwartz (Eds.), *Applied metacognition* (p. (pp. 15–38)). Cambridge, UK: Cambridge University Press.

Sperling, R. A., Howard, B. C., Staley, R., & DuBois, N. (2004). Metacognition and self regulation learning constructs. *Educational Research and Evaluation*, *10*(2), 117–139.

Sternberg, R. J. (1982). *Handbook of human intelligence.* New York: Cambridge University Press.

Sternberg, R. J., & Williams, W. M. (1996). *How to develop student creativity.* Alexandria, VA: Association for Supervision and Curriculum Development.

Strauss, A., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques.* Newbury Park, CA: Sage.

Stubbs, M.S and Gordon, D. . (1989, August). The individual student is the center of learning. *Architecture: Incorporating Architectural Technology Magazine*, 62–70.

Suwa, M., & Tversky, B. (1997). What architects and students perceive in their sketches: A protocol analysis. *Design Studies*, *18*, 385–403.

Takaya, K. (2008). Jerome Bruner's theory of education: From early Bruner to later Bruner. *Interchange*, *39*(1), 1–19.

Tanner, K. D. (2012). Promoting student metacognition. *CBE—Life Sciences Education*, *11*, 113–120.

Tarricone, P. (2011). *The taxonomy of metacognition*. New York, NY: Psychology Press.

Taylor, S. J. (1987). Observing abuse: Professional ethics and personal morality in field research. *Qualitative Sociology*, *10*(3), 288–302.

Teong, S. K. (2002). The effect of metacognitive training on mathematical word-problem solving. *Journal of Computer Assisted Learning*, *19*, 45–46.

Thiede, K. W., Anderson, M. C., & Therriault, D. (2003). Accuracy of metacognitive monitoring affects learning of texts. *Journal of Educational Psychology*, *95*, 66–73.

Veenman, M. V. J., & Van Hout Wolters, B.H.A.M & Afflerbach, P. (2006). Metacognition and learning: conceptual and methodological considerations. *Metacognition & Learning*, *1*, 3–14.

Veenman, M. V. J., Wilhelm, P., & Beishuizen, J. J. (2004). The relation between intellectual and metacognitive skills from a developmental perspective. *Learning and Instruction*, *14*, 89–109.

Vogeley, K., Kurthen, M., Falkai, P., & Maier, W. (1999). Essential functions of the human self model are implemented in the prefrontal cortex. *Consciousness and Cognition*, *8*, 343–363.

Walker, J. C., & Evers, C. W. (1988). The epistemological unity of educational research. In J. P. Keeves (Ed.), *Research methodology and measurement: An international handbook* (pp. 28–36). Oxford: Pergamon Press.

Weatherhead, A. (1941). *The history of collegiate education in architecture in the United States*.

Wenden, A. L. (1999). An introduction of metacognitive knowledge and beliefs in language learning: beyond the basics. *System*, *27*(4), 435–441.

Whitford, F. (1984). *Bauhaus*. London, England: Thames and Hudson.

Wilson, J. (1998). Metacognitive within mathematic: A new and practical multi-method approach. In C. Kanes, M. Goos, & E. Warren (Eds.), *Teaching Mathematics in New Times (proceedings of the 21st annual conference of Mathematics Education Research Group of Austeralia, Gold Coast, pp 693-700).* Brisbane: MERGA.

Wilson, J. (2001). *Methodological difficulties of assessing metacognition: A new approach.* Paper presented at the Annual Meeting of the Australian Association for Research in Education.

Wilson, J., & Clarke, D. (2004). Towards the modelling of mathematical metacognition. *Mathematics Education Research Journal.*, *16*(2), 25–48.

Winne, P. H. (1996). A metacognitive view of individual differences in self- regulated learning. *Learning and Individual Differences*, *8*(4), 327–353.

Winne, P. H. (2004). Students' calibration of knowledge and learning processes: Implications for designing powerful software learning environments. *Educational Research*, *41*, 466–488.

Winters, F. I., Greene, J. A., & Costich, C. M. (2008). Self-regulation of learning within computer-based learning environments: A critical analysis. *Educational Psychology Review.*, *20*, 429–444.

Zimmerman, B. (1995). Self-regulation involves more than metacognition: A social cognitive perspective. *Educational Psychologist*, *30*(4), 217–221.

Zimmerman, B. J., & Martinez-Pons, M. (1990). Student differences in self-regulated learning: Relating grade, sex, and giftedness to SE and strategy use. *Journal of Educational Psychology*, *82*(1), 51–59. Retrieved from http://dx.doi.org/10.1037/0022-0663.82.1.51

Zimmerman, B. J., & Moylan, A. R. (2009). Self-regulation: Where metacognition and motivation intersect. In D. J. Hacker, J. Dunlosy, & A. C. Graesser (Eds.), *Handbook of metacognition in education (pp.299-315).* New York, NY: Routledge.

Zimmerman, B. J., & Schunk, D. H. (2011). *Handbook of self-regulation of learning and performance.* New York: Routledge.

Appendix

Appendix A: IRB Approval Form (Pilot Study)

VirginiaTech

Office of Research Compliance
Institutional Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: October 7, 2014

TO: Patrick Miller, Shabnam Kavousi

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires April 25, 2018)

PROTOCOL TITLE: Focus on students Learning process in Architectural Design Studio

IRB NUMBER: 14-996

Effective October 7, 2014, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 5,6,7**
Protocol Approval Date:	**October 7, 2014**
Protocol Expiration Date:	**October 6, 2015**
Continuing Review Due Date*:	**September 22, 2015**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution

Appendix B: IRB Approval Form

VirginiaTech

Office of Research Compliance
Institutional Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE:	November 20, 2015
TO:	Patrick Miller, Shabnam Kavousi
FROM:	Virginia Tech Institutional Review Board (FWA00000572, expires July 29, 2020)
PROTOCOL TITLE:	Metacognitive Learning in the Foundation Design Lab
IRB NUMBER:	15-388

Effective November 20, 2015, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 6,7**
Protocol Approval Date:	**November 20, 2015**
Protocol Expiration Date:	**November 19, 2016**
Continuing Review Due Date*:	**November 5, 2016**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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Appendix C: IRB Renewal Approval Form

VirginiaTech

Office of Research Compliance
Institutional Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4606 Fax 540/231-0959
email irb@vt.edu
website http://www.irb.vt.edu

MEMORANDUM

DATE: March 29, 2016

TO: Patrick Miller, Shabnam Kavousi

FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)

PROTOCOL TITLE: Metacognitive Learning Foundation Design Lab in School of Architecture + Design at Virginia Tech

IRB NUMBER: **15-388**

Effective March 29, 2016, the Virginia Tech Institution Review Board (IRB) Chair, David M Moore, approved the Amendment request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

http://www.irb.vt.edu/pages/responsibilities.htm

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As:	**Expedited, under 45 CFR 46.110 category(ies) 6,7**
Protocol Approval Date:	**November 20, 2015**
Protocol Expiration Date:	**November 19, 2016**
Continuing Review Due Date*:	**November 5, 2016**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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Appendix D: Consent Form

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants in Research Projects
Involving Human Subjects

Title of Research Project: The Process of Thinking and Making in Beginning Design Students

Investigator: Shabnam Kavousi, Ph. D Candidate, Professor Patrick Miller, Faculty Advisor; School of Architecture +Design Research, Virginia Polytechnic Institute and State University

I. Purpose of this Research/Project

Educators are increasingly required to assist learners not simply with subject content, but with developing metacognitive skills for independent learning, interdisciplinary learning and lifelong learning. Recent years have seen increasing interest in the role of metacognition in ill-defined problem solving. However, there is a dearth of research on the nature of metacognitive processing in architecture field, and how metacognitive strategies are applied and developed when students are in the first years of their study. Therefore, this study concerns itself with furthering understanding of metacognition, cognition and problem solving procedure in architectural fields within the first year of study in foundation studio program. The findings will add new knowledge to the fields of metacognition and self-regulated learning by identifying the conscious processing occurring during foundation studio program.

II. Procedures

You are being asked to conduct a personal interview with Shabnam Kavousi—a doctoral student in Virginia Tech's PhD program: Architecture + Design Research. This study will consist of doing a task (to look back to what they have done from the beginning of the semester and to develop an exercise similar to one of the exercises that they did for the class) for those who are currently a first year student in foundations in school of Architecture + Design. The process of accomplishing the task is video recorded through GoPro camera. You are also being asked to describe your cognitive and metacognition process about tasks during a one-on-one interview. Your participation in the above-mentioned interview will involve retrospective probe the subject for information after the completion of the task-induced processes. For example, participants asked to report just after the process has been completed. Your participation is voluntary and will take approximately 3 hours for doing the task and 1 hour for the interview before and after the task. This interview will take place in studio or at another mutually agreed upon place. The interview will be audio recorded, and video taped and will be accessible only by the researcher and her faculty advisor. The transcript interview will be kept in a secured location.

III. Risks

The risks associated with participating in this study are considered to be minimal.

IV. Benefits

No promise or guarantee of benefits has been made to encourage you to participate, but we are grateful for your consideration. The data collected from you during this study will be used for publishing and participating in conference. The principal investigator will be happy to provide you with a copy of paper as an appreciation.

V. Extent of Anonymity and Confidentiality

Your identity, and that of any individuals who you mention, will be kept confidential at all times and will be known only to the principal investigator. The above-mentioned interview will be audio recorded and later transcribed by the principal investigator. When the audio recording is transcribed, pseudonyms (i.e., false names) will be used for your name and for the names of any other individuals who you mention. Any details in the audio recording that could potentially identify you or anyone who you mention will also be altered during the transcription process. After the transcribing is complete, the audio recording will be stored securely by the principal investigator. Moreover, the video recorded from your participation in doing the task is just used to analyze your metacognitive process of thinking. This audio recording, all paper and electronic copies of the interview transcript, the recorded video, and this consent form will be erased or shredded promptly after the above-mentioned course has been completed.

It is possible that the Institutional Review Board (IRB) at Virginia Tech will view this study's collected data for auditing purposes. The IRB is responsible for overseeing the protection of human subjects who are involved in research.

VI. Compensation

You will not receive any form of compensation for participating in this study.

VII. Freedom to Withdraw

Your participation in this study is entirely voluntary, and your refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. Similarly, you are free to withdraw from this study at any time without penalty or loss of benefits to which you are otherwise entitled. If you choose to withdraw from the study, any information about you and any data that you have provided will be destroyed. You are also free to choose to not answer any question, or to not complete any activity, and this choice will result in no penalty or loss of benefits to which you are otherwise entitled.

VIII. Optional:

By initialing my name, I consent to have my interview audio / video recorded ____________

IX. Participant's Responsibilities

I voluntarily agree to participate in this study. I have the following responsibilities: to participate in a one-on-one interview of no more than one hour, as described in Section II above.

X. Participant's Permission

I have read and understand the *Informed Consent* and the conditions of this study. I have also had all of my questions answered. I hereby acknowledge the above and give my voluntary consent:

Signature of Participant

Date (D/M/Y)

Should I have any questions about this study or its conduct, or participants' rights, I may contact:

Faculty Advisor:
Dr. Patrick Miller
Virginia Tech Professor
pmiller@vt.edu

Investigator:
Shabnam Kavousi
Doctorate candidate
Shabnamk@vt.edu

If I should have any questions about the protection of human research participants regarding this study, you may contact Dr. David Moore, Chair, Virginia Tech Institutional Review Board for the Protection of Human Subjects, telephone: (540) 231-4991; email: moored@vt.edu; address: Research Compliance Office, 1880 Pratt Drive, Suite 2006 (0497), Blacksburg, VA 24061, USA.

Appendix E: Photo Release

Virginia Polytechnic Institute and State University
Photograph Release Form

Title of study: The Process of Thinking and Making in Beginning Design Students
Investigator (s): Shabnam Kavousi, Dr. Patrick Miller

Photograph Release to be signed by participant
Authorization for the use of photograph

I give Shabnam Kavousi the right to use any photos of myself or anything related to my project during my participation in this study in her publications and presentations. I wave the right of inspection and approval of the final photos or any printed materials that can be used in conjunction with it now or in the future, whether that use is known or not by myself, and waive the right to royalties or compensation that may use result the use of the photo.

Name   Date (D/M/Y)

Signature

Appendix F: List of Questions Formulated by the Students for the First learning-task

Students Pseudonyms	Question
Nicky	What happens when the vertical and the horizontal parts interact – an exploration of what happens when they collide?
Pandora	How joints and connecter points provide mobility?
Andres	Making an exploration of a given material.
Hana	How do many become one?
Edward	How repetition can be used to make a design
Marie	How to create a project using motion and shifting?
Ju Ju	How do elements connect to make form?
Tanya	How does arranging planes create dimension in an internal space?
Ava	How is motion formed through different elements with a focus on repetition, movement, material?
Linda	How can different parts be unified in a way that also compliments differences?
Kara	How can one thing do two things?
Catherine	How do you use planes and intersections to define a space?
Bill	How does this form [his wood model] translate into a different material so it becomes stronger as a result.
Steve	How do parts contribute to the whole?
Taylor	How do diagonal objects make movement?
Noah	How can different spaces be created without a physical wall?
Autumn	How do straight lines make a curve?
Max	How to make the joints of a cube smooth and correct?
Daisy	How do different materials bring different characteristic/properties in different projects?
Layla	How can straight sections and curves be created using negative space
William	What forms a pattern?

Appendix G: Questionnaire

❖ Please identify if the following issues are associated with changing your perception about your abilities or strategies in developing this project. Yes/ No (circle one)

Relative to this project did you find yourself:	Relative to your perception about your abilities		Relative to your strategies	
Having an incorrect impression of task difficulty	Yes	No	Yes	No
Thinking you needed to have more knowledge before taking a design action	Yes	No	Yes	No
Requiring more knowledge and skill	Yes	No	Yes	No
Developing/Formulating ideas	Yes	No	Yes	No
Fear of failing or not being able to satisfy self-expectations	Yes	No	Yes	No
Not fully understanding the project directives/objectives at the beginning	Yes	No	Yes	No
Lacking the ability to focus on the project	Yes	No	Yes	No
Being inventive	Yes	No	Yes	No
Underestimating his/her ability	Yes	No	Yes	No
Having over-confidence at the beginning of the project	Yes	No	Yes	No
Having ability to complete the task	Yes	No	Yes	No
Employing inaccurate design/planning strategies	Yes	No	Yes	No
Successfully adopting new Strategies	Yes	No	Yes	No
Benefiting from peers' advice/work	Yes	No	Yes	No
Utilizing a new means of exploration	Yes	No	Yes	No
Being challenged during the design process	Yes	No	Yes	No
Using newly acquired knowledge in design task	Yes	No	Yes	No
Having produced an unsuccessful design	Yes	No	Yes	No
Using multiple approaches	Yes	No	Yes	No
Searching for alternative solution	Yes	No	Yes	No
Enhancing/developing the design approach	Yes	No	Yes	No
Searching for a simpler design strategy	Yes	No	Yes	No
Strategizing in response to changing conditions the project posed	Yes	No	Yes	No
Experiencing unanticipated problems	Yes	No	Yes	No
Focusing on smaller details of the project	Yes	No	Yes	No
Significantly changing the initial design	Yes	No	Yes	No
Strongly relying on one solution to focus the project	Yes	No	Yes	No
Finding new materials and using them effectively	Yes	No	Yes	No
Discovering a new interpretation of the stated project directives/ objectives	Yes	No	Yes	No
Overcoming limited time	Yes	No	Yes	No

Appendix H: Categories and Definitions

Table 31.Main categories of Metacognitive processing

Category	Definition
Reflective Process Knowledge	Learner's knowledge regarding how to learn, which could influence the process of learning
Reflective Process Monitoring	Judgments made by learners regarding the status of learning (how learning is progressing, how learning should progress)
Reflective Process Control	Decision-made or actions taken by learners that influence the progress of the learning-task

Table 32. Reflective Process Knowledge

Category	Definition
Reflective Process Knowledge	Learner's knowledge regarding how to learn, which could influence the process of learning
Cognitive Strategies Knowledge	Thinking about cognition and cognitive strategies
Declarative Knowing	The knowledge about one's general processing abilities is called declarative knowledge
Procedural Knowing	where procedural knowledge refers to the knowledge about how to successfully solve problems
Conditional Knowledge	Conditional knowledge is defined as knowledge about when to employ specific strategies
Self-Awareness	Thinking about how learners as individuals learn
Task-Awareness	Thinking about the learning-task and how to proceed based on their existing understanding

Table 33. Reflective Process Monitoring

Category	Definition
Reflective Process Monitoring	Learner's judgment regarding the status of learning (how learning is progressing, how learning should progress)
Personal feeling Monitoring	Learner's thinking about his/her influential emotional state during the design progress
Self-reliance	Learner's judgment (positive or negative) of his/her confidence to do the design task
Personal Feeling of the Task	Learner's judgment (positive, negative, and neutral) of the design task difficulty
Personal Feeling of performance	Learner's judgment of his or her performance in the design task
Situational Actions Monitoring	Learner's thinking about Decision-made or actions taken in the progress of design task
Idea Generation Monitoring	Learner's judgment of sources for design idea generation, either in form of resourcefulness or hindrance.
Idea Development Monitoring	Learner's judgment of design idea development process in terms of time, strategy, process, and outcome

Table 34. Reflective Process Control

Category	Definition
Reflective Process Control	Decision-made or actions taken by learners that influence the progress of the design task
Control of Environment	Thinking about what actions to take to control (change/maintain) the physical environment before the start of, or during the design process
Preparing material	Thinking about what actions to take to ensure that all the design materials are ready for use
Preparing Physical Environment	Thinking about what actions to take to prepare the physical environment that the design will take place
Control of Personal Feelings	Thinking about what actions to take to change, or maintain emotional state
Control of Situational Actions	Thinking about what actions to take to complete/finish the design task
Control of Idea Generation	Thinking about what actions to take to generate a suitable idea for the design task for better inspiration
Control of Idea Development	Thinking about what actions to take to develop the selected idea for the design task

Table 35. Physical Processing

Category	Definition
Physical Processing	Learner's physical feelings and how the physical environment is impacting the learning process.
Physical Discomfort	Learner's physical discomfort due to environmental factors such as sickness, headaches, and so on
Tiredness	Learner's physical tiredness due to lack of sleep or frustration about the progress of the task

Table 36. Affective Processing

Category	Definition
Affective Processing	Learner's moods, emotions, motivations in relation to the learning-task, which could be positive, negative, or neutral.