Applying Curricular Alignment to Improve the Effectiveness of Computer Science Education

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ABSTRACT

According to Fossati and Guzdail, many CS instructors rely on their intuition, feedback from students and anecdotal advice from other instructors to make course improvements. Guzdail noted that: “Computing educators' practice would dramatically improve if we drew on evidence, rather than intuition”. This means that Computer Science instructors may benefit from processes and tools that help them make informed changes to their curriculum.

An evidence-based approach to course improvement is *curriculum alignment*, which evaluates the degree which the learning objectives, course content, and assessment methods are in agreement with each other. This provides instructors with a detailed view of their course and areas that need improvement. Current alignment processes are impractical for a course instructor to apply, requiring a panel of experts and training on the process.

In this research, I developed a computer-assisted alignment process (CAAP) that uses the concept of traceability from software engineering, to define a process that is applicable by a single course instructor limiting the need for a panel of experts. In an initial application CAAP took 75 hours to apply, consequently a prototype alignment tool (AlignET) was designed to automates the new alignment process providing instructors with results they can use to make course improvements.

I evaluated the practicality of AlignET by conducting collective case studies with four participants. Observations and interviews were used to collect data. AlignET reduced the time to complete CAAP to less than 11 hours and the participants identified course improvements, gaps in their instructional methods, and learning objectives they emphasized more than others. The findings from the case study presented key improvements to AlignET.
Applying Curricular Alignment to Improve the Effectiveness of CS Education

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GENERAL AUDIENCE ABSTRACT

So far Computer Science (CS) research has shown that many CS educators do not use an evidence-based approach to make changes to their course. They rely on their intuition, student feedback and anecdotal evidence to make course improvements. Using these approaches makes it difficult to identify the effectiveness of the course improvements. In instructional design, *curriculum alignment* is used to evaluate the degree with which the learning objectives, course content, and assessment methods are in agreement with each other. This provides instructors with a detailed analysis of their course and areas that need improvement. Researchers have shown a strong relationship between good course alignment and student achievement and progression in a course.

Current alignment processes are impractical for an instructor to apply, requiring a panel of content experts and training on the process. I developed a computer-assisted alignment process (CAAP) that uses the concept of traceability from software engineering, to define a process that is applicable by a single course instructor limiting the need for a panel of experts. I developed a prototype alignment tool, AlignET, that limits the need for experts and training. In an initial application CAAP took 75 hours to apply, consequently a prototype alignment tool (AlignET) was developed to automate the new alignment process providing instructors with results they can use to make course improvements.

I evaluated the practicality of AlignET by conducting collective case studies with four participants. AlignET reduced the time to complete CAAP to less than 11 hours and the participants identified course improvements, gaps in their instructional methods, and learning objectives they emphasized more than others. The findings from the case study highlighted the potential benefits of using AlignET when designing a course, particularly for CS educators with no instructional design training or experience in teaching.
Dedication

I dedicate this dissertation to the memory of my father, Sami Barakat, who always loved and believed in me. You are gone but your belief in me has made this journey possible.
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# Table of Contents

**Chapter 1: Introduction**

1.1 Purpose and Research Questions .................................. 3  
1.2 Research Design and Methodology ................................ 4  
1.3 Significance of the Work ......................................... 5  
1.4 Delimitations of the Work ....................................... 6  
1.5 Organization of the Document ................................... 7  

**Chapter 2: Literature Review** ......................................... 8  

2.1 Instructional Design and Software Engineering ..................... 8  
   2.1.1 Software Engineering Principles Applied to Instructional Design ... 9  
   2.1.2 Computer-Aided Instructional Design Tools .................. 12  
2.2 Alignment .................................................................. 15  
   2.2.1 Types of Alignment ........................................... 17  
   2.2.2 Approaches for Evaluating Alignment ....................... 18  
   2.2.3 Alignment Models ........................................... 19  
2.3 Conclusions ........................................................... 24  

**Chapter 3: Computer Aided Alignment Process** ................. 26  

3.1 Design of Computer Aided Alignment Process (CAAP) .......... 26  
3.2 Computer Aided Alignment Process ................................ 29  
   3.2.1 Defining the Learning Objectives ........................... 29  
   3.2.2 Building the Content Matrix ................................ 32  
   3.2.3 Building Assessment Matrix ................................ 35  
   3.2.4 Evaluating the Degree of Alignment ....................... 37  
3.3 Initial Application ................................................... 40  
   3.3.1 CS1 Course .................................................... 41  
   3.3.2 Step 1: Defining CS1 Learning Outcomes .................. 43  
   3.3.3 Step 2: Building the Content Matrix ....................... 45  
   3.3.4 Step 3: Building the Assessment Matrix ................. 55  
   3.3.5 Step 4: Evaluating Alignment .............................. 58  
   3.3.5.1 *Structure of Knowledge* ................................. 58  
   3.3.5.2 *Depth and Range of Knowledge* ...................... 58  
   3.3.5.3 *Balance of Representation* ............................... 60
Chapter 4: The Prototype Alignment Tool (AlignET) ............................................. 67
  4.1 Design of AlignET ..................................................................................... 67
  4.2 About the Course .................................................................................... 68
  4.3 Guiding the Instructor through the Alignment Process ............................ 70
      STEP 1: Defining the Learning Objectives ................................................. 70
      STEP 2: Building the Content Matrix ....................................................... 73
      STEP 3: Building the Assessment Matrix ................................................ 74
      STEP 4: Evaluation of Alignment ............................................................. 75
  4.4 Conclusions ............................................................................................ 76

Chapter 5: Evaluation Methodology ................................................................. 77
  5.1 Sample Selection ..................................................................................... 79
  5.2 Case Study Protocol .............................................................................. 80
      5.2.1 Observations ................................................................................... 80
      5.2.2 Interviews ...................................................................................... 81
  5.3 Data Collection ....................................................................................... 82
  5.4 Data Analysis .......................................................................................... 83
  5.5 Trustworthiness ...................................................................................... 84
  5.6 Positionality ........................................................................................... 85
  5.7 Conclusion .............................................................................................. 86

Chapter 6: AlignET Findings ............................................................................ 87
  6.1 About the participants ............................................................................ 87
      6.1.1 CS Instructor 1 ................................................................................. 87
      6.1.2 CS Instructor 2 ................................................................................ 88
      6.1.3 ED Instructor 1 ............................................................................... 90
      6.1.4 ED Instructor 2 ............................................................................... 91
  6.2 Time Required to Evaluate Alignment using AlignET ............................... 92
  6.3 Summary of Results from AlignET Reports ............................................. 95
      6.3.1 CS Instructor 1 ................................................................................. 96
      6.3.2 CS Instructor 2 ................................................................................ 98
      6.3.3 ED Instructor 1 ............................................................................... 99
      6.3.4 ED Instructor 2 ............................................................................... 100
6.4 Conclusions ................................................................................................................. 101

Chapter 7: Evaluation Findings ................................................................................ ..103

7.1 AlignET’s Useful Results - Making Informed Changes to the Course .... 103
  7.1.1 Identifying changes to the course ................................................................. 103
  7.1.2 Balance of representation as a metric for alignment ................................ 107
  7.1.3 Autonomy over the design of the course ..................................................... 110

7.2 AlignET and CAAP’s Difficulty of Use ................................................................. 111
  7.2.1 Difficulty when formulating Learning Objectives ....................................... 111
  7.2.2 Impact of instructional design knowledge .................................................. 114
  7.2.3 Improvements to the tool ............................................................................. 116

7.3 AlignET’s Time Investment – The Instructors’ Perceived Effort .............. 117
  7.3.1 Time consuming but not challenging ............................................................ 118
  7.3.2 Reusing the tool again .................................................................................. 119
  7.3.3 Seeing the “Big Picture” .............................................................................. 121

7.4 Conclusions ............................................................................................................ 121

Chapter 8: Conclusions ..................................................................................................123

8.1 Revisiting Research Questions ............................................................................. 123
  8.1.1 Research Question 1: Does the alignment process produce results that
        support instructors in making informed changes to their course? ........... 124
  8.1.2 Research Question 2: How difficult or cumbersome is the alignment
        process and tool for instructors to use? ..................................................... 127
  8.1.3 Research Question 3: To what extent do instructors find the time invested
        to evaluate their course alignment to be practical? ............................... 128
  8.1.4 Research Question 4: What role does instructional design knowledge play
        in the instructor’s ability to apply the alignment process and tool? ......... 130

8.2 Limitations ............................................................................................................. 132

8.3 Implications ........................................................................................................... 133

8.4 Future Work .......................................................................................................... 135

References ......................................................................................................................138

Appendices .....................................................................................................................144

Appendix A: Alignment Instruction Manual ......................................................... 144
Appendix B: Help Features in AlignET ................................................................. 150
Appendix C: Template Alignment Report .............................................................. 155
Appendix D: Alignment Reports ............................................................................. 159
<table>
<thead>
<tr>
<th>Appendix</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appendix E</td>
<td>Email to Gatekeeper</td>
<td>171</td>
</tr>
<tr>
<td>Appendix F</td>
<td>Email to Potential Participants</td>
<td>172</td>
</tr>
<tr>
<td>Appendix G</td>
<td>Protocol for Screen Meeting</td>
<td>173</td>
</tr>
<tr>
<td>Appendix H</td>
<td>Informed Consent Form</td>
<td>175</td>
</tr>
<tr>
<td>Appendix I</td>
<td>Interview Protocol</td>
<td>179</td>
</tr>
<tr>
<td>Appendix J</td>
<td>Observation Form</td>
<td>182</td>
</tr>
<tr>
<td>Appendix K</td>
<td>IRB Approval</td>
<td>183</td>
</tr>
<tr>
<td>Appendix L</td>
<td>Digitized Observation Forms</td>
<td>184</td>
</tr>
<tr>
<td>Appendix M</td>
<td>Digitized Interview Notes</td>
<td>196</td>
</tr>
</tbody>
</table>
List of Figures

Figure 3.1: Bloom's Taxonomy adapted from [79] ................................................................. 31
Figure 4.1: Static Wireframe Mockup Prompt for Course Components ................................. 69
Figure 4.2: Static Wireframe Mockup Prompt for Course Assessments ................................. 69
Figure 4.3: Google Sheet for Course Components and Assessments ..................................... 70
Figure 4.4: Static Wireframe Mockup Step 1 Defining Learning Objectives ............................ 71
Figure 4.5: Google Sheet for Defining the Learning Objective ............................................... 71
Figure 4.6: Static Wireframe Mockup of Level of Cognitive Skill for each Learning Objective 72
Figure 4.7: Google Sheet for Level of Cognitive Skill for each Learning Objective ................. 72
Figure 4.8: Static Wireframe Mockup of Build Content Matrix Screen from the Alignment Tool .............................................................................................................................................. 73
Figure 4.9: Google Sheet for Building Content Matrix ............................................................ 73
Figure 4.10: Static Wireframe Mockup for Building Assessment Matrix from Tool ............... 74
Figure 4.11: Google Sheet for Assessment Matrix ................................................................. 74
Figure 4.12: Static Wireframe Mockup from Tool Displaying the Alignment Report ............ 75
Figure 6.1: Time required to complete each phase of the alignment process by the participants 94
Figure 6.2: Scatterplot of the Number of Course Components and Time required to Fill out Content Matrix for each participant ................................................................. 94
Figure 6.3: Scatterplot of the Number of Questions on Summative Assessment and Time required to Fill out Assessment Matrix for each participant ............................................. 95
Figure 6.4: Percentage of under-represented, over-represented and balanced learning objectives for participants ........................................................................................................ 97
Figure 7.1: ED Instructor 1’s Content Matrix ........................................................................... 107
List of Tables

Table 2.1: Content Matrix from Porter et al. [67] ................................................................. 21
Table 2.2: Webb's alignment criteria and attributes ................................................................. 22
Table 3.1: Portion of a filled Content Matrix for a Programming Course ................................. 33
Table 3.2: Sample Assessment Matrix for a Programming Course ........................................... 35
Table 3.3: Content in CS1 Syllabus Fall 2017 for the learning objectives on the Polymorphism topic .......................................................................................................................... 50
Table 3.4: Content in CS1 Syllabus Fall 2017 for the learning objectives on the Arrays and 2D Arrays topic ........................................................................................................................................ 51
Table 3.5: Content in CS1 Syllabus Fall 2017 for the learning objectives on the Scanners and Equality and Identity topics ........................................................................................................... 54
Table 3.6: Test 1 and Test 2 Assessment Matrix ........................................................................ 56
Table 3.7: Final Exam Assessment Matrix .................................................................................. 57
Table 3.8: Summary of Balance of Representation Results for Learning Objectives ............. 63
Table 6.1: Summary of Participants in the Case Study ............................................................. 89
Table 6.2: Summary of the results of the alignment process for each participant .................... 96
Table 6.3: Percentage of assignments with no learning objectives and percentage of broken links in content matrix .............................................................................................................. 100
Chapter 1: Introduction

Course evaluation allows instructors to assess their curriculum, instructional methods and the impact it has on their student’s learning [1]. The results of the course evaluation inform instructors on what components of their course curriculum and instructional methods need to change to improve the students’ learning. According to Fossati and Guzdial, many CS instructors rely on their intuition, feedback from students and anecdotal advice from other instructors to make course improvements [2]. Guzdial further suggests: “Computing educators' practice would dramatically improve if we drew on evidence, rather than intuition”[3]. Other studies including Barker et al. [4] and Taylor et al. [5] have reported similar findings as Fossati and Guzdial. This means that Computer Science instructors may benefit from processes and tools that help them make informed changes to their curriculum. It is possible that faculty in other disciplines operate the same, and would benefit as much as faculty in CS, but I limit the literature review and domain of study in this work to CS.

Instructional Design is the systematic design of instruction to produce predetermined learning outcomes [6]. *Curriculum alignment* is a process used in instructional design, to evaluate how much a course’s learning objectives, content and assessments are in agreement with each other [7]. Alignment indicates how well the elements in an educational system work together to direct the course instruction and student learning. Alignment is often compared to validity, the degree which an instrument measures what it is supposed to measure, more specifically content validity [8]. Content validity refers to how accurately an assessment tool measures specific domain content [9]. Course alignment looks at the connection between the course objectives, the learning activities and the assessments, including the validity of the assessment tools. Along with the alignment of
the learning objectives and assessments, the learning activities or instructional content provided to students also need to be in alignment [10].

Strong alignment, high degree of agreement between the learning objectives and instructional content, can improve the quality of the educational system [10-13]. For example, if the course content, learning objectives and assessments are strongly aligned with each other, then the assessment tools are likely to be accurate and valid [13]. This means that more reliable inferences may be made about the course from results of the assessment tools and may contribute to accountability [13]. The results from studying the alignment of a course may be used to help educators, assessment developers and policymakers to make decisions about the curriculum, assessment methods and instructional methods [10].

The alignment of assessments and course content with the learning objectives increases the opportunities that students have to learn and practice the knowledge and skills in which they will be tested on [13]. When assessments and objectives are aligned, the students’ performance on the assessments can be translated to how well they have learned the topics covered [10]. When objectives and assessments are misaligned, the students’ focus is not on learning what the instructor believes is important. If a course is well aligned and has a consistent message, then the course materials are considered valid. Instructors are more likely to view the course materials as useful and can benefit their students, increasing the instructors’ interest and investment in the course [8].

Applying alignment models to Computer Science courses can provide instructors with an evidence-based approach to curriculum development. However, current alignment models have
limitations that make them impractical for a single course instructor to apply. Applying alignment models to a course historically is an arduous and time-consuming process involving a panel of experts reviewing documents and making judgements about the course content. The panel of experts need to be trained on the alignment model and how to assess alignment [8]. All these factors make it impractical for a course instructor to evaluate the degree of alignment of their course, thus an instructor would not benefit from the evaluation in their course design.

1.1 Purpose and Research Questions

Motivated by the benefits of applying curriculum alignment to a course and using the results to make informed changes to the curriculum and instruction, I developed an instructional process to address the limitations of current curriculum alignment models. The computer-assisted alignment process (CAAP) would meet the following design goals:

D.G.1. **Evaluate** the **degree of alignment** of the learning objectives, content and assessments for a course.

D.G.2. **Produce results** an instructor can use to make **informed changes** to their course

D.G.3. Be **applied** by a **single course instructor**

D.G.4. **Reduce time** required to evaluate alignment

D.G.5. Require **limited knowledge of instructional design** and **training** on the process.

I created an instructional process that can be used to evaluate the degree of alignment of a course by an instructor only. The process is clear and concise, where the instructor would follow the steps outlined in the process to evaluate the degree of alignment of the course, more specifically the degree of alignment between the course learning objectives, content and assessment methods. Unlike existing alignment models that require extensive training and a panel of experts, CAAP should not be time consuming, should be followed by an instructor with no knowledge of
alignment, and should not require training. CAAP was applied to portions of a CS1 course and the process was found to be time consuming taking 75 hours to complete. To reduce the time required to complete the process, a low-fidelity prototype tool AlignET (Alignment Evaluation Tool) was designed. The tool automates the alignment process, reducing the overall time required to complete the alignment evaluation.

The purpose of this research is to create an alignment process that meets the previous design goals, to design a prototype tool to guide the instructor through the alignment process, and to evaluate the practicality of the alignment process and the tool. The research answers the following questions:

R.Q.1. Does the alignment process produce results that support instructors in making informed changes to their course?

R.Q.2. How difficult or cumbersome is the alignment process and tool for instructors to use?

R.Q.3. To what extent do instructors find the time invested to evaluate their course alignment to be practical?

R.Q.4. What role does instructional design knowledge play in the instructor’s ability to apply the alignment process and tool?

1.2 Research Design and Methodology

To evaluate the practicality of CAAP and AlignET, I chose to conduct a collective case study with four cases. Collective case studies are multiple-case studies that collectively help researchers to understand a population or phenomenon [14]. A collective case study allowed for rich data about the process and the tool to better understand the practicality as well as necessary improvements to the process and tool. I used two data collection methods, observations and interviews, to
understand the instructors’ perceptions of the alignment process and tool. I used four lenses to evaluate the practicality of the alignment process and tool, which were the instructor’s perceptions of *usefulness, ease of use, difficulty* and *time commitment* of the process and tool. Two participants of the case study were Computer Science instructors with no knowledge of instructional design and the other two were instructors from the School of Education with a strong background in instructional design. Data was collected by observing and interviewing the participants. The instructors were observed as they applied the alignment process to their course using the tool, noted the challenges they faced and the time required to complete the process. Multiple interviews were conducted with the instructors to get their perceptions of the alignment process and the tool.

### 1.3 Significance of the Work

It is common in higher education for faculty graduating from non-education majors to have limited instructional design knowledge, Computer Science faculty are no exception. The Computer Assisted Alignment Process (CAAP) can be used by instructors with limited instructional design knowledge to make informed changes to their course. Instructors often inherit courses to teach with the syllabus and course content, having an instructional process to evaluate the alignment of the course can help inform the instructions on what changes they need to make to the course. Furthermore, course instructors may not always be given enough time to develop their courses. An instructional process to evaluate alignment that does not require a lot of time to apply would be a practical solution for course instructors.

More specifically, CAAP addresses key limitations of current alignment models. CAAP evaluates the degree of alignment of the learning objectives, content and assessments for a course producing results an instructor can use to make informed changes to their course. Furthermore, the content
matrix in the alignment process provides a visual representation of the course which instructors have used to gain a deeper understanding of the course content distribution. In contrast to other alignment models, CAAP reduces the need for a panel of experts and training on the alignment process, making the process applicable by a single course instructor. Currently, there are no tools available to evaluate alignment. AlignET presents a low fidelity prototype tool to reduce the time required to evaluate curriculum alignment and help limit the knowledge of instructional design or training on the alignment process.

To comply with the ABET criteria for student outcomes, all of the courses in a program should align with the overall program objectives/ABET student outcomes. Ideally each course’s learning objectives, content and assessment methods should be addressing the overall program objectives. An assessment coordinator would benefit from a process that would allow them to evaluate alignment of the overall program objectives/ABET student outcomes and the course content.

1.4 Delimitations of the Work

This research work had several initial delimitations. First, this research work aims to define an instructional process that can evaluate the degree of alignment of a course as part of the course’s evaluation. There are multiple steps to develop a course [15] and there are methods for evaluating the alignment of the course throughout these steps [16]. In this research, I am concerned with the assessment of the alignment of the course after it has been developed, during the stage of course evaluation.

The second delimitation is the definition of alignment. In the context of education, alignment has many definitions [7, 8, 11, 17]. For this research, I am concerned with curriculum alignment
defined as the action of bringing the objectives, activities and assessment of a course into agreement [7]. I am interested in evaluating a course’s alignment and producing results an instructor can use to make course improvements. The third delimitation is the goal of the research, to develop a process for instructors to use to identify course improvements. As a result, I am interested in evaluating the instructor’s perceptions of the process. This research will not address with the impact the instructional process has on students’ learning.

The final delimitation is the scope of the case study. The case study is designed to observe instructors evaluate the degree of alignment of their course using the CAAP and AlignET. The goal is for instructors to use the results of the alignment to identify changes to make to their courses. This research is focused on the first pass by instructors to evaluate their course, it does address later attempts to reassess the changes that were made to the course.

1.5 Organization of the Document

This document is organized into eight chapters. Chapter one introduced the topic, the purpose and research questions, and the significance of the study. Chapter two reviews relevant work in the literature. Chapter three describes the alignment process and the initial application. Chapter four describes the development of the prototype alignment tool. Chapter five describes the evaluation methodology used detailing the sampling, data collection, and data analysis procedures. Chapter six summarizes the participants of the case study and the alignment results from AlignET, Chapter seven highlights the findings and emerging themes from the case study, and Chapter eight discusses the conclusions and the implications of the work.
Chapter 2: Literature Review

In this chapter, multiple works that are relevant to my research are reviewed. The relevant work is divided into two sections: instructional design and software engineering, and alignment. In the first section, the similarities between the two disciplines of instructional design and software engineering are described detailing how software engineering principles have been used to improve instructional design methods. In the second section, the concept of alignment is introduced, how it has been applied and commonly used alignment models are briefly discussed. This chapter concludes with a discussion of the conceptual framework for my research: Webb’s Alignment Model.

2.1 Instructional Design and Software Engineering

Instructional design is the systematic design, development and assessment of learning content to produce desired learning outcomes [18]. The field of instructional design draws from different disciplines such as educational psychology and cognitive science [6]. Instructional designers use a variety of instructional design models to create courses and curriculum. Software engineering is a field that has many similarities with instructional design [19]. Similar to instructional design, software engineers use a systematic approach to the design and development of software [20]. They use models to design, develop, test, and deploy a system that meets the user’s requirements. Both fields have similar strategies and practices for developing their systems [21]. For example, assessment evaluation in instructional design and unit testing in software engineering are practices to ensure the validity of the system. Curriculum alignment in instructional design is similar to quality management in software engineering, where the learning objectives (software requirements) and course components (software artifacts) are in agreement with each other.
The practice of software engineering is dynamic, with new tools and processes being introduced to improve quality of software [22]. Many instructional design researchers [6, 18, 20, 23] believe that the software design methods can benefit the field of instructional design. System design models, task analysis tools and software development principles can all be used to improve instructional design. In the following section we summarize how software engineering principles have been applied to instructional design.

2.1.1 Software Engineering Principles Applied to Instructional design

Instructional designers have borrowed design principles from software engineering models and applied them to instructional design to improve an instructional design process [6]. Software designers describe the design of software using diagrams that can help visualize the design of software. An early tool used by software engineers to define procedures were flowcharts, similarly, instructional designers use flowcharts to define instructional procedures [24]. As software engineers moved to modular software development, other tools were created to define procedures. Structure charts describe the organization of various program modules and have been used by instructional designers to visualize the relationship between instructional tasks [20]. Similarly, state diagrams describe the transitions between objects and have been used by instructional designers to plan instructional methods that describe complex systems [20, 23]. When designing a course, instructional designers consider how to present information to learners and how the information relates. This is key to organize instruction so that the learners can retrieve the knowledge appropriately reducing the development of misconceptions [20]. Jones et al. use semantic networks and frames as a visual way to represent the organization and relationship of knowledge [25]. The instructional design process can be complex and expensive. Some
instructional designers are using tools such as the Unified Modelling Language to create and analyze learning designs [6, 26]. The goal for using these types of tools is to increase efficiency within the instructional design process with the hopes to reduce cost. The Education Modelling Language (EML) was developed to help instructional designers model learning units independent of the pedagogical approach used [27].

Along with software design tools, instructional designers have borrowed software engineering methodologies used to develop software [18]. A prominent instructional design model, ADDIE, can be traced back to the 1970s [28]. The model uses five phases to develop a course: analysis, design, development, implementation and evaluation. A course instructor would have to complete each phase of the ADDIE model before moving onto the next phase. This is very similar to the waterfall software development lifecycle. The waterfall software development lifecycle presents a six-phase model that uses a sequential approach to develop software. Software engineers must complete each phase (requirements analysis, design, development, implementation, verification, and maintenance) before moving onto the next [29]. Both the Waterfall and ADDIE are linear models and work best if there is a set of clear requirements or learning objectives. A disadvantage for both models is that they do not allow for iterative design, any changes that happen to earlier stages can impact the cost and effort spent on the process. This makes both models difficult to implement.

The concept of rapid prototyping, using an iterative approach to develop prototypes that evolve into the final product, has been used in instructional design as a quick way to develop course materials [30]. Professors in higher education were asked to use rapid prototyping to develop
The findings of the study concluded that rapid prototyping was useful in quickly developing curriculum. Other studies support these findings [30, 32, 33], indicating that the instructional products produced by rapid prototyping are re-usable and of high quality.

Agile methodologies have also been applied to instructional design but have not been widely used [6]. They are more often used in information technology or software engineering education [34]. A study by Scott et al. had found that multiple universities included agile methodologies, more specifically Scrum, in software engineering courses to adapt to industry requirements [35]. Applications of agile methodologies in classroom projects have helped students build better team working and collaborative skills [36]. Agile methods have positive impacts on group work improving skills such as time management, organization, information sharing, and peer evaluations [37].

Instructional designers have also applied object-oriented programming principles to instructional design [6]. The concept of abstraction, in object-oriented design, where essential attributes that are relevant to the problem is shown and irrelevant information is hidden [38]. In instructional design abstraction is used when designing teaching strategies for a topic, instructional designers focus on the relevant ideas for learning a topic and maintain some of the abstract information as supplemental information [39]. Students are introduced to concrete examples of models and phenomenon as an introduction to abstract concepts [40]. Applications of abstraction in instruction design have been prominent in the fields of mathematics [40, 41].
Other object oriented principles such as modularity, cohesion and coupling, have been applied to the design of e-learning courses [42]. E-learning courses are developed differently than in-person courses, the course is partitioned into modules by creating chunks of small learning units for a course [6]. Modules are dynamic and would change depending on the audience for the course. Ideally the coupling of the modules is designed to be as low as possible and the cohesion should be high to simplify the learning process [6].

Reusability is another software engineering principle implemented by instructional designers. Instructional designers are using reusable learning objects in the design of instructional systems [43]. Instructional designers have used design patterns when developing Massive Open Online Courses (MOOCs) which are similar to design patterns used in software design [44]. Researchers developed a set of 21 design patterns to address MOOC design challenges [45], that can be adopted by any instructional designer to their existing solutions.

In the design of the computer assisted alignment process (CAAP), I continued to use software engineering principles to inform the design of instructional design. I used traceability and trace matrices to inform an alignment model, making it applicable by a single course instructor. The details about the design of the process and the application of the traceability can be found in Chapter 3, section 3.2 of this document.

2.1.2 Computer-Aided Instructional Design Tools

The term instructional design tool is broad and includes computer based tools, learning theories, instructional methodologies, techniques, and approaches [46]. A variety of instructional design tools have been developed to assist instructional designers [47]. Instructional design tools can
enhance instructional design and the quality of instructional design products [48]. Competence in the knowledge and use of instructional design tools are important skills needed by instructional designers in the job market [49-51]. Consequently, computer-based instructional design tools are of interest to instructional designers.

The oldest computer-based instructional design tool was Computer Assisted Instruction (CAI), used to teach deaf students how to use a ruler [52]. Since then, computer-based instructional design tools have evolved to assist instructional designers in various contexts [46]. A software package Digital Planning Boards (DPB) was developed to assist instructors with implementing learning activities, tracking the progress of the learner, and serving as a tool for managing an academic record [53]. In a pilot study of DPB, the researchers reported that the customization and individualization of DPB by an instructor had a positive impact on the instruction [53]. Current learning management systems (LMS) share many design elements from DPB [46]. Other tools were developed to assist instructional designers in collaborations, improving the team collaborative work and allowing for the reuse of instructional materials. DocuShare is a tool that facilitates the communication and collaboration amongst instructional designers [54].

Some computer-based instructional design tools assist instructional designers in the development of instructional or training content. Computer Assisted Curriculum Analysis, Design and Evaluation (CASCADE) is a software package to assist instructional designers in the development, implementation, and evaluation of lesson plans [55]. CASCADE improved the quality of instructional materials and saved instructors time [56]. Advance Design Approach for Personalized
Training-Interactive Tools (ADAPT IT) supported the design, analysis and evaluation of instructional design tasks, improving the quality of training programs [57].

Expert systems for instructional design assist inexperienced instructional designers by providing domain-specific decision-making and analysis functions [58]. ID Expert [59], Guided Approach to Instructional Design Advising (GAIDA) [60], and Experimental Advanced Instructional Design Advisor (XAIDA) [61] are examples of prototype expert systems. Instructional design expert systems have not been widely adopted [58], current expert systems cannot support analysis and design tasks [62] and rely on the knowledge and experience of the individual practitioner [63].

Other computer-based instructional design tools guide instructional designers through a course development model assisting them in the development of their course. Designer’s Edge guides an instructor through the phases of the instructional system design model, supporting and guiding in experienced instructional designers through the design and development stages [64]. Similarly, Designer’s Edge 3.0 provides support for inexperienced instructional designers by guiding them through the ADDIE model [65]. Both versions of Designer’s Edge provide a graphical and step-by-step view of the instructional design model used, cross-referencing the data entered at each step to ensure continuity, and producing course documents (lesson plans, course outlines, and evaluation instruments).

I have not found any tools to evaluate the alignment of a course. Developing a tool to assist in the evaluation of curriculum alignment would be beneficial to the instructional design community. I discuss a low-fidelity design for a prototype tool (AlignET) in Chapter 4 of this document.
2.2 Alignment

Alignment theories date back to the 1940s, first studying the impact of the alignment of curricula with learning objectives to more recent studies that look at the alignment of accountability measures outlined in the No Child Left Behind Act with policy, curricula, instructional methods and assessment [66]. Alignment approaches are domain specific, some theories apply to mathematics and science standardized curricula [8] others have been applied to elementary school mathematics and physics curricula [67]. A variety of alignment research projects have been conducted on K-12 courses [10, 16, 66-68], on different educational systems worldwide [17, 69].

More research can be conducted on alignment in higher education [13], fields like Mathematics, Physics, Chemistry, Pharmaceuticals and Medicine have explored how alignment can improve the students’ performance in a course [13, 70, 71]. According to Roach et al. [11] it is not clear the degree of alignment necessary to enable learning and improve outcomes for students, suggesting that further exploration is necessary.

In the field of Computer Science education there are limited studies on alignment. In a study by Ramesh et al. [72], the researchers looked at the assessment instruments of various courses at Mumbai University for the past 5 years. They found that average alignment is poor, where the content was biased towards lower order skills and the content coverage was not well distributed. I have found no other contribution to alignment work in the field of Computer Science.

In the context of education, alignment has many definitions. In 1949, Tyler [7] briefly defined alignment as the action of bringing the objectives, activities and assessment of a course into
agreement. Alignment can also refer to the degree to which curriculum, standards, assessments and instruction are designed at a level of cognitive demand that allows students to meet learning objectives [8]. Alignment has been used to describe the agreement between standards and assessments, as well as standards and instruction methods, and instruction methods and assessments [17]. Standards refers to policy documents, such as learning outcomes for a course.

Strong alignment can improve the quality of the educational system [10-13]. For example, if the course content, learning objectives and assessments have a good degree of alignment with each other, then the assessment tools are likely to be accurate and valid [13]. This means that more reliable inferences may be made about the course from results of the assessment tools and may contribute to accountability [13]. The results from studying the alignment of a course may be used to help educators, assessment developers and policymakers to make decisions about the curriculum, assessment methods and instructional methods [10].

The alignment of assessments and course content with the learning objectives increases the opportunities that students have to learn and practice the knowledge and skills in which they will be tested on [13]. When assessments and objectives are aligned, the students’ performance on the assessments can be translated to how well they have learned the topics covered [10]. When objectives and assessments are misaligned, the students’ focus is not on learning what the instructor believes is important. The focus is shifted to activities that will lead to good grades on assessments. If a course is well aligned and has a consistent message, then the course documents are considered valid. Teachers are more likely to view the course materials as useful and can benefit their students, increasing the teachers’ interest and investment in the course [8].
2.2.1 Types of Alignment

Alignment can be applied to various components of an educational system. Alignment can be applied to a course, *curriculum alignment*. Curriculum alignment has often been compared to content validity, which refers to how accurately an assessment tool measures specific domain content [8]. Validity is the degree which an instrument measures what it is supposed to measure [73]. While validity of assessment tools is an important component of alignment, alignment takes more broader view, analyzing the connection between the course objectives, the learning activities and the assessments [10].

Policy makers can use alignment to evaluate whether educational policies and standards and courses are aligned. *Horizontal alignment* focuses on the alignment on one level of an educational system [74]. It explores the degree to which the elements of an educational system such as the standards, frameworks, and assessments are aligned at the policy level [8]. For example, a 6th grade math class might be taught by multiple teachers in a school. Horizontal alignment would ensure that the instructional methods, assessments and standards for all of the classes align. Horizontal alignment creates consistency across all the courses.

*Vertical alignment* looks at the degree to which the elements in a level of an educational system are aligned to each other [8]. For example, in a school do the math classes across all the grades align? Vertical alignment can help create flow between the grades of a course. Concepts can be built upon in consecutive courses allowing students to reach higher levels of cognitive thinking. Ideally, all components of an educational system should be aligned from classroom instruction and learning outcomes to educational policies and standards [66].
2.2.2 Approaches for Evaluating Alignment

There are three main approaches for assessing course alignment as suggested in literature and current practice: sequential development, expert review, and document analysis [8]. These methodologies are often adapted and used in combination with other approaches to compare a variety of different standards and assessments, from matching content to measure the depth and comprehensiveness [74].

2.2.2.1 Sequential Development

Sequential development is a common and simple method of alignment. In this method the standards and framework are developed in a series of steps, the standards are developed first then course developers use the standards to create the structure and the content of the course and assessment [74]. Sequential development allows course developers to align the course in a logical process, since each step is dependent on the previous step. For example, the course objectives and standards must be developed before creating the course content or assessments. In the next step when the course developers are creating the course content, they will have known criteria for developing the content. During the development process course developers can create checks of alignment, where input by experts or other stakeholders can be provided, creating a record of evidence of alignment or an opportunity to correct any misalignments [12]. Sequential development is time consuming and doesn’t allow for the organic development of courses. For example, developing assessments can allow course developers to think about instructional methods and what students are potentially learning [8].

2.2.2.2 Expert Review

Expert reviews rely on a panel of content specialists to give their opinion about the alignment of the content and assessments [8]. Unlike sequential development where a course is being developed
from scratch, expert reviews involves the evaluation of the alignment of existing content and assessments to the course standards. Training the expert reviewers on the format of the review process as well as the how to judge alignment of items can help decrease the discrepancies among reviews [67].

2.2.2.3 Document Analysis

Document analysis uses an encoding system for the content and structure of a course to analyze standards and assessment. The alignment is evaluated by quantifying and comparing the course documents [8]. Any document related to the course can be evaluated using document analysis, such as textbooks or even accreditation documents. Similar to expert review, the quality of the alignment study is dependent on the reliability of the content specialists [74].

In the computer assisted alignment process (CAAP), I chose document analysis as the approach to extract information about the course alignment is being applied to. Document analysis is an essential approach to allow the instructor to familiarize themselves with their course content and assessments. A detailed explanation of how document analysis is applied in the CAAP can be found in chapter 3, section 3.2 of this document.

2.2.3 Alignment Models

Historically, alignment referred to the one-to-one matching between the learning objectives of a course and the content of the course. After the No Child Left Behind Act (NCLBA), states were required to develop assessments that strongly aligned to established content standards [10], holding schools accountable to the expectations of high student achievement. High achievement was measured through a range of qualities, for example assessments must “measure the depth and breadth of the state academic content standards for a given grade level” [74]. Other qualities such
as the comprehensiveness of the content and clarity for the users were added, resulting in a need for a more complex definition of alignment. Alignment methodologies that included qualitative analysis of alignment as well as the one-to-one matching between the standards and content were developed. In this section we explore the most commonly used alignment models.

2.2.3.1 Surveys of Enacted Curriculum (SEC) Model

Surveys of Enacted Curriculum (SEC) model developed by Porter classifies standards and assessments of a course by content topics and the cognitive demand for each subject area [67]. A content two-dimensional matrix (see Error! Reference source not found.) is created with the categories of cognitive demand on one axis and the course topics on another. Categories of cognitive demand are course specific and they define what it is about a specific topic a student should be able to know or do [67]. Teachers are surveyed on the level of coverage of a topic, how long they spent covering the topic as well, their answers are put on a scale of 0 to 3 where 0 is not covered, 1 is slightly covered (less than 1 class), 2 is moderate coverage (1 – 5 classes) and 3 is sustained coverage (more than 5 classes). The emphasis given to each category of cognitive demand is also put on a scale of 0 – 3 where 0 is not emphasized, 1 is slightly emphasized (less than 25% of class time spent on the topic), 2 is moderate emphasis (between 25% - 33% of class time spent on the topic) and 3 is sustained emphasis (more than 33% of class time spent on the topic).
<table>
<thead>
<tr>
<th>Topic</th>
<th>Memorize</th>
<th>Perform procedures</th>
<th>Communicate understanding</th>
<th>Solve nonroutine problems</th>
<th>Conjecture/generalize/prove</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple-step equations</td>
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</tr>
<tr>
<td>Inequalities</td>
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<td>Linear equations</td>
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<tr>
<td>Lines/slope and intercept</td>
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<tr>
<td>Operations on polynomials</td>
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<tr>
<td>Quadratic equations</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.1: Content Matrix from Porter et al. [67]

A similar matrix is created for assessments, then the cells for the matrices are converted to a weighted value of the total instruction time spent on each topic. The matrices are used to compare the degree of alignment between content and assessment. The matrix can be applied to any component of an educational system [69]. The matrices have also been used to assess alignment between various versions of the same course, for example a 5th grade mathematics course in Virginia and a 5th grade mathematics course in Ohio [74].

2.2.3.2 Achieve Model

The Achieve model was developed at the Learning Research and Development Center at the University of Pittsburgh [11]. The model uses qualitative and quantitative analysis of the alignment of assessments to standards by judging the quality and the rigor of individual test items [74]. The model uses content centrality, performance centrality, challenge, balance, and range as criteria for assessing alignment [12]. Content centrality compares the content of each test item to the corresponding standard. Performance centrality compares the cognitive demand of each item to the difficulty required by the corresponding standard. Challenge examines if the test items are at the level of cognitive demand defined by the standards. Balance and range compare the emphasis of the topics in the assessment tools to the topics in the standards. Similar to Porter’s alignment
model, a panel of experts use a numeric scale to judge the degree of alignment for each of the criteria. This data is then computed to provide an evaluation of the degree of alignment and is further refined by reviewers commenting on the findings.

2.2.3.3 Webb’s Alignment Model

Webb’s alignment model describes a process to match curriculum standards and assessments [8]. Webb identifies five categories for judging alignment; content focus, articulation across grades and ages, equity and fairness, pedagogical implications and system applicability. Webb defines attributes for some of the alignment criteria. The categories and attributes are summarized in Table 2.2. For each of the alignment criterion the evaluator compares the standards and assessments of a course and the level for the degree of alignment. There are 3 levels of degree of alignment; full, acceptable and insufficient.

<table>
<thead>
<tr>
<th>ALIGNMENT CRITERIA</th>
<th>ATTRIBUTES</th>
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</thead>
<tbody>
<tr>
<td>Content Focus</td>
<td>Categorical Concurrence</td>
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<tr>
<td></td>
<td>Depth of Knowledge Consistency</td>
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<tr>
<td></td>
<td>Range of Knowledge Correspondence</td>
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<td></td>
<td>Structure of Knowledge Comparability</td>
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<td></td>
<td>Balance of Representation</td>
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<td></td>
<td>Dispositional Consonance</td>
</tr>
<tr>
<td>Articulation Across Grades and Ages</td>
<td>Cognitive soundness determined by best research and understanding</td>
</tr>
<tr>
<td></td>
<td>Cumulative growth in content knowledge during students’ schooling</td>
</tr>
<tr>
<td>Pedagogical Implications</td>
<td>Engagement of students and effective classroom practices</td>
</tr>
<tr>
<td></td>
<td>Use of Terminology, materials, and tools</td>
</tr>
</tbody>
</table>

Table 2.2: Webb’s alignment criteria and attributes

Content focus looks at the development of student knowledge of subject matter. The five attributes of content focus are categorical concurrence, depth of knowledge consistency, range of knowledge correspondence, structure of knowledge comparability, balance of representation, and dispositional consonance [8]. Categorical concurrence evaluates the consistency between the categories that appear in the assessments and the standards. Structure of knowledge compares what
students are expected to know as defined by the learning objectives, and what is assessed in the assessment tool. Depth of knowledge consistency evaluates the level of complexity of the content defined by the standards to what is measured by the assessment. Range of knowledge correspondence compares “the span of knowledge required by the standards in a subject area to that of the assessments” [74]. Balance of representation evaluates the emphasis given to topics in the standards to the emphasis the same topics are given in the assessments. Dispositional consonance evaluates the students’ attitudes and beliefs about the course, whether an assessment instrument measures the broader vision [8].

Articulation across grades and ages evaluates how students’ knowledge grows over time. Webb identifies two attributes to measure articulation, cognitive soundness determined by best research and understanding and cumulative growth in content knowledge during students’ schooling. Webb applied his model to mathematics education and refers to current research on learning mathematics. Webb suggests that assessments and standards should align with research on how students learn. Cumulative growth in content knowledge during students’ schooling, suggests that standards and assessments must represent the structure of the content knowledge the student needs to develop. A strongly aligned assessment will expose whether the student is expected to have foundational knowledge or matured knowledge of a topic.

Instructional methods and classroom practices influence what students learn. Pedagogical implications take into consideration the instructors’ views by asking them how they interpret the standards and assessments of a class [68]. Webb describes two elements to consider; engagement of students and effective classroom practices and use of terminology, materials, and tools.
Equity and fairness between standards and assessments means that all students are given a fair chance to learn the content as well as equal opportunities for them to demonstrate their level of learning. System applicability requires standards and assessments to be aligned in ways that are understandable, valuable and acceptable to stakeholders in the educational system.

I adapted some of Webb’s content focus attributes to define alignment in the computer assisted alignment process (CAAP). Webb’s alignment model provides a broad definition of alignment and the content focus attributes would provide an in-depth analysis of all the aspects of alignment. In chapter 3, section 3.1 I explain which of the content focus attributes have been applied. In section 3.2 I elaborate how I have adapted the attributed for CAAP.

2.3 Conclusions

In this chapter I introduced relevant literature to my research. Software Engineering principles, methodologies, and tools have been used to enhance instructional design methods. Object-oriented programming, agile methodologies, rapid prototype, and other software engineering methodologies have applied to the development of instructional content in instructional design. Furthermore, the use of computers is prevalent in instructional design, assisting instructors in the design and delivery of content. Since 1977, computer-aided instructional tools have been in use and continue to evolve to meet the need of instructional designers.

Curriculum alignment models have been in use since the 1940s. Alignment models are domain-specific requiring content experts to evaluate the degree of alignment. Many of the alignment models discussed are designed to align complex educational systems taking into consideration
factors like educational policies and requirements for standardized curricula. The models were applied to a variety of K-12 educational systems and to some post-secondary mathematics, physics, nursing, midwifery and pharmaceutical courses. All of the alignment models presented require a panel of content experts.

The similarities between the disciplines of software engineering and instructional design will allow me to borrow other software engineering principles from software quality management such as traceability and trace matrices. These principles can be used to enhance curriculum alignment to eliminate the need of a panel of experts and define an alignment process that is applicable by a course instructor. I have used Webb’s content focus attributes to evaluate alignment in the computer assisted alignment process. In the next chapter I will outline how I have adapted Webb’s content focus attributes and used traceability.
Chapter 3: Computer Aided Alignment Process

In Chapter one, I outlined the design goals for a proposed alignment process that address the limitations of current alignment models. The computer-aided alignment process should meet five design goals. First, it would evaluate the degree of alignment of the learning objectives, content, and assessment methods for a course. Second, the process would produce results an instructor can use to make informed changes to their course. Third, it should be applied by a single course instructor. Fourth, it should reduce the time required to evaluate alignment. Finally, the process should limit need for a background in instructional design and require no training on the process. In this chapter, I introduce the design of the new alignment process, the initial application of the alignment process and the lessons learned that informed changes to the process.

3.1 Design of Computer Aided Alignment Process (CAAP)

Webb’s alignment model [74] served as a conceptual framework for the design of the process. Webb’s alignment model has been widely used, as it is the broadest in definition and many other alignment models are based on it [75]. Webb’s alignment model uses three alignment criteria; content focus, articulation across grades and ages, and pedagogical implications [74]. Using these three alignment criteria to evaluate alignment can provide a holistic view of the course, however would result in a lengthy and time-consuming process. For course evaluation purposes, an instructor will be more concerned with the content of their course, as a result the content focus attributes from Webb’s alignment model would be most appropriate to evaluate the alignment of a course.
Design Goal 1: Evaluate the degree of alignment of the learning objectives, content and assessments for a course.

Webb’s content focus attributes are depth of knowledge consistency, range of knowledge correspondence, structure of knowledge comparability, balance of representation, categorical concurrence, and dispositional consonance [8]. Four of Webb’s content focus attributes were selected to evaluate the degree of alignment of the learning objectives, content and assessments for a course: structure of knowledge, depth of knowledge consistency, range of knowledge, and balance of representation. For structure of knowledge, depth of knowledge, and range of knowledge the degree of alignment is evaluated on a scale of full, acceptable and insufficient. For balance of representation the degree of alignment is evaluated on the scale of over-represented, balanced, and under-represented. Categorical concurrence evaluates the consistency between the categories that appear in the assessments and the standards. This attribute is particularly helpful when evaluating instructional content and standardized assessments [75]. Dispositional consonance evaluates the students’ attitudes and beliefs about the course, and whether an assessment instrument measures the broader vision of the course [8]. Both categorial concurrence and dispositional consonance are out of scope for my research. They help evaluate the alignment of a course to overall program level requirements, however I am concerned with the alignment within a course.

Design Goal 2: Produce results an instructor can use to make informed changes to their course.

The results from the structure of knowledge, depth of knowledge consistency, range of knowledge, and balance of representation of a course should help inform the instructor about their course. The degree of alignment of the structure of knowledge as defined by Webb (full, acceptable,
insufficient)[8] will inform the instructor about the questions on the assessments and how they correspond to the learning objectives. Depth of knowledge consistency will inform the instructor about the level of complexity of the content as defined by the learning objectives to what is measured by the assessment. Range of knowledge correspondence will inform the instructor about the assessments and to what degree does the course content prepare students for the assessments. Finally, balance of representation will inform the instructor of the course’s emphasis on learning objectives compared to others.

*Design Goals 3 and 4: Process should be applied by a single course instructor and reduce time required to evaluate alignment.*

Current curriculum alignment processes require a panel of experts to go through a combination of document analysis and expert review to make decisions on the degree of alignment. The process requires the recruitment of a panel of experts, their training, their review of the documents, and finally their agreement on the degree of alignment of a course. To complete these steps is very time consuming and not practical for a typical course instructor. In order to eliminate the use of a panel of experts, I turned to a similar problem in software engineering, software quality management. Software engineers use traceability to track the lifecycle of a requirement and ensure that it matches the final product’s artifacts [76]. Software engineers use trace matrices to map the software requirements to the final artifacts [77]. Similarly, CAAP will use data structures to store details about a course. These data structures can then be used when evaluating alignment. An adaptation of the Surveys of Enacted Curriculum (SEC) content matrix [67] and trace matrices [77], can be used to record course details and provide a visual representation of the course. In turn these matrices and traceability can be used to evaluate the structure of knowledge, range of
knowledge, depth of knowledge, and balance of representation, eliminating the need for a panel of experts and reducing time.

*Design Goal 5: Require limited knowledge of instructional design and training on the process.*

The use of a panel of experts to evaluate alignment requires identifying content experts with experience in instructional design and training them on how to make the alignment evaluations [75]. CAAP eliminates the need for a panel of experts, reducing the need for training on the alignment process and knowledge of instructional design. In order to scaffold any instructional design knowledge or knowledge of the alignment process, manuals and tutorials were developed to support instructors.

### 3.2 Computer Aided Alignment Process

In order to evaluate the degree of alignment between course content, learning objectives and assessment methods, I designed the CAAP [78]. The process is made up of four iterative phases: defining the learning objectives for the course, building a content matrix, building an assessment matrix and evaluating the alignment using modified Webb’s content attributes [8].

#### 3.2.1 Defining the Learning Objectives

In the “defining the learning objectives” phase, instructors are required to list the course’s learning objectives. For each learning objective, the instructor identifies the level of cognitive skill required for the student to achieve it. The level of cognitive skill is defined by Bloom’s Revised Taxonomy [79]: remembering, understanding, applying, analyzing, evaluating and creating.
Learning objectives are used to describe the skills and abilities that students should master and demonstrate at the end of a course [80]. Learning objectives tell students what they are supposed to be learning in a course and where to direct their attention. Instructors use different types of assessments to reveal whether a student has achieved a learning objective, as well as various instructional strategies to reinforce them [81].

According to Bloom’s Taxonomy (Figure 3.1) [82], there are six levels of learning: remembering, understanding, applying, analyzing, evaluating and creating. Remembering is the foundational cognitive skill and refers to the retention of information like facts or definitions. The understanding level is where students can explain ideas and concepts, while the applying level is where said knowledge learned is used in a new context. The analyzing level consists of breaking the concept into parts and identifying how these parts connect and relate to the overall structure. The evaluating level is where a student can justify decisions and make judgments. Finally, creating is the highest cognitive skill level, where students build on the lower level skills, putting elements together to create a new idea or product. Bloom’s Taxonomy was introduced to encourage instructors to design instructional methods that support students to think in more complex ways. Learning objectives can be mapped to the different levels of Bloom’s Taxonomy depending on the levels of cognition an instructor wants their students to achieve. The taxonomy is hierarchical, to reach a higher or more complex level, mastery of the lower levels is needed first.

Bloom’s Taxonomy was later revised to fit the educational practices of the 21st century [79]. Originally, the six levels of learning were characterized by nouns but were later changed to verbs because verbs denote actions which can better describe cognitive processes. Learning outcomes
can be written using Bloom’s Revised Taxonomy making them more meaningful. Sharing the learning outcomes in a syllabus can be helpful for students by encouraging them to become self-directed learners. Learning outcomes that are phrased using verbs act as prompts for students, encouraging them to assess whether they have met that outcome or not.

Figure 3.1: Bloom's Taxonomy adapted from [79]

Bloom’s Taxonomy can be used to help design a course because an instructor can think of the learning objectives and topics they want their students to master. Each learning objective can be mapped to a level of cognitive demand, which can guide instructors on how to design the course content. Assessments can be developed to match the course’s learning objectives and cognitive level of mastery.

The purpose of this phase is to identify the learning objectives and the level of cognitive skill for each learning objective. This will assist instructors in understanding the rigor required to meet the learning objective. In turn, this can help them assess the rigor of the course content and assessments.
3.2.1.1 Justification

Having a set of learning objectives for a course is important for any alignment process. Learning objectives set the expectations for a course and by asking instructors to list them we can assess the course content. Bloom’s Revised Taxonomy was used to identify the level of cognitive demand for each learning objective because it’s widely used [82], and instructors are likely to have heard of it.

3.2.1.2 Challenges

Assumptions were made that course instructors will be familiar with the concept of learning objectives and the use of Bloom’s taxonomy. Instructors may not have any learning objectives for a course. In anticipation of such an event, I created a collection of materials describing how to create or modify the learning objective for a course. The materials were compiled from [79, 82, 83].

3.2.2 Building the Content Matrix

In this phase the instructors identify the components of their course and the course components required to complete each learning objective. A course component is an instructional or assessment method, where students are exposed to topics and where the learning objectives are being met. This information is filled out in the content matrix, which was adapted from the SEC Content Matrix [67]. Error! Reference source not found. shows a sample content matrix for a programming course. The row headers are the learning objectives for a course and the column headers are the different course components.

The content matrix is built iteratively. In the first iteration, the instructor maps each course component to the corresponding learning objective by listing the question numbers or specific
portions of an assignment that address the learning objective. There may be components that do not fit into the learning objectives, a record of them is made separately. In the next iterations, the course instructor verifies that the course content listed in the matrix matches the correct learning objective. It’s important to go through the course content multiple times to verify that no course component was left out.

The purpose of this phase is to methodically go through all the course content and assessments to evaluate whether the learning objectives have been met. A modified version of the SEC Content Matrix is used to record course components that meet the learning objectives, this is a reference for instructors to refer back to when making decisions about the degree of alignment.

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Labs</th>
<th>Homework</th>
<th>Lectures</th>
<th>Programming Assignments</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>To apply inheritance</td>
<td>Lab 2, 3, 4, 5, 6, 7, 8, 9 Post-lab Quiz 2 (Q1, Q2, Q5)</td>
<td>Reading 1, 2, 10 Reading Quiz 1 (Q9, Q10) Homework 2(Q2) Reading Quiz 2 (Q2) Reading Quiz 4 (Q4, Q8)</td>
<td>Lecture 2 (Polymorphism)</td>
<td>Program 2, 5</td>
<td>Test 2 (Q11, Q12) and Final Exam (Q22, Q27, Q28)</td>
</tr>
<tr>
<td>To implement subclasses that inherit and override superclass methods</td>
<td>Lab 2, 3, 4, 5, 6, 7, 8, 9 Post-lab Quiz 2 (Q2, Q4, Q5/5) Post-lab Quiz 8 (Q1/5) Post-lab Quiz 13(Q1, Q4, Q5/5) Reading 2 Homework 2 (Q6)</td>
<td>Lecture 2 (Polymorphism)</td>
<td>Program 2, 5</td>
<td>Test 1 (Q8), Test 2 (Q11), Final Exam (Q22, Q27, Q28)</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.1 Portion of a filled Content Matrix for a Programming Course

3.2.2.1 Justification

Document review is a necessary step in any alignment process [69]. An instructor needs to go through the various course documents (components) to be able to make conclusions about the
degree of alignment within their course. Having a data structure to store the findings of the document review can benefit an instructor because they do not have to rely on their memory when making decisions about the degree of alignment of the course. Furthermore, another instructor may validate the results of the alignment process by building their own content matrix for the course and comparing both content matrices.

From the literature, the SEC content matrix was used by reviewers to code assessments into a two-dimensional matrix [67], it provided a method to visually represent the similarities and differences in the course content [10]. In traceability, software engineers track the lifecycle of a requirement and ensure that it matches the final product’s artifacts [76]. Software engineers use trace matrices to map the software requirements to the final artifacts [77]. The content matrix was adapted from the SEC Content Matrix and designed to have a high level of granularity (details about the course components). The content matrix and assessment matrix are both similar to trace matrices, where traceability can be applied to both to track which learning objectives map to assessment questions and vice versa.

The content matrix is built iteratively because it allows the instructor to review the course content and assessments multiple times. This will help instructors re-evaluate decisions they made about categorizing certain course components and re-evaluate the relevance of the course components to the learning objectives. Whether it impacts the alignment results or not, an instructor may be more informed about their course which may lead to changes in the curriculum.
3.2.2.2 Challenges

Two of the constraints of the alignment process are effort and time. An iterative design process means that certain components have to be repeated and refined, which may require more time and effort. Though multiple iterations of this phase may be helpful to refine the content matrix, it will be time consuming and taxing on an instructor. Another challenge is identifying the minimum number of iterations needed to produce an accurate content matrix but not require too much time or effort.

3.2.3 Building Assessment Matrix

After completing the content matrix, instructors build an assessment matrix where they map the questions on each summative assessment to an existing course component as defined in the content matrix. Only content with the same level of cognitive skill is listed. Table 3.2 shows a sample assessment matrix for a programming course. The columns of the assessment matrix are the summative assessments for the course, each question on the assessment and the learning objectives that correspond to the question on the assessment, and the content with similar cognitive skills for each question.

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Question</th>
<th>Learning Objectives</th>
<th>Content with Similar Cognitive Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 1</td>
<td>Q1</td>
<td>To apply the concept of polymorphism</td>
<td>Reading 1, 2, Post-lab Quiz 2 (Q5), Reading Quiz 1 (Q9, Q10), Reading Quiz 2 (Q2), Reading Quiz 4 (Q4, Q8), Polymorphism Lecture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>To use the common superclass Object and its methods</td>
<td>Post-lab Quiz 2 (Q1), Homework 2 (Q2, Q6)</td>
</tr>
<tr>
<td></td>
<td>Q8</td>
<td>To implement subclasses that inherit and override superclass methods</td>
<td>Reading 2, Post-lab Quiz 8 (Q2), Polymorphism Lecture</td>
</tr>
</tbody>
</table>

Table 3.2 Sample Assessment Matrix for a Programming Course
Similar to the content matrix, the assessment matrix is built over multiple iterations. In the first iteration, the instructor maps the course components that have similar cognitive demand to the summative assessment question. The content matrix can help identify the course components that address each learning objective. There may be summative assessment questions that do not map to any course components, and these should be highlighted in the content matrix. In the consequent iterations, the course instructor verifies that the course content listed in the assessment matrix is listed under the correct assessment question. It’s important to go through the content matrix again to verify that no course component was left out.

The purpose of this phase is to categorize the assessment questions by the corresponding learning objectives and course content with the same level of cognitive demand. This provides a preliminary view into the alignment of the course. If an assessment method doesn’t match any of the course content, then an instructor may be evaluating students with an inappropriate assessment tool. The results of the assessment will not measure the students’ understanding of the learning objective.

3.2.3.1 Justification

Similar to the content matrix, there are the same benefits from asking the course instructor to go through the various course documents (components) and the same benefits from using an iterative approach for this phase. An assessment matrix allows instructors to view how the assessment methods evaluate the student’s understanding and mastery of the learning objectives and the various course components. This step is a validity test for the assessment methods.

3.2.3.2 Challenges

Similar to building the content matrix, this phase can be repeated multiple times to refine the assessment matrix, but it will impact the time and effort needed to complete it. A major challenge
is identifying the minimum number of iterations needed to produce an accurate assessment matrix but not require too much time or effort.

3.2.4 Evaluating the Degree of Alignment

To evaluate the degree of alignment between learning objectives and content, learning objectives and assessment methods, and assessment methods and content, four of Webb’s content focus attributes were used [84]: depth of knowledge consistency, range of knowledge, balance of representation and structure of knowledge. Each of these attributes is assigned a value on a scale: full, acceptable and insufficient except balance of representation, which is assigned balanced, under-balanced or over-balanced. The purpose of this phase is to help the instructor to understand where there is misalignment in the course and how it is evident in the curriculum.

3.2.4.1 Structure of knowledge

Structure of knowledge compares what students are expected to know as defined by the learning objectives, and what is assessed in the assessment tool. I defined this by checking that every question in the assessment matrix has at least one corresponding learning objective. If the question has no learning objectives it’s given a score of 0, if the question has at least one learning objective, the question is given a score of 1 and if there is more than 1 the question is given a score of 2. The number of 0, 1, and 2 scores are calculated. *Acceptable* alignment means that mode of the scores is 1; *insufficient* alignment is when the mode is 0; and *full* alignment is when the mode is 2.

3.2.4.2 Depth and the Range of Knowledge

*Depth of knowledge consistency* compares the level of complexity of the content as defined by the learning objectives to what is measured by the assessment. *Range of knowledge correspondence* compares “the span of knowledge required by the learning objectives in a subject area to that of
the assessments” [74]. Both are evaluated by applying traceability between the content matrix and assessment matrix.

Traceability allows software engineers to track the lifecycle of a requirement, from the source, to development, to deployment, to any refinements (upward), and backwards (downwards) from the end of the product lifecycle back to deployment, development and the source [23]. Requirements may change anytime in the product life-cycle, traceability allows software engineers to ensure that the final product’s specifications match the requirements for a product [76]. Similar to verifying the alignment of the learning objectives with the instructional methods, software engineers verify the alignment between the software requirements to the final product.

The goal of applying traceability between the content and assessment matrices is to find “broken links” between both matrices. Each entry in the assessment matrix is cross referenced to the content matrix. A broken link is course content that is not in the assessment matrix but on the content matrix. This may mean that the content’s level of cognitive demand does not match that in the assessment matrix. A count of the number of broken links is kept. Full alignment is when all the course content in the assessment matrix is cross-referenced in the content matrix. Acceptable alignment is when few course contents in the content matrix are not matched in the assessment matrix and insufficient alignment is when none of the course content in the assessment matrix is cross-referenced in the content matrix.
3.2.4.3 Balance of Representation

Balance of representation evaluates the emphasis given to topics in the learning objectives and the emphasis on the same topics given in the assessments. The context matrix is re-evaluated to consider the following criteria:

- Are there a variety of instructional methods for the learning objectives? Are there any gaps?
- Compared to the other learning objectives of similar cognitive demand, is there more or less content?

I reused Webb’s definition of balance of representation (variety of instructional methods and content with similar cognitive demand) and defined a method to numerically assign balance of representation a value.

**VARIETY OF INSTRUCTIONAL METHODS**

The content matrix is evaluated to see whether there are a variety of instructional methods for each learning objective. A score of -1 is allocated to the learning objective if there is only 1 type of course component in the content matrix. A score of 1 is allocated if there is content in every type of course component in the content matrix. Anything else is assigned a score of 0.

**CONTENT WITH SIMILAR COGNITIVE DEMAND**

Each learning objective is compared to other learning objectives with similar cognitive skill to assess if there is more or less content in the content matrix. Counting the amount of content available for each learning objective with similar cognitive skill and creating a frequency distribution table, the median is calculated. A score of -1 is assigned if the amount of content available for each learning objective is less than the median, 0 if it is the median and 1 if it is more than the median.
The balance of representation score is calculated for each learning objective by adding the scores for the variety of instructional methods and content with similar cognitive demand. If the score is 0 then the learning objective is balanced, if it is a negative number then it is under-represented and if it is a positive number then it is over-represented.

3.2.4.4 Justification

Using Webb’s content attributes [74] to evaluate alignment provides instructors with a detailed definition of alignment. Webb’s content attributes look at different aspects of alignment of a course and provide a holistic view of the curriculum.

3.2.4.5 Challenges

The values assigned for the degree of alignment of each attribute are usually decided by a panel of experts. The definitions for full, acceptable and insufficient are adapted from Webb’s content attributes [74], these definitions may be too limiting or too broad depending on the instructor and the course. It may be difficult for an instructor to come to a decision on the degree of alignment on their own.

Another challenge is that the values to assess the degree of the alignment (full, acceptable, insufficient or balanced, under-represented or over-represented) can be subjective and open to the instructor’s interpretation. This means that different instructors viewing the exact same content and assessment matrices may come up with different results.

3.3 Initial Application

During the design of CAAP four concerns arose: *time required to apply the CAAP, minimum number of iterations needed to produce an accurate content and assessment matrices, the difficulty
in determining the degree of alignment for each attribute based on the definitions of full, insufficient and acceptable, and the instructor’s perceptions of the results of CAAP. I applied CAAP to part of an introduction to programming in Java course (CS1 course), to address some of the concerns that emerged during the design of CAAP and help inform improvements to the process. Five topics in the CS1 course were selected, allowing for a controlled study which was feasible to complete within the time frame available. In this next section I will discuss the findings from the applied alignment process.

3.3.1 CS1 Course

The CS1 course is object-oriented first [85], based on Joe Bergin’s object-early course [86], where students are introduced to object-oriented principles at the start of the course before they are taught other programming constructs [85]. Students complete a 15-week course where they are exposed to the content through a variety of instructional methods. Every week students complete a module comprising of a combination of in-person instruction, such as the lab and lecture components, and out-of-class work, such as homework and reading assignments. Students’ learning is assessed throughout the course using a combination of formative and summative assessment methods. I selected five topics in the CS1 course to apply the alignment process to: polymorphism, arrays/2D arrays, scanners, and equality and identity.

In Java, polymorphism describes the language’s ability to process objects of various classes and data types through a single interface. There are 2 types of polymorphism: compile time polymorphism and runtime polymorphism. In the CS1 course, polymorphism is one of the first concepts covered as it is a threshold concept [87] where students will continue to apply it throughout the course and in future courses. Class Inheritance describes the process by which a
new class derives properties and methods of another class. Inheritance is a foundational concept for object-oriented programming languages, students need to understand the concept of class inheritance before they can understand polymorphism. Inheritance along with objects and classes are covered in the first few weeks of the course. I included inheritance with polymorphism in the list of topics in the initial application because you need an understanding of one to understand the other. Both concepts are complicated for programming beginners, thus making it a good topic to use in the alignment process.

An array in Java is a data structure to store multiple elements with the same data type. There are only a fixed number of elements in a Java array. Arrays can be single dimensional or multidimensional. In the CS1 course, both single dimensional or multidimensional arrays are covered. Students are exposed to two different classes and data structures for arrays; Arraylists and Arrays class. Each data structure requires a different approach and algorithms for dealing with them. This makes it a potentially tricky topic for beginners to grasp and a good topic to use in the alignment process.

Scanner is a class in the java.util package used for getting the input of primitive types like int (integer values), double (decimal numbers) and strings (text). Unlike the previous topics, scanners are Java language specific, but they are an important concept that Java programmers will use frequently making it another good topic in the alignment process.

Object identity in Java is when a variable holds the same instance as another variable, while object equality is when two objects contain the same state and can be used interchangeably. Equality and
identity are foundational object-oriented principles, they require students to have an understanding of the implementation of programming languages. As Computer Science majors, students will need an understanding of the difference between equality and identity to success in future courses. This makes equality and identity good to use in the CAAP.

CAAP was applied to the five topics (polymorphism, arrays/2D arrays, scanners, and equality and identity). First the learning objectives are defined, then a content matrix is built, then an assessment matrix is built and lastly the alignment is evaluated.

3.3.2 Step 1: Defining CS1 Learning Outcomes

The CS1 course had a list of topics and subtopics that are covered in the course but instructors could not direct me to the course’s written learning objectives or cognitive competencies the students are expected to achieve. The Association of Computing Machinery (ACM) created a report outlining the curricula standards for various undergraduate degrees in computing. The report for Computer Science outlines knowledge areas all computer science graduates must be exposed to as well as topics and learning outcomes for the knowledge areas [88]. One of the knowledge areas is Software Development Fundamentals. The topics described in the Software Development Fundamentals are similar to the CS1. Using the BlueJ Objects First textbook [89] as a starting point for the course learning outcomes and cross-referencing with the learning outcomes of the Software Development Fundamentals defined by ACM [88], a list of learning outcomes was developed. The instructors of the CS1 course were then asked to review the learning outcomes, crossing-out the ones that did not apply to the course and add any outcomes that were not included. The following list of outcomes are ones that are agreed upon by the CS1 instructors and relate to the topics I selected:
Polymorphism

To recognize inheritance (level 1: knowledge)

To implement subclasses that inherit and override superclass methods (level 3: application)

To apply the concept of polymorphism (level 1: knowledge)

To use the common superclass Object and its methods (level 3: application)

Arrays and 2D Arrays

To collect elements using arrays and array lists (level 3: application)

To apply enhanced for loop for traversing arrays and array lists (level 3: application)

To apply common algorithms for processing arrays and array lists (level 3: application)

To apply common algorithms for working with two-dimensional arrays (level 3: application)

Scanners

To write programs that read input and produce formatted output (level 3: application)

To write programs that read and write text files (level 3: application)

Equality and Identity

To distinguish the difference between objects and object references (level 2: comprehension)

To apply object identity (level 1: knowledge)

To apply object equality (level 1: knowledge)
Using Bloom’s Taxonomy [83], the instructors for the CS1 course and I identified the cognitive competencies the students are expected to achieve at each of the learning outcomes. I used Bloom’s Taxonomy to categorize the level of cognitive demand required for each learning outcome. The learning outcomes are at the complexity levels of knowledge (level 1), comprehension (level 2) or application (level 3). This is because the CS1 course is an introductory course where students have no prior programming knowledge. A lot of time would be allocated to activities that require low levels of cognitive domain. In the 16 weeks of the course, as students progress, they will be exposed to more activities that require the application of complex concepts.

3.3.3 Step 2: Building the Content Matrix

To get a more clear understanding of the course, I built a content matrix (see Table 3.3) where I mapped the learning objectives for each topic to the course content and assessments. To identify the course components, I conducted a document analysis of the course from the Learning Management System (Canvas) site. There were six course components: homework, reading assignments, lectures, lab work, programming assignments, and tests.

Homework is a course component to be completed outside of the classroom before the lab section. In the Fall 2017 version of the course, there were 9 homework assignments in total. Homework assignments may be multiple questions on topics that will be covered in the lab or short programming tasks on CodeWorkout, an online programming environment [90], on a specific programming concept. CodeWorkout allows multiple submissions and provides feedback to the students on their submissions.
The course uses an Object’s First book, Objects First with Java: A Practical Introduction using BlueJ [89]. Students are required to read some chapters from the book and then answer a reading quiz. The reading quiz is made up of 10 multiple choice questions. On some of the readings, students might be asked to also read some chapters from the online book [91]. The book explains some programming concepts and the application programming interface (API) that students will use.

Students are assigned lab assignments that are released at the beginning of each week and students are encouraged to work on them at their own pace outside of the lab time. Students are then required to submit the lab assignment during the 2-hour lab section where a Teaching Assistant (TA) is available to assist students with any questions they may have. Lab assignments are collaborative tasks, where students are asked to select a lab partner to work with to complete the assignment. At the end of each lab, students must complete a 5 question post-lab quiz. The quiz can only be submitted once, so students are encouraged to work with their partner and use any resource available to them to answer the questions correctly. There are 14 lab assignments and 14 post-lab quizzes in the course.

The CS1 lectures are twice a week for 55 minutes each, where the lecturer introduces students to new programming concept or concepts. This allows students to learn the theoretical aspects of the programming concept before applying it on a lab assignment. In Fall 2017, the course coordinator added a collaborative learning component to the lectures: iClicker questions. In a pre-test/post-test format, students were given 15 seconds to answer a question about a programming concept they were going to learn about in the lecture. Students were given a few minutes to discuss their answers
in groups and after going over the concept in the lecture, students were then asked the same question again.

Every few weeks, students have a programming assignment that covers various concepts introduced over the past weeks. There are 5 programming assignments in total. Unlike lab work and the lectures, the programming assignments are not collaborative, therefore must complete these tasks on their own.

To assess their learning, students have a total of 3 tests, including a final exam. Tests are comprehensive, therefore cover all the programming concepts students learned up until the test. The tests are made up of two components; multiple choice questions and short programming tasks on CodeWorkout. These tests are completed during lecture times.

In the content matrix, the course content was only included if it directly met the learning objectives. For example, there were many exercises; homework questions, reading quizzes, test questions, labs and programs that would use the Java keyword “super”, super is part of the superclass object. I did not include those exercises in the learning objective “To use the common superclass object and its methods” because having an understanding of the use of “super” did not affect the students’ ability to answer the exercises since the exercises’ focus was not the super keyword. My findings are summarized by topic in a content matrix in Table 3.3, Table 3.4, and Table 3.5.

3.3.3.1 Polymorphism

In the CS1 course, the topics of polymorphism and inheritance are covered during the first week. Lecture 2 walks students through an example of these concepts. The second lab (Lab 2) guides
students through an example of polymorphism. Using GreenFoot4Sofia API and the custom Jeroo subclasses students were asked to create three classes and were guided through an example of inheritance and polymorphism. Similarly, in program 2 students are told that this program requires them to use inheritance and are given some prompts to guide them through the solution. It is important to note that the students were exposed to the various concepts on polymorphism mostly through in-person interactions, there are few readings and homework on polymorphism concepts. One of the learning objectives “to apply the concept of polymorphism” has no out-of-class practice.

CS1 students are required to apply the concepts of polymorphism on other topics throughout the course. Labs 3 – 9 do not focus on polymorphism but in order to complete the labwork, the students must have an understanding of polymorphism and how it can be applied. Programs 2 and 5 focused on polymorphism, and programs 1, 3, 4, and 6 do not require the use of polymorphism. On the assessments, students are tested on polymorphism on all three tests.

3.3.3.2 Arrays

In the CS1 course students are introduced to the topic arraylists in weeks 9 and 10 before the arrays topic is covered in detail during week 13 of the course. Labs 9 and 10 work with students on arrays and array lists and lab 13 focuses on 2D arrays. For the arrays topic, students have multiple out-of-class activities, homework 9 is dedicated to arrays and some readings and reading quizzes are on the arrays topic. Course content was only included if it directly met the learning objectives, as a result, homework 7 (string manipulation) was not included in the content matrix. There are no questions on arrays on test 1, because students haven’t covered it in class yet. Test 2 and Final exam have questions on applying the enhanced for loop for traversing arrays and array lists and
common algorithms for processing arrays and array lists. There are no questions that test students on collecting elements from user input or text file and storing them in an array or array list.

3.3.3.3 2-D Arrays

In the CS1 course 2-D Arrays, multidimensional arrays are introduced to the students in week 13. Students have a lecture on arrays and 2D arrays in week 13, as well as a lab (lab 13) which focused solely on 2D arrays. There is not much out-of-class exercise for 2D arrays, only 1 question on reading 9. Furthermore, there are no programming assignments for students on 2D arrays. Students only get 2 questions on the final exam about 2D arrays.
<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning Objective</th>
<th>Labs</th>
<th>Homework</th>
<th>Lectures</th>
<th>Programming Assignments</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymorphism</td>
<td>To apply inheritance</td>
<td>Lab 2, 3*, 4*, 5*, 6* 7*, 8*, 9</td>
<td>Reading 1, 2, 10 Reading Quiz 1 (Q9, Q10) Homework 2(Q2) Reading Quiz 2 (Q2) Reading Quiz 4 (Q4, Q8)</td>
<td>Lecture 2 (Polymorphism)</td>
<td>Program 2, 5</td>
<td>Test 2 (Q11, Q12) and Final Exam (Q22, Q27, Q28)</td>
</tr>
<tr>
<td></td>
<td>To implement subclasses that inherit and override superclass methods</td>
<td>Lab 2, 3*, 4*, 5*, 6* 7*, 8*, 9</td>
<td>Reading 2 Homework 2 (Q6)</td>
<td>Lecture 2 (Polymorphism)</td>
<td>Program 2, 5</td>
<td>Test 1 (Q8), Test 2 (Q11), Final Exam (Q22, Q27, Q28)</td>
</tr>
<tr>
<td></td>
<td>To apply the concept of polymorphism</td>
<td>Lab 2 Post-lab Quiz 2 (Q5)</td>
<td>Lecture 2 (Polymorphism)</td>
<td>Program 2, 5</td>
<td>Test 1 (Q1), Test 2 (Q1), Exam (Q22, Q27, 28)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To use the common superclass Object and its methods</td>
<td>Post-lab Quiz 2 (Q2) Post-lab Quiz 8 (Q2) Post-lab Quiz 9 (Q1/5) Lab 2, 3*, 4*, 5*, 6* 7*, 8*, 9</td>
<td>Reading 1, 2</td>
<td>Lecture 2 (Polymorphism)</td>
<td>Program 1, 2, 3, 5, 6</td>
<td>Test 1 (Q1)</td>
</tr>
</tbody>
</table>

Table 3.3: Content in CS1 Syllabus Fall 2017 for the learning objectives on the Polymorphism topic

*not the primary focus of the lab but an understanding of polymorphism is needed to be able to successfully complete the lab
<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning Objective</th>
<th>Labs</th>
<th>Homework</th>
<th>Lectures</th>
<th>Programming Assignments</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arrays</strong></td>
<td>To collect elements using arrays and array lists</td>
<td>Lab 9, 10 Post-lab Quiz 9 (Q1)</td>
<td>Reading 6 Reading Quiz 6 (Q1, Q5, Q7)</td>
<td>Week 9 (Grouping Objects) Week 10 (Array lists) Week 13 (Arrays)</td>
<td>Program 6</td>
<td>Final Exam (Q11)</td>
</tr>
<tr>
<td></td>
<td>To apply enhanced for loop for traversing arrays and array lists</td>
<td>Lab 9, 10 Post-lab Quiz 9 (Q2) Post-lab Quiz 10 (Q3)</td>
<td>Reading Quiz 6 (Q10) Homework 9(all questions)</td>
<td>Week 9 (Grouping Objects &amp; Looping idioms) Week 10 (Array lists) Week 13 (Arrays)</td>
<td>Program 6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To apply common algorithms for processing arrays and array lists</td>
<td>Lab 9, 10 Post-lab Quiz 13 (Q3, Q5) Post-lab Quiz 14 (Q2)</td>
<td>Reading 6 Reading Quiz 6 (Q1, Q5, Q7) Reading Quiz 8(Q8) Reading Quiz 9(Q1, Q3, Q4, Q10) Homework 9(all questions)</td>
<td>Week 9 (Grouping Objects) Week 13 (Arrays)</td>
<td>Program 6</td>
<td>Test 2 (Q6, Q7), Final Exam (Q11, Q13, Q14, Q16, 25)</td>
</tr>
<tr>
<td><strong>2D Arrays</strong></td>
<td>To apply common algorithms for working with two-dimensional arrays</td>
<td>Lab 13 Post-lab Quiz 13 (Q2, Q4)</td>
<td>Reading Quiz 9(Q5)</td>
<td>Week 13 (Arrays)</td>
<td>None</td>
<td>Final Exam (Q13, Q25)</td>
</tr>
</tbody>
</table>

Table 3.4: Content in CS1 Syllabus Fall 2017 for the learning objectives on the Arrays and 2D Arrays topic
3.3.3.4 Scanners

In the CS1 course, scanners were introduced in week 11 of the course. During the lecture, students are walked through examples of how to read input using scanners and produce formatted output. They are also taught how to use scanners to read and write to text files. Lab 11 focuses on using scanners to read from a text file and manipulate the input. Lab 13 is focused on using 2D arrays but requires students to use scanners to format the output. Students have some out-of-class practice on the reading 9 quiz questions on the scanners topic, other than those 5 questions they have no other opportunity to practice using scanners. Program 6 requires students to read data from a text file, store the information in an array, then manipulate the information and make calculations before formatting the output. There are only two questions on scanners on the final exam.

3.3.3.5 Equality and Identity

In the CS1 course, equality and identity are introduced in the lecture “Variable and Scope” in week 11. There are no labs, homework assignments or programming assignments on equality or identity. Students have to answer two questions on reading quiz 8 that require an understanding of the difference between objects and object references, and object equality. In the assessments, there is one question on test 2 about the difference between objects and object references, and the final exam had three questions about equality and identity.

From observing the matrices for the different topics, there are some clear imbalances in the types of content for the different learning objectives. This might not necessarily indicate a misalignment because students might have enough exposure to a topic through a type of instructional method and might not need other instructional methods. For example, polymorphism is a foundational
concept that is difficult for beginner programmers to grasp. The CS1 course focuses on covering polymorphism through a variety of face-to-face instructional methods and there is very little coverage through out-of-class instruction. It might be helpful because an interactive environment where students can ask questions, troubleshoot problems on the spot and get help from their peers, provides many different opportunities for students to learn the concept.
<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning Objective</th>
<th>Labs</th>
<th>Homework</th>
<th>Lectures</th>
<th>Programming Assignments</th>
<th>Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scanners</strong></td>
<td>To write programs that read input and produce formatted output</td>
<td>Lab 11, 13</td>
<td>Reading 9</td>
<td>Week 11 (Scanners)</td>
<td>Program 6</td>
<td>Final Exam (Q13)</td>
</tr>
<tr>
<td></td>
<td>To write programs that read and write text files</td>
<td>Lab 11, 13</td>
<td>Reading 9</td>
<td>Week 11 (Scanners)</td>
<td>Program 6</td>
<td>Final Exam (Q10)</td>
</tr>
<tr>
<td><strong>Equality and Identity</strong></td>
<td>To distinguish the difference between objects and object references</td>
<td></td>
<td>Reading Quiz 8 (Q3)</td>
<td>Week 11 (Variables and Scope)</td>
<td>None</td>
<td>Test 2 (Q9), Final Exam (Q2, Q3, Q4)</td>
</tr>
<tr>
<td></td>
<td>To understand object identity</td>
<td></td>
<td></td>
<td>Week 11 (Variables and Scope)</td>
<td>None</td>
<td>Final Exam (Q4)</td>
</tr>
<tr>
<td></td>
<td>To understand object equality</td>
<td></td>
<td>Reading Quiz 8 (Q8)</td>
<td>Week 11 (Variables and Scope)</td>
<td>None</td>
<td>Final Exam (Q2, Q3)</td>
</tr>
</tbody>
</table>

Table 3.5: Content in CS1 Syllabus Fall 2017 for the learning objectives on the Scanners and Equality and Identity topics
3.3.4 Step 3: Building the Assessment Matrix

After going through the content and creating a matrix mapping the learning objectives to the content, this informed me of some potential imbalances in the course. These imbalances may cause misalignment between the learning objectives and the course content. To further investigate the impact of the imbalance, the assessment matrix was built. The aim was to find the course components where students have been exposed to the concept at a similar level of cognitive demand the assessment question is testing. This is different from content mapping because a question on the test might be related to a specific learning objective, but if it is asking students to do a task they have not gotten experience with or is at a level of cognitive demand higher than the content, then the question is biased. This is an example of imbalance between the content and the assessment tool.

It is worth noting that many questions on tests 1, 2 and the final exam required students to “trace” code. Code tracing is a technique for simulating the execution of code by hand to manually verify that the code works correctly. Students do not practice code tracing in any of the instructional methods for CS1. Students might be encouraged to “trace” their code when they are troubleshooting programming assignments with the TAs but there is no tracing practice worked into the curriculum. This might present a problem for students who have not practiced tracing before.
<table>
<thead>
<tr>
<th>Assessment</th>
<th>Question</th>
<th>Concept</th>
<th>Content with Similar Cognitive Demand</th>
</tr>
</thead>
</table>
| **Test 1** | Q1       | To apply the concept of polymorphism | Reading 1, 2  
Post-lab Quiz 2 (Q5)  
Reading Quiz 1 (Q9, Q10)  
Reading Quiz 2 (Q2)  
Reading Quiz 4 (Q4, Q8)  
Polymorphism Lecture |
|            |          | To use the common superclass Object and its methods | Post-lab Quiz 2 (Q1)  
Homework 2 (Q2, Q6) |
|            | Q8       | To implement subclasses that inherit and override superclass methods | Reading 2  
Post-lab Quiz 8 (Q2)  
Polymorphism Lecture |
| **Test 2** | Q1       | To implement subclasses that inherit and override superclass methods | Post-lab Quiz 2 (Q1, Q2, Q5)  
Reading Quiz 1 (Q9, Q10) |
|            |          | To apply the concept of polymorphism | |
|            | Q6       | To apply common algorithms for processing arrays and array lists | Grouping Objects & Looping idioms Lecture  
Arraylists Lecture  
Lab 10  
Reading 6  
Reading Quiz 6(Q10)  
Post-lab Quiz 9 (Q1) |
|            | Q7       | To apply common algorithms for processing arrays and array lists | Grouping Objects & Looping idioms Lecture  
Arraylists Lecture  
Homework 9 |
|            | Q9       | To distinguish the difference between objects and object references | Variables and Scope Lecture |
|            | Q11      | To implement subclasses that inherit and override superclass methods | Lab 2  
Reading 1, 2  
Program 1, 2, 5 |
|            | Q12      | To apply inheritance | Reading 10 |

**Table 3.6: Test 1 and Test 2 Assessment Matrix**
<table>
<thead>
<tr>
<th>Assessment</th>
<th>Question</th>
<th>Concept</th>
<th>Content with Similar Cognitive Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q2</td>
<td>To distinguish the difference between objects and object references</td>
<td>Variables and Scope Lecture Reading Quiz 8 (Q3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To apply object equality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q3</td>
<td>To distinguish the difference between objects and object references</td>
<td>Variables and Scope Lecture Reading Quiz 8 (Q3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To apply object equality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q4</td>
<td>To distinguish the difference between objects and object references</td>
<td>Variables and Scope Lecture Reading Quiz 8 (Q3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To apply object identity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q10</td>
<td>To write programs that read input and produce formatted output</td>
<td>Program 6 Reading 9 Lab 11 Reading Quiz 9 (Q4, Q6, Q9) Post-lab Quiz (Q4, Q5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To write programs that read and write text files</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q11</td>
<td>To apply enhanced for loop for traversing arrays and array lists</td>
<td>Grouping Objects &amp; Looping idioms Lecture Arraylists Lecture Post-lab Quiz 9 (Q1, Q2) Post-lab Quiz 13 (Q5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To apply common algorithms for processing arrays and array lists</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q13</td>
<td>To write programs that read input and produce formatted output</td>
<td>Grouping Objects &amp; Looping idioms Lecture Arraylists Lecture Lab 13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To apply common algorithms for processing arrays and array lists</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>To apply common algorithms for working with two-dimensional arrays</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q14</td>
<td>To apply common algorithms for processing arrays and array lists</td>
<td>Homework 9 (all questions) Post-lab Quiz 13 (Q4) Grouping Objects &amp; Looping idioms Lecture Arraylists Lecture</td>
<td></td>
</tr>
<tr>
<td>Q16</td>
<td>To apply common algorithms for processing arrays and array lists</td>
<td>Arrays Lecture Homework 9 (X48) Post-lab Quiz 13 (Q2, Q4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To apply common algorithms for working with two-dimensional arrays</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q22</td>
<td>To apply the concept of polymorphism</td>
<td>Polymorphism Lecture Reading 1 Lab 2, 9 Program 2, 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To implement subclasses that inherit and override superclass methods</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>To apply inheritance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q25</td>
<td>To apply common algorithms for processing arrays and array lists</td>
<td>Arrays Lecture Lab 13 Homework 9(X48) Post-lab Quiz 13(Q2, Q4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To apply common algorithms for working with two-dimensional arrays</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>To apply the concept of polymorphism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q27 and Q28</td>
<td>To implement subclasses that inherit and override superclass methods</td>
<td>Polymorphism Lecture Lab 2, 9 Reading 1 Program 2, 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>To apply inheritance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3.7: Final Exam Assessment Matrix
3.3.5  **Step 4: Evaluating Alignment**

I used the content focus attributes defined by Webb [8] and outlined in CAAP to assess the degree of alignment of the CS1 course.

### 3.3.5.1 Structure of Knowledge (Full Alignment)

Structure of knowledge is evaluated by checking that every question in the assessment matrix has at least one corresponding learning objective. After assessing the test questions, all the questions are of the same cognitive demand as the learning objectives. Questions also had the same depth of knowledge as the related instructional methods, with similar types of questions repeating. On one test, a question type can be repeated but with different values. In one topic, two questions on the final exam (Q27 and Q28) were very similar to Q1 on test 2 but with different values. This indicates that there was full alignment where there is more than one learning objective for an assessment question.

### 3.3.5.2 Depth and Range of Knowledge (Acceptable Alignment)

To evaluate the depth of knowledge consistency and the range of knowledge correspondence I applied traceability between the content matrix and assessment matrix to find broken links. I cross-referenced the assessment matrix with the content matrix to find broken links. In an ideal situation, all the assessment questions for a learning objective must map to the content in the content matrix, and all the content in the content matrix must map to an assessment question in the assessment matrix.

From Table 3.6 and Table 3.7, there are no broken links from the assessment matrix. That means that all the assessment questions are covered by some instructional method with a similar cognitive demand. When the assessment matrix was cross-referenced with the content matrix, a few broken
links were found. The list of content below, did not match the level of cognitive skill required to complete any of the assessment questions:

**Arrays and 2D Arrays**

Reading Quiz 6 (Q1, Q5, Q7)
Post-lab Quiz 14 (Q2)
Reading Quiz 8 (Q8)
Reading Quiz 9 (Q1, Q3, Q5, Q10)

**Scanners**

Reading Quiz 9 (Q7, Q8)
Post-lab Quiz 11 (Q2, Q3)

**Equality and Identity**

Reading Quiz 8 (Q8)

This content suggests a possible misalignment in the course. Students are spending time completing tasks that do not align with assessments, and the level of cognitive skill of the content is not the same as the learning objectives. This means that students are focused on tasks that do not align with the learning objective. The Depth and Range of Knowledge are considered *acceptable* with definite room for improvement.
3.3.5.3 Balance of Representation

For each topic I used the content matrix to assess whether the content and assessment tools were under-represented, balanced, or over-represented by considering the following criteria:

• Are there a variety of instructional methods for the learning objectives? Are there any gaps?
• Compared to the other learning objectives of similar cognitive demand, is there more or less content?

I followed the instructions in section 3.2.4.3 of this document to evaluate whether a learning objective was over-represented, balanced or under-represented.

Polymorphism Learning Objectives:

i. To apply inheritance (level 1: knowledge) **OVER-REPRESENTED**

ii. To implement subclasses that inherit and override superclass methods (level 3: application) **BALANCED**

iii. To apply the concept of polymorphism (level 1: knowledge) **UNDER-REPRESENTED**

iv. To use the common superclass Object and its methods (level 3: application) **BALANCED**

When looking at the content matrix, polymorphism learning objective (i) is the same level of cognitive skill as polymorphism learning objective (iii) however there are more exercises, labs and programming practice that require a basic knowledge of inheritance, compared to polymorphism. Furthermore, there are more assessment questions on inheritance than polymorphism. This suggests an imbalance in these two learning objectives. Polymorphism learning objectives (ii and iv) have similar content coverage as well as assessment questions.
Arrays and 2D Arrays Learning Objectives:

i. To collect elements using arrays and array lists (level 3: application) UNDER-REPRESENTED

ii. To apply enhanced for loop for traversing arrays and array lists (level 3: application) BALANCED

iii. To apply common algorithms for processing arrays and array lists (level 3: application) BALANCED

iv. To apply common algorithms for working with two-dimensional arrays (level 3: application) UNDER-REPRESENTED

Arrays and 2D Arrays learning objectives (ii and iii) are balanced, they are covered in assessment questions and there are a variety of instructional methods for each. Arrays and 2D Arrays learning objectives (i and iv) are under-represented. Both are tested on assessments but they are not covered sufficiently in programming practice. There are few opportunities to apply students’ understanding of the learning concepts other than when they’re being tested.

Scanners Learning Objectives:

i. To write programs that read input and produce formatted output (level 3: application) UNDER-REPRESENTED

ii. To write programs that read and write text files (level 3: application) UNDER-REPRESENTED
Learning objectives on scanners are both under-represented, there are assessment methods testing for (i and ii) however there is not much diversity in the instructional methods. More importantly students are asked to have a level of understanding that allows them to apply the materials, but there are not enough opportunities to do that outside of the assessments.

**Equality and Identity Learning Objectives:**

i. To distinguish the difference between objects and object references (level 2: comprehension) **UNDER-REPRESENTED**

ii. To apply object identity (level 1: knowledge) **UNDER-REPRESENTED**

iii. To apply object equality (level 1: knowledge) **UNDER-REPRESENTED**

All of the learning objectives for equality and identity are under-represented. Students have very little practice although they are being tested on the concepts. There are no labs, homework exercises, or programming exercises on any of these learning objectives. This suggests a strong imbalance in the content.
### Table 3.8: Summary of Balance of Representation Results for Learning Objectives

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>LEARNING OBJECTIVE</th>
<th>BALANCE OF REPRESENTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymorphism</td>
<td>To implement subclasses that inherit and override superclass methods (level 3: application)</td>
<td>BALANCED</td>
</tr>
<tr>
<td></td>
<td>To use the common superclass Object and its methods (level 3: application)</td>
<td>BALANCED</td>
</tr>
<tr>
<td></td>
<td>To apply inheritance (level 1: knowledge)</td>
<td>OVER-REPRESENTED</td>
</tr>
<tr>
<td></td>
<td>To understand the concept of polymorphism (level 1: knowledge)</td>
<td>UNDER-REPRESENTED</td>
</tr>
<tr>
<td>Arrays and 2D Arrays</td>
<td>To apply common algorithms for processing arrays and array lists (level 3: application)</td>
<td>BALANCED</td>
</tr>
<tr>
<td></td>
<td>To apply enhanced for loop for traversing arrays and array lists (level 3: application)</td>
<td>BALANCED</td>
</tr>
<tr>
<td></td>
<td>To apply common algorithms for working with two-dimensional arrays (level 3: application)</td>
<td>UNDER-REPRESENTED</td>
</tr>
<tr>
<td></td>
<td>To collect elements using arrays and array lists (level 3: application)</td>
<td>UNDER-REPRESENTED</td>
</tr>
<tr>
<td>Scanners</td>
<td>To write programs that read input and produce formatted output (level 3: application)</td>
<td>UNDER-REPRESENTED</td>
</tr>
<tr>
<td></td>
<td>To write programs that read and write text files (level 3: application)</td>
<td>UNDER-REPRESENTED</td>
</tr>
<tr>
<td>Equality and Identity</td>
<td>To distinguish the difference between objects and object references (level 2: comprehension)</td>
<td>UNDER-REPRESENTED</td>
</tr>
<tr>
<td></td>
<td>To apply object identity (level 1: knowledge)</td>
<td>UNDER-REPRESENTED</td>
</tr>
<tr>
<td></td>
<td>To apply object equality (level 1: knowledge)</td>
<td>UNDER-REPRESENTED</td>
</tr>
</tbody>
</table>

#### 3.3.6 Lessons Learned

Applying the alignment process to five topics in the CS1 course, allowed for the refinement of CAAP and addressed some concerns raised during the design of the process. During the design of CAAP four concerns arose: *time required to apply the CAAP, minimum number of iterations needed to produce an accurate content and assessment matrices, the difficulty in determining the degree of alignment for each attribute based on the definitions of full, insufficient and acceptable, and the instructor’s perceptions of the results of CAAP*. 

63
In this section, I will summarize the lessons learned from the initial application of CAAP and the improvements that were made to the process. The results of the initial application have been summarized and published [78].

**Concern 1: Time required to apply the CAAP**

It took me a total of 75 hours over a period of 6 weeks; four iterations in each phase were completed. This was a lengthy process and took a long time because I was not familiar with the course and going through the course documents one-by-one was time consuming. It is possible that an instructor for the course would have been able to complete the alignment process in a shorter time, due to their familiarity with the content, learning objectives, and the assessments.

Decisions about what to include the content matrix and assessment matrix were sometimes difficult, and often, there was some debate on what was relevant and what was not. This also contributed to the time spent. I anticipated that a course instructor may not have these doubts and debates however they probably are more quickly resolved because of their content knowledge as well as their predetermined expectations of the students in the course.

**Concern 2: The minimum number of iterations needed to produce an accurate content and assessment matrices but not require too much time or effort**

Repeating each step four times was unnecessary, by the second iteration the majority of corrections were made, minimal new information was found. If a course instructor were to go through two iterations for each step of the process, I anticipated that they would get an accurate content and assessment matrices. This would cut down the time to complete the process significantly.
Concern 3: The difficulty to determine the degree of alignment for each attribute based on the definitions of full, insufficient and acceptable

In the majority of instances, I agreed with the definitions of the attributes and could easily apply them. In some instances, however such as the balance of representation attribute, it was harder to follow the definition.

Concern 4: The instructor’s perceptions of the results of CAAP

Discussions with a previous course instructor did not yield too much information about the usefulness of the process, however the instructor indicated that these findings were expected and that they had had their suspicions based on the students’ performance on the assessments.

3.4 Conclusions

Computer Assisted Alignment Process (CAAP) was developed using five design goals:

D.G.1. Evaluate the degree of alignment of the learning objectives, content and assessments for a course.

D.G.2. Produce results an instructor can use to make informed changes to their course

D.G.3. Be applied by a single course instructor

D.G.4. Reduce time required to evaluate alignment

D.G.5. Require no knowledge of instructional design and no training on the process.

To address these design goals, four of Webb’s content focus attributes (structure of knowledge, range of knowledge, depth of knowledge and balance of representation) were used to evaluate alignment and two data structures (content and assessment matrices) were developed. To address
some of the design challenges of CAAP, I conducted an initial application where CAAP was applied to portions of a CS 1 course. The results of the application allowed me to make revisions to the process. The application took 75 hours to complete, suggesting the need to automate CAAP.
Chapter 4: The Prototype Alignment Tool (AlignET)

The results of the initial application of CAAP indicated that it was too time consuming to be applied by a single instructor in a typical setting. Automating CAAP may be beneficial to instructors and may help reduce the overall time spent on the process. To design a prototype alignment tool (AlignET), static wireframe mockups were designed to assist a CS instructor in the evaluation of the alignment of their course without a panel of experts or requiring knowledge of instructional design. The user interface for AlignET was designed and the back-end logic of the tool follows all four phases of the computer assisted alignment process [78]. In designing AlignET, I used the same five design goals as CAAP:

- The tool had to evaluate the *degree of alignment* of course
- The tool must produce results an instructor can use to make informed changes about their course.
- The tool can be used by a *single* course instructor.
- The tool must reduce *time required* to evaluate alignment
- The tool must require *limited knowledge* of instructional design

4.1 Design of AlignET

The prototype alignment tool (AlignET) is a low fidelity prototype [92], where the user using the prototype can distinguish the prototype from the final system [93]. The goal was to rapidly design a static wireframe mockup that would illustrate the overall vision of the end product. I focused on the look and feel of the user interface. The user interface of AlignET was designed using WireframePro [94]. The images of the interfaces are shown to the user at the beginning of each phase of CAAP to introduce the users the current phase of the process. Once an instructor clicks
on a functionality of the interface, I would direct them to the appropriate image mimicking the functionality of the tool. The users are directed to Google sheets [95] to input information prompted by the user interface. In the next sections I am going to describe the user interfaces the instructor went through and how they interacted with the prototype to evaluate the alignment of their course using CAAP.

4.2 About the Course

AlignET was designed to break the Computer Assisted Alignment Process (CAAP) into mini steps. Before the phases of the process begin, the instructor is asked a series of questions about the course. I used the information provided to create the content and assessment matrices on Google sheets for the instructor to fill out. Figure 4.1 shows a prompt for the course components where the instructor is asked to list all of the components of the course. The instructor is also asked to select which of these course components are assessments. On the Google sheets, the instructor would make the assessments bold. In the next step the instructor is asked to give more details about the assessments. In Figure 4.2, the instructor gives details on how many questions are on each exam.
Figure 4.1: Static Wireframe Mockup Prompt for Course Components

Figure 4.2: Static Wireframe Mockup Prompt for Course Assessments
Figure 4.3 shows the google sheet where the instructor enters the course components and summative assessments. Help and Information buttons are an important design aspect of the user interface of AlignET. The Help and Information buttons clarify steps in the tool or provide explanations of the steps. When an instructor clicks on any of these information buttons, I would read out the information that would have been displayed. Similarly, for the help buttons I would read out the information or share the information printed on a sheet. A summary of all of the help and information button features and the scripts I used are in Appendix B.

4.3 Guiding the Instructor through the Alignment Process

Once the instructor has defined their course, instructor is guided through the four phases of CAAP. Each phase is broken into multiple steps:

**STEP 1: Defining the Learning Objectives**

The user interface prompts the instructor to input all of the learning objectives for their course (Figure 4.4). The instructor is directed to the Google sheet shown in Figure 4.5, where they fill out the learning objectives for their course. The learning objectives are grouped by topic. I sort the
learning objectives by topic before moving onto the next step. Next, the user interface prompts the instructor to select from the list what is the highest level of cognitive skill required to achieve the learning objective (Figure 4.6). The instructor is directed to the next Google sheet where each learning objective and topic are copied from the previous sheet (Figure 4.7). The instructor selects from a dropdown list the level of cognitive skill for each learning objective.

![Figure 4.4: Static Wireframe Mockup Step 1 Defining Learning Objectives](image)

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basics</td>
<td>To learn about programming</td>
</tr>
<tr>
<td>Basics</td>
<td>To compile and run your first JAVA program</td>
</tr>
<tr>
<td>Basics</td>
<td>To learn how to align your code</td>
</tr>
<tr>
<td>Basics</td>
<td>To describe an algorithm with pseudocode</td>
</tr>
<tr>
<td>Basics</td>
<td><strong>To be able to call methods</strong></td>
</tr>
<tr>
<td>Basics</td>
<td>To become familiar with the process of implementing classes</td>
</tr>
<tr>
<td>Basics</td>
<td>To be able to write javadoc comments</td>
</tr>
</tbody>
</table>

![Figure 4.5: Google Sheet for Defining the Learning Objective](image)
Figure 4.6: Static Wireframe Mockup of Level of Cognitive Skill for each Learning Objective

<table>
<thead>
<tr>
<th>Topic</th>
<th>Learning Objective</th>
<th>Level of Cognitive Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basics</td>
<td>To learn about programming</td>
<td>Level 2: Understanding</td>
</tr>
<tr>
<td>Basics</td>
<td>To compile and run your first JAVA program</td>
<td>Level 3: Applying</td>
</tr>
<tr>
<td>Basics</td>
<td>To learn how to align your code</td>
<td>Level 1: Remembering</td>
</tr>
<tr>
<td>Basics</td>
<td>To be able to call methods</td>
<td>Level 1: Remembering</td>
</tr>
<tr>
<td>Basics</td>
<td>To become familiar with the process of implementing classes</td>
<td>Level 2: Understanding</td>
</tr>
<tr>
<td>Basics</td>
<td>To be able to write javadoc comments</td>
<td>Level 1: Remembering</td>
</tr>
<tr>
<td>Basics</td>
<td>To hand-trace the execution of a program</td>
<td>Level 2: Understanding</td>
</tr>
</tbody>
</table>

Figure 4.7: Google Sheet for Level of Cognitive Skill for each Learning Objective
STEP 2: Building the Content Matrix

With the course information the instructor defined before starting the process, I generate an empty content matrix for the instructor. The user interface prompts the instructor to fill out the content matrix by listing all of the course components required that address each learning objective (Figure 4.8). They are then directed to the Google sheet with the empty content matrix for them to fill out (Figure 4.9).

![Figure 4.8: Static Wireframe Mockup of Build Content Matrix Screen from the Alignment Tool](image)

![Figure 4.9: Google sheet for Building Content Matrix](image)
STEP 3: Building the Assessment Matrix

Similar to the content matrix, I generated an empty assessment matrix for the instructor using the information about the course assessments defined before starting the process. Figure 4.10 shows the interface prompting the instructor to fill out the assessment matrix. The instructor is directed to the Google sheet for assessment matrix (Figure 4.11), wherein the instructor is asked to list all of the questions on each assessment in their course, which learning objective(s) meet the question, and other course content with similar cognitive demand.

![Figure 4.10: Static Wireframe Mockup for Building Assessment Matrix from Tool](image)

![Figure 4.11: Google sheet for Assessment Matrix](image)
STEP 4: Evaluation of Alignment

In the last step, I generate an alignment report for the instructor by following the instructions outlined in CAAP (Chapter 3, section 3.2). Using the content and assessment matrices filled out by the instructor on Google sheet, I created a weighted score for the rows and cross checked the tables to assess each attribute. After the evaluation is completed, I filled out a template alignment report (Appendix C) on the results of the evaluation. Figure 4.12 shows the interface with the alignment report detailing the value of each alignment attribute for the course. The instructor is given a copy of the alignment report, all the reports can be found in Appendix D.

![Figure 4.12: Static Wireframe Mockup from Tool Displaying the Alignment Report](image)
4.4 Conclusions

In this chapter I presented the Static Wireframe Mockup of AlignET, a low fidelity prototype alignment tool that automates the Computer Assisted Alignment Process (CAAP). AlignET follows the same design goals as CAAP:

- The tool had to evaluate the degree of alignment of course
- The tool must produce results an instructor can use to make informed changes about their course.
- The tool can be used by a single course instructor.
- The tool must reduce time required to evaluate alignment
- The tool must require limited knowledge of instructional design

I mimicked the functionality of AlignET by following the process outlined in CAAP to evaluate alignment. I produced an alignment report that details the degree of alignment of a course. For a useable implementation of AlignET, the static wireframe mockups would need to be implemented into a user interface and back end logic consisting of the step by step description of the Computer Assisted Alignment Process (CAAP) in 3.2 would need to be implemented.
Chapter 5: Evaluation Methodology

The purpose of this case study research is to create an alignment process that meets the five design goals previously outlined, to design and implement a prototype tool to guide an instructor through the alignment process, and to evaluate the practicality of the alignment process and the tool by addressing four research questions. I designed a computer aided alignment process (CAAP) and a prototype tool (AlignET) that evaluates the degree of alignment of the learning objectives, content and assessments for a course. CAAP and AlignET produce results that an instructor can use to make informed changes to their course and can be applied to a single course instructor. CAAP and AlignET reduce the time required to evaluate alignment and require no knowledge of instructional design and no training on the process.

In order to evaluate the practicality of CAAP and AlignET collective case studies were used. The case studies were designed to answer the following questions:

**RQ.1.** Does the alignment process produce results that support instructors in making informed changes to their course?

**RQ.2.** How difficult or cumbersome is the alignment process and tool for instructors to use?

**RQ.3.** To what extent do instructors find the time invested to evaluate their course alignment to be practical?

**R.Q.1.** What role does instructional design knowledge play in the instructor’s ability to apply the alignment process and tool?

Case studies are a research methodology that allow researchers to get a deep understanding of the cases’ thinking processes and self-perceptions [96]. A case is defined by the researcher and may be an individual or a system [97]. Case studies often use multiple methods for collecting data,
which may be qualitative or quantitative or both, to obtain the deepest possible understanding of
the case [14].

There are three types of case studies [14]: intrinsic, instrumental, and collective. Intrinsic case
studies target a specific interest, such as how a person recovered from a dangerous accident.
Instrumental case studies provide insight into an issue or can be used to refine a theory. For
example, an instrumental case study of a student might provide insights into the K-12 system in
the U.S. Finally, collective case studies are multiple-case studies that collectively help researchers
to understand a population or phenomenon. For example, 10 experienced instructors could be
studied as individual but related cases to understand best practices for developing curricula.

To evaluate the practicality of CAAP and AlignET, I chose to conduct a collective case study with
four cases. A collective case study allowed for rich data about the process and the tool to better
understand the practicality as well as necessary improvements to the process and tool. I used two
data collection methods, observations and interviews, to understand the instructors’ perceptions of
the alignment process and tool. I used four lenses to evaluate the practicality of the alignment
process and tool, which were the instructor’s perceptions of the:

1. *Time* required to complete the alignment process using the tool
2. *Effort* required to complete the alignment process using the tool
3. *Difficulty* of completing the alignment process using the tool with no training or knowledge of
   instructional design
4. *Usefulness* of the results of the alignment tool in their course design.
5.1 Sample Selection

Participants in the study had to meet two criteria. First, the participant was or had been the sole instructor for a course with access to all of the course content. This was important so that the participant would have all the resources to complete all of the phases of the alignment process. Second, only half of the participants should have experience in instructional design. This criterion allowed for assessment of the impact of instructional design knowledge on the instructor’s ability to complete the alignment process using the alignment tool.

Purposive criterion sampling [98] and three gatekeepers were used to recruit participants. The gatekeeper’s role was to identify potential participants. The gatekeepers were the Graduate Program Coordinator for the Computer Science department, a faculty member in the School of Education, and a faculty member in the Graduate Education Development Institute. The Graduate Program Coordinator for the Computer Science department received information about the case study, the purpose of the research and criteria for participant selection through a meeting. The other gatekeepers received information via email due to preference (see Appendix E). The email to the gatekeepers provided information about the case study, purpose of the research, methodology, and participation criteria. All of the gatekeepers were asked to identify potential participants. Computer Science instructors from the Spring 2019 semester Virginia Tech Timetable of Classes were contacted asking them for participation in the study. These instructors received detailed information about the study, the purpose of the study, time commitment and a request for their consent to participate in the study (Appendix F). A total of 24 potential participants were contacted, 6 responded with interest.
Once a potential participant responded, a 10-minute pre-screening meeting was scheduled to verify the eligibility of the participant, to answer questions they had about the study and to obtain written consent if they met the study criteria (interview protocol in Appendix H). The consent form used can be found in Appendix G.

All of the participants that met the study criteria and signed a consent form were asked to identify four to five times to meet to conduct the study. The duration of the meeting was defined according to the participant’s schedule. They received Google Calendar meeting invitations to schedule the meetings and to serve as a reminder. Participants were asked to identify their preferred meeting location, to prevent unforeseen environmental factors from interfering with the study.

5.2 Case Study Protocol

A combination of changing observation roles (participant and non-participant) [99] and interviews were used to collect data. Interviews were semi-structured [98] and conducted at the start of each participant’s study, after the completion of a phase of the alignment process and after finishing the alignment process and reviewing the results. The interviews provided insights into the participant’s thoughts on the process, tool and their experiences.

5.2.1 Observations

Depending on the situation, I served in one of two observation roles. The non-participant role involved observing the participant as they used the tool and completed the phases of the alignment process while taking descriptive notes to capture time spent on each phase and whether the participant appeared hesitant or confused. The notes also included any incorrect or missing information at each phase and what changes were made to the previous phases. In the non-participant role, there was no interaction or engagement with the participant at all.
The participant role involved passive observation, answering questions about the alignment process and the tool but limiting participation so as not to influence any decisions made. Questions were answered with the Socratic method, an approach to questioning that guides an individual to the answer [100]. For example, when a participant asked, “How do I define the learning objectives for my course?” they were referred to the learning objective tutorial and then asked what the tutorial stated. All participant questions and the responses were noted. The participant role further enabled questions about the participant’s justification to changes they made to previous phases or questions about decisions they made. This role provided insight into problems, hesitations and the participants’ decision-making process. Handwritten fieldnotes using the format shown in Appendix I included both reflective and descriptive notes. Reflective notes highlighted insights or themes that emerged during the observations. Descriptive notes were used to record start time, end time, questions asked by participants for each phase, content not included/missed in the content matrix as well as any hesitations the participants had.

5.2.2 Interviews
Semi-structured interviews were used to evaluate CAAP using AlignET. A semi-structured approach provided the flexibility to guide the conversation with the preset questions and also to probe participants for additional details to further explore topics raised when answering the interview questions. The participants were interviewed before the study (pre-alignment), after completing a phase (post-phase) and after completing the alignment process and discussing the results with them (post-alignment). The interview protocol is summarized in Appendix H.
The first interview (pre-alignment), was 10-20 minutes long. The purpose of the interview was to learn more about the participant as an instructor, their teaching experiences, curriculum design experiences, and assessment experiences. The participant was asked to share their design goals for the course and any information they had about the course design. Understanding the participant’s prior knowledge and pedagogical experience helped put into perspective decisions they made when following the alignment process. The interview provided an opportunity to build rapport with the participants so that they were more likely to share information throughout the study.

The second interviews (post-phase), were completed after every phase: a total of three times for each participant. The interviews were 10-20 minutes long. The purpose of the interviews was to get feedback on the phase, probing the instructors to provide feedback on their perceptions of difficulty, usefulness and ease of use. The final interviews were after the participant completed the alignment process to discuss the results (post-alignment). The post-alignment interviews allowed participants to share what they thought of the alignment process results and discuss changes they may make to their course. Furthermore, it allowed for feedback on the whole process and the alignment tool.

5.3 Data Collection

Institutional Research Board (IRB) approval at my institution was obtained before conducting the case study (Appendix J). Participants were recruited after IRB approval was granted. All participants were given a copy of the IRB approval and an unsigned copy of the informed consent form. Participants were asked to select a pseudonym, which was recorded on their consent form, pseudonym to course code. The case study protocol was followed, using handwritten notes for both the observations and interviews, to ensure consistency amongst all the participants. Each
participant’s pseudonym was used to identify them in the handwritten notes. At the end of each meeting, the handwritten notes were reviewed with the participants, allowing them to correct or add information. After every meeting, the handwritten notes were digitized so that it would be easier to search. To protect the chain of evidence and ensure the security of the documents, all signed informed consent forms and handwritten notes were stored in a physical location where they were locked in files accessible only by a privately-owned key. The digitized notes are located on a Google Drive folder accessible only by my private username and password.

5.4 Data Analysis

The qualitative process of data analysis is iterative, moving between data collection and analysis [98]. Unlike quantitative research, in which all the data is collected and then analyzed, qualitative research data collection and analysis occur simultaneously so that any insight gained from data analysis may help inform future data collection [98]. As data is collected, it is also digitized for analysis. Analysis occurs through multiple readings of the data to develop a greater understanding of the information collected from the participants [14]. The data is then encoded by locating text segments and assigning them a label, which is repeated until all of the data collected has been encoded [98]. The goal is to analyze the encoded data labels to find common themes that generate a large picture [101]. Qualitative data analysis is “interpretive” in that the researcher’s interpretation and personal assessment of the data will impact the codes and themes selected [98]. Guidelines for qualitative data analysis exist to help researchers [102-104].

Following Saldaña’s guidelines [104], once a set of notes was digitized, data analysis began with two reviews of the responses to the interview questions and the observation notes. The digitized observation notes can be found in Appendix K and the digitized interview notes can be found in
Appendix L. A summary of the notes was created using a worksheet. The worksheet had protocol questions (organized by phase) and questions asked to the participant during the case study as the column headers. If there were responses or observations that did not fit into any of the headers, they were copied into a separate document. This process was completed twice to avoid overlooking any responses or observation notes.

The worksheet summarizing the interview responses and observations was used to identify topics, patterns and meaningful units for each of the four lenses for evaluation (\textit{time, difficulty, effort, and usefulness}). The topics for each participant by lens were recorded. This process was repeated for the responses and observations that did not fit into any header. Overarching themes were determined for each evaluation lens by categorizing the topics, patterns and meaningful units for all of the participants, looking for similarities or differences.

5.5 Trustworthiness

In qualitative research, trustworthiness refers to the strategies used by the researcher to ensure the accuracy and credibility of the research \cite{98}. In this case study, four strategies were used to ensure the accuracy and credibility of the data. The first strategy was member checking. Member checking is asking participants in a study to correct or comment on a draft of the interview or observations \cite{14}. I reviewed the interview notes with the participants resulting in more accurate notes based on verification, feedback and clarification. The second strategy was method and data triangulation. Triangulation is the process of drawing conclusions from multiple sources of data, individuals or processes \cite{98}. In the case study, data was collected through both interviews and observations (method triangulation) and the same data was collected from multiple individuals (data triangulation). The third strategy was an external audit, which is recruiting an individual outside
of the research team to evaluate the findings [98]. A faculty member with no knowledge of the case study served as an external audit. They reviewed the case study protocol and data analysis. The fourth strategy was a pilot study with a participant to evaluate the case study protocol. The pilot study allowed for refinements and improvements of the protocol.

5.6 Positionality

My positionality and worldview have influenced this case study. I am invested in the alignment process and tool and believe that they can help instructors identify ways to improve their course. Furthermore, I hold certain assumptions that may not be true. I assume that the instructors have control over their course syllabus and the changes they can make to the course. I assume that if a participant has good knowledge of curriculum design or has received pedagogical training, then they should be able to complete the phases of the alignment process faster and with fewer struggles than a participant who has no training. I recognize that factors such as the participants’ understanding of the instructions as described in the tool, terminology used and their prior knowledge all play a role. I assume that the participants in the study will have an average degree of computer literacy and will have no problems interacting with the interface due to lack of knowledge about computers or software; I assume that any issues that arise from the interactions are a result of the design of the interface. Further personal influences include nine years of teaching experience at two different institutions; participation in several workshops, trainings and certification programs; and a personal investment and interest in education. My instruction style is student-centered, and my approach to developing and evaluating courses is systematic. I assume that the participants are motivated and willing to evaluate and improve their teaching techniques.
5.7 Conclusion

In this chapter I presented the methodology used to evaluate the practicality of CAAP and AlignET. Collective case studies were used to collect data. Four participants were selected to complete the study. The participants were selected using purposive criterion sampling using three gatekeepers. Following the data collection method outlined in this chapter, the participants signed an informed consent form and selected a pseudonym. The case study protocol was followed to collect data about the participants through observations and interviews using handwritten notes. Member checking was utilized so that participants reviewed the notes to correct or add information. After the observation notes were digitized, data analysis began using the data encoding and theme discovery [103] outlined in this chapter.
Chapter 6: AlignET Findings

The collective case study was conducted with four participants. The participants were observed as they applied CAAP to their course. An alignment report about each participant’s course was generated, which were discussed with the participant in a post-alignment interview. In this chapter, I introduce the participants of the case study, then I will summarize the results from the alignment report for each participant.

6.1 About the participants

In this section, I introduce each participant, their experience teaching the course and their prior knowledge of instructional design. A summary of the course the participant is applying the alignment process to and how they have made changes to the course is provided. Table 6.1 summarizes the participants in the case study. I have chosen not to refer to participants using their pseudonyms, for the Computer Science instructors they’re referred to as CS instructors. The instructors with a training in instructional design they are referred to as ED instructors. The CS and ED instructors were randomly assigned numbers.

6.1.1 CS Instructor 1

CS Instructor 1 was the instructor for the Introductory programming in Python course, a course for non-Computer Science majors. They were teaching the course for the third time and was following the curriculum set by another instructor. CS Instructor 1 has seven years of teaching experience however they had not received any instructional design or pedagogical training. CS Instructor 1’s teaching philosophy is that they do not like to lecture from slides, they feel it is more impactful to teaching coding by using examples and showing students how to write and troubleshoot code.
CS Instructor 1 had inherited the course and taught it multiple times without making any changes to the course. They enjoyed teaching the course and felt it was important to make the course as applicable to each student as possible. CS Instructor 1’s area of research is data visualization and is passionate about teaching it. CS Instructor 1 decided to add the topic “data science” to the course because they felt that it was a necessary topic for students in the course to understand. This topic allowed students to see how the course could be applicable to their major. CS Instructor 1’s goal for the course was to help students develop programming skills that could be applied to their various majors. In the version of the course they were applying alignment to, they made minor changes to the curriculum such as changing the order in which some topics were introduced and the way they taught the lectures. CS Instructor 1 based these changes on feedback from previous instructors for the course and on students’ performance on the various course assignments. They had seen students develop misconceptions in their course, to try and combat these misconceptions they would emphasize concepts and use examples to highlight the concepts students had trouble with.

6.1.2 CS Instructor 2

CS Instructor 2 was the instructor for the Introductory programming in JAVA course and had taught the course a total of 4 times. CS Instructor 2 had never received any instructional design or pedagogical training. Their teaching experiences came from informally helping fellow students, as a graduate teaching assistant and when they became the instructor for the Introductory programming in JAVA course. When CS Instructor 2 had first taught the course they just used the slides provided by the course coordinator, they did not enjoy the experience much because they felt that the course did not teach the essential skills students need to know. CS Instructor 2 felt that the course was moving at a very fast pace and the students did not have enough time to digest the
information presented or learn from their mistakes. CS Instructor 2’s goal for the course was to prepare students for the next sequence of programming courses. They felt there were a set of skills that the student had to learn in their course that would equip them to be better programmers, they called it “street skills”. Skills such as debugging code, learning to use different libraries or finding packages to use.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Affiliation</th>
<th>Course</th>
<th>Instructional Design Training</th>
<th>Number of Years Teaching Experience</th>
<th>Number Times Taught this Class Before</th>
<th>Changes to Course Before the Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS Instructor 1</td>
<td>Computer Science Department</td>
<td>Introductory programming in Python</td>
<td>No</td>
<td>7</td>
<td>3</td>
<td>Minor: reordering lecture topics</td>
</tr>
<tr>
<td>CS Instructor 2</td>
<td></td>
<td>Introductory programming in JAVA</td>
<td>No</td>
<td>3</td>
<td>4</td>
<td>Major: changed all assessments</td>
</tr>
<tr>
<td>Ed Instructor 1</td>
<td>School of Education</td>
<td>Civic Identity Development</td>
<td>Yes</td>
<td>4</td>
<td>4</td>
<td>Major: completely changed curriculum</td>
</tr>
<tr>
<td>Ed Instructor 2</td>
<td>Engineering Education</td>
<td>Foundations of Engineering</td>
<td>Yes</td>
<td>6</td>
<td>4</td>
<td>Minor: added 3 more assignments</td>
</tr>
</tbody>
</table>

Table 6.1: Summary of Participants in the Case Study

CS instructor 2 did not feel that was captured the course, so when they had complete autonomy over the course in the summer session CS Instructor 2 had made many changes to the curriculum.

The version of the course they were applying alignment too had been changed drastically from the
previous semester, CS Instructor 2 adapted the syllabus to the students enrolled in the class. The majority of students in the class were repeating it and a few were just taking the class for the first time. CS Instructor 2 wanted to slow the pace down of the course, focusing on the basics. CS Instructor 2 reduced the number formative and summative assessments in the course. They had also made their exams untimed and used handwritten tests and no multiple-choice questions. They felt that the goal of the assessments was to see how well students learned the content and using timed exams will not help them do that. CS Instructor 2 wanted to keep students at ease allowing them to focus on their answers not the time. They based their course changes on the students’ performance in the course over the previous semesters and what they thought would most benefit the students.

6.1.3 ED Instructor 1

ED Instructor 1 was the instructor for a Civic Identity Development course and had taught the course four times. ED Instructor 1 had four years of teaching experience. They had attended multiple pedagogy workshops and took many education courses. ED Instructor 1 is very passionate about teaching and more specifically the civic identity development course. ED Instructor 1 had inherited the course and they did not like the curriculum. They felt that the curriculum did not address key issues of social justice that present itself with any civic identity work. They also felt that the course was lacking the “community” component, which they are an expert in. ED Instructor 1 wanted to make the course eligible for their institution’s general education requirements, allowing different students with different majors to enroll in the course. As a result, ED Instructor 1’s course had to meet some minimum requirements for the general education courses.
ED Instructor 1 made major changes to the curriculum from the previous instructor. They wanted to start with a clear vision that articulated what they expected students learn from the course. They changed all of the learning objectives for the course and used Bloom’s taxonomy when rewriting the learning objectives. They consulted three experienced faculty in the School of Education who helped them formulate the learning objectives, making sure that the learning objectives were correct. ED Instructor 1 also changed all of the assignments and the format of the class. They had a more interactive format, with fewer lecturing and brought guest speakers for class discussions. They were purposeful with the design of their class making sure that all of the assignments and lectures addressed the overall class goals. ED Instructor 1 based their course changes on the feedback from students about the course and by discussing the course objectives and design with the experienced faculty in the School of Education.

6.1.4 ED Instructor 2

ED Instructor 2 was the instructor for a Foundations of Engineering course and had taught the course four times. The course was the second sequence of preparatory courses for first year engineering majors. ED Instructor 2 has six years of teaching experience. They had attended multiple workshops for teaching development and taken many education courses. ED Instructor 2 wanted students in their course to acquire a combination of interpersonal, technical and writing skills. The Foundations of Engineering course curriculum was set by the Engineering Education department and all the instructors for the course meet weekly to make decisions about the curriculum. ED Instructor was invested in the course and viewed themselves as critical to preparing future engineers by giving them the critical thinking skills that they will later use.
ED Instructor 2 changed the curriculum from the previous semesters, they added three more assignments on ethics. They felt that engineering ethics is a very important topic that was not covered thoroughly in the previous curriculum. ED Instructor 2 added the assignments to give students more opportunities to think about ethical issues in engineering. ED Instructor 2 used the results from the summative assessments as well as evaluating the course content to decide on these course.

### 6.2 Time Required to Evaluate Alignment using AlignET

I recorded the time each participant spent on each phase of the computer assisted alignment process. The participants of the study took between 45 minutes and 11 hours to complete the alignment process using AlignET. Figure 6.1 summarizes the total time each participant took to complete the alignment process and the time they spent on each phase of the alignment process. CS Instructor 2 took the longest time to complete the process (10.70 hours) and ED Instructor 1 took the least amount of time (45 minutes). In the first phase, identifying learning objectives and assigning level of cognitive skill, ED Instructor 2 took the most amount of time to complete the phase (2.40 hours) and in contrast ED Instructor 1 took the least amount of time (0.3 hours). Both ED Instructors had a background in instructional design and knew how to create learning objectives. ED Instructor 2’s course had a predefined list of learning objectives that they did not agree with. ED Instructor 2 reformulated the learning objectives of their course, taking time to “think of the best wording” for each learning objective. Both CS Instructors have no instructional design background and took approximately the same time to complete the phase.

For building content matrix, the second phase, the instructor went through all of their course materials identifying course content that addressed each learning objective. CS Instructor 2 took a
long time to complete the phase (5.37 hours). There are many reasons why this could be the case. Since the methodology used is a case study, I do not have evidence to explain the time spent. I did not control for time, task complexity, distractions or other possible effects on time performance. One possible explanation is the number of course components in the course captured by this instructor. CS Instructor 2’s course had 20 lectures, 44 in-class iClicker questions, 11 lab assignments, 8 post-lab quizzes, 7 in-class quizzes, 8 reading assignments, 11 homework, 3 programming assignments, and 2 exams. This course had the most components to be entered into AlignET and thus it is possible that this was a significant factor explaining the time to complete the task. In contrast, ED Instructor 1 had fewer course components: 14 lectures, 7 reflection assignments, 1 ePortfolio, 5 papers, and 3 homework assignments. It took them 0.35 hours to build a content matrix. Figure 6.2 summarizes the time required to complete the content matrix and how many course components the instructor had.

In the final phase, building assessment matrix, the instructors mapped the learning objectives that each assessment question addressed and listed any content with similar cognitive skill. CS Instructor 1 and the ED Instructors took around the same time (average 9 minutes). They had fewer assessments and questions on each assessment than CS Instructor 2. It took CS Instructor 2 4.22 hours to complete the assessment matrix. They had a midterm exam with 29 questions and a final exam with 25 questions. CS Instructor 2 had made their exams “untimed” to give students no time constraints, resulting in their exam having many questions. Figure 6.3 summarizes the time required to complete the assessment matrix and how many questions on the summative assessment the course had.
Figure 6.1: Time required to complete each phase of the alignment process by the participants

<table>
<thead>
<tr>
<th>Instructor</th>
<th>Learning Objectives</th>
<th>Content Matrix</th>
<th>Assessment Matrix</th>
<th>Total (in hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ed Instructor 1</td>
<td>0.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ed Instructor 2</td>
<td></td>
<td>3.50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS Instructor 1</td>
<td></td>
<td>3.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS Instructor 2</td>
<td></td>
<td></td>
<td></td>
<td>10.70</td>
</tr>
</tbody>
</table>

**Legend:**
- **Learning Objectives**
- **Content Matrix**
- **Assessment Matrix**
- **Total (in hours)**

Figure 6.2: Scatterplot of the Number of Course Components and Time required to Fill out Content Matrix for each participant
Figure 6.3: Scatterplot of the Number of Questions on Summative Assessment and Time required to Fill out Assessment Matrix for each participant

6.3 Summary of Results from AlignET Reports

Each participant in the case study followed CAAP prompted by the static wireframe mockups of the alignment tool (AlignET) to evaluate the degree of alignment of their course. I automated the evaluation of the course alignment and generated a report for the participants to review (Appendix D). Alignment was evaluated using the four attributes: structure of knowledge, range of knowledge, depth of knowledge, and balance of representation. The degree of alignment was assigned a value on a scale (full, acceptable and insufficient) while balance of representation is assigned a value under-represented, over-represented and balanced. Table 6.2 summarizes the results of the alignment report for all of the participants for structure of knowledge, depth of knowledge and range of knowledge. Table 6.3 summarizes the percentage of assignments with no learning objectives. In this section I describe the results from alignment report for each of the participants.
<table>
<thead>
<tr>
<th>Participant</th>
<th>Structure of Knowledge</th>
<th>Depth of Knowledge</th>
<th>Range of Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS Instructor 1</td>
<td>Full</td>
<td>Acceptable</td>
<td>Acceptable</td>
</tr>
<tr>
<td>CS Instructor 2</td>
<td>Full</td>
<td>Insufficient</td>
<td>Acceptable</td>
</tr>
<tr>
<td>ED Instructor 1</td>
<td>Full</td>
<td>Full</td>
<td>Full</td>
</tr>
<tr>
<td>ED Instructor 2</td>
<td>Full</td>
<td>Acceptable</td>
<td>Full</td>
</tr>
</tbody>
</table>

Table 6.2: Summary of the results of the alignment process for each participant

6.3.1 CS Instructor 1

The degree of alignment of the structure of knowledge for CS Instructor 1’s course was full, where all the questions on the assessment matrix matched a learning objective. The depth of knowledge for the Introductory programming in Python course was acceptable, with 7% of the assignments having no learning objectives. For range of knowledge the course had acceptable alignment, with 5% of broken links between the content and assessment matrices. The balance of representation for CS Instructor 1’s course was evaluated for each learning objective. Figure 6.4 summarizes the percentage of under-represented, over-represented and balanced learning objectives for participants. The course had a total of 44 learning objectives, 18% of the learning objectives were under-represented, 65% were balanced, and 18% were over-represented.
One key imbalance in CS Instructor 1’s course was related to the learning objectives about data science where all of the learning objectives for that topic were under-represented. CS Instructor 1 was surprised.

*CS Instructor 1*: “I thought I was focusing enough on Data Science. I think it’s the most relevant and important part of the course.”

Although the instructor had a variety of course content to cover the learning objectives in that topic, they required students to demonstrate high order thinking and compared to other topics with a similar cognitive skill they were spending fewer lecture time, assigning fewer homework, and did not have enough questions on the assessments.
Overall, the results from the alignment report did not surprise CS Instructor 1, they had noticed students’ blank faces in class or noticed patterns in their submitted work.

CS Instructor 1: “it’s what I expected. I could tell from their results.”

From their experience teaching the course CS Instructor 1 had identified a few misconceptions students had about programming in Python. They found trends in their responses and common questions students asked. To address these misconceptions, CS Instructor 1 modified their instructional method. They tried to emphasize these misconceptions in their lectures and showed students code examples instead of teaching from the lecture slides. The alignment report confirmed some of the misconceptions and challenging topics students faced in the introductory programming in Python class. CS Instructor 1 thought that modifying the lectures would be enough to address the misconceptions, after viewing the alignment report they would make changes to the course so students could practice problems addressing the misconceptions outside of the lecture.

6.3.2 CS Instructor 2

CS Instructor 2’s course also had full structure of knowledge, where all the questions on the assessment matrix matched a learning objective. The depth of knowledge for the introduction to programming in JAVA course was insufficient, with 56% of the assignments having no learning objectives. For range of knowledge the course had acceptable alignment, with 4% of broken links between the content and assessment matrices. The balance of representation for CS Instructor 2’s 54 learning objectives of the course were: 9% of the learning objectives under-represented, 77% balanced, and 14% over-represented.

CS Instructor 2’s course had many course components (Lectures, iClicker Questions, Lab Assignments, Post-lab Quiz, Homeworks, Reading Quizzes, Programming Assignments, and
Exams). They inherited the course syllabus and made modifications to the content based on what they thought were important skills students needed to know. Many of the learning objectives focused on only one or two types of content, creating an imbalance in the variety of instructional methods. CS Instructor 2 identified many goals for the introduction to programming in JAVA course.

CS Instructor 2: “There are just things they have to know! They need to be able to use logic and think.”

CS Instructor 2 believed in the importance of critical thinking skills, to encourage their students to develop those skills they used tracing problems. They asked students to hand trace a program snippet to understand and solve the problem. However, this was over-emphasized taking class time and content away from other skills. Another goal was to ensure students had a strong understanding of the foundational concepts of the course. As a result, many of the learning objectives with low order cognitive skills were over-represented and many of the learning objectives with higher-order cognitive skills were under-represented. CS Instructor 2 felt that the results from the alignment report helped them understand their course, by looking at the content matrix they could articulate how the course content was distributed and where there were gaps. Their course was the least aligned out of all the instructors.

6.3.3 ED Instructor 1

ED Instructor 1’s course had full structure of knowledge, range of knowledge, and depth of knowledge. There were no broken links in their content and assessment matrices, and there were no assessment questions with no learning objectives. The course had a total of 7 learning objectives, with 14% of under-represented learning objectives, 86% of balanced learning objectives, and no over-represented learning objectives. Compared to other learning objectives
with similar cognitive skill, the under-represented learning objectives had fewer reflection assignments and were not part of the final paper.

*ED Instructor 1:* “This is so validating! All of the hard work and time I put into redesigning my course.”

ED Instructor 1 felt that the results of the alignment report reflected their intentional course design, and the time and effort spent to create a course that “worked well together”. They had redesigned their course with the help of experienced faculty in the School of Education. Out of all of the participants their course was the most aligned.

![Table 6.3](image)

<table>
<thead>
<tr>
<th>Participant</th>
<th>Assignments with no learning objective</th>
<th>Broken Links</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS Instructor 1</td>
<td>7%</td>
<td>5%</td>
</tr>
<tr>
<td>CS Instructor 2</td>
<td>56%</td>
<td>4%</td>
</tr>
<tr>
<td>Ed Instructor 1</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Ed Instructor 2</td>
<td>11%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 6.3: Percentage of assignments with no learning objectives and percentage of broken links in content matrix

### 6.3.4 ED Instructor 2

ED Instructor 2’s course had full structure of knowledge and range of knowledge. Their course had acceptable depth of knowledge with 11% of their assignments not corresponding to a learning objective. It is important to note that all of these assignments were to prepare students for future class activities. For example, downloading and installing software. For balance of representation,
the foundations of engineering course had 30 learning objectives: 20% were underrepresented, 80% were balanced, and none were over-represented.

The majority of the course’s under-represented learning objectives were on topics covering the design process. The learning objectives were assigned a high level of cognitive skill by the instructor, compared to other learning objectives with similar cognitive skill, the learning objectives had fewer individual assignments and no group assignments addressing them. The alignment report did not provide ED Instructor 2 with much new information and they found none of the information surprising.

6.4 Conclusions

In this chapter I introduced the participants from the case study, the time the participants took to complete CAAP as well as the results from the alignment reports generated by AlignET. Four instructors applied CAAP to their courses, two instructors were from Computer Science and had no instructional design background, and two instructors were from the School of Education with a strong background in instructional design. The instructor’s courses’ alignment was evaluated using the structure of knowledge, range of knowledge, depth of knowledge and balance of representation attributes. For structure of knowledge all of the participants had full alignment. For depth of knowledge only ED Instructor 1’s course had full alignment, CS Instructor 1 and Ed Instructor 2’s courses had acceptable alignment and CS Instructor 2’s course had insufficient depth of knowledge where 56% of their assignments had no learning objectives. Both Ed Instructors had courses with full range of knowledge while the CS Instructors had courses with acceptable range of knowledge. Both instructors had approximately 5% of broken links between their content and assessment matrices (Table 6.2).
All of the participants had learning objectives that were balanced and under-represented, the ED instructors had no over-represented learning objectives. Both ED instructors had 14% - 20% of their learning objectives that were under-represented. The CS Instructors also had under-represented learning objectives, CS Instructor 1 had 9% of their learning objectives under-represented and CS Instructor 2 had 18% of their learning objectives as under-represented.
Chapter 7: Evaluation Findings

Through the case study observations and interviews I explored the instructor’s perceptions of the usefulness of the results of AlignET, the difficulty of applying the AlignET, and the time invested to complete AlignET. In this chapter I summarize the findings and emerging themes from the study.

7.1 AlignET’s Useful Results - Making Informed Changes to the Course

The results of the alignment process highlighted misalignments in each of the participant’s courses. The alignment report detailed how each course’s alignment was evaluated using structure of knowledge, depth of knowledge, range of knowledge, and balance of representation. CS Instructor 2’s course had the most misalignments, ED Instructor 1’s course had the least and CS Instructor 1 and ED Instructor 2 had a few misalignments. All of the participants had full alignment of the structure of knowledge of their courses.

After an instructor completed each phase of the alignment process, I conducted a post-phase interview as well as an exit interview where we discussed the findings of the alignment report. The interviews allowed me to determine the instructor’s views on the usefulness of the results of the alignment tool. The following three themes emerged from the discussions: identifying changes to the course, balance of representation as a metric for alignment, and autonomy over the design of the course.

7.1.1 Identifying changes to the course

After reviewing the alignment report the participants were able to identify areas in their course that they could improve. From the results of the range of knowledge CS Instructors 1, 2 and ED
Instructor 2 had assignments with no learning objectives. CS Instructors 1 and 2 added new learning objectives to address the assignments with no learning objectives. CS Instructor 1 had 7% of their assignments that did not correspond to a learning objective, they were focused on what the instructor described as “basics”. These were assignments that were designed to introduced a topic and were not directly related to the topic. Similarly, CS Instructor 2 had “basics” assignments to introduce a topic but they were not directly related to the topic. CS Instructor 2 had 56% of their assignments with no corresponding learning objective. ED Instructor 2 did not feel that they needed to add learning objectives to address the assignments since the purpose of those assignments was to prepare students for future assignments for example, installing software.

(1) **ED Instructor 2**: “They’re not assignments like the others, the goal is to have an activity every week.”

Through reflections and discussions, ED Instructor 2 decided that there should be learning objectives added to address these assignments. ED Instructor 2 mentioned that all the activities in a course should “work together” to help address any learning objective. The CS Instructors also understood the importance of having their assignments map to a learning objective so that students learning is directed to what the instructors expect students to learn.

(2) **CS Instructor 1**: “I need to think carefully about what learning objectives are in my course and what do I want them to convey”

CS Instructor 1 recognized the importance of starting off with learning objectives that are conveying the expectations they have from students, including their “unconscious” expectations. CS Instructor 1 was realizing the importance of reflecting on their expectations of students in their course. AlignET had provided them with an opportunity to view their course from a different perspective.
Another change identified by the instructors was changing the course work to better address the learning objectives. CS Instructor 1 re-evaluated the purpose of some of the activities in the course, they recognized that there was a gap between their expectations from the students and the assessment methods. They identified five assessment questions they would change. CS Instructor 1 had continued to reflect on the alignment of their course and how to impacts their teaching.

(3) CS Instructor 1: “This strategy is useful, listing all I want to cover in my course and mapping it to course work”

From quote 3, CS Instructor 1 recognized that the way they design their course may be improved. They felt it would be more beneficial to start with the learning objectives of the course and then design the course content to map to the learning objectives.

Similarly, CS Instructor 2 needed to change their course expectations.

(4) CS Instructor 2: “I want students to achieve a level 2 cognitive skill for reading and writing files but I don’t have assignments.”

From quote 4, CS Instructor 2’s course had many low-level cognitive skills learning objectives, a few of them were covered heavily in the beginning of the semester leaving fewer class-time later on in the semester to cover other topics. A key change that CS Instructor 2 highlighted in the quote below:

(5) CS Instructor 2: “I need to change my assignments; I focus too much talking about the basics”.

Many of the learning objectives with low level cognitive skills were over-represented in the course, while learning objectives with higher level cognitive skills were under-represented. CS Instructor 2 had dedicated more time to covering the basics. They felt that this was important because the course was a foundational course with foundational concepts students needed to master before
moving on to other topics. After discussing the alignment report with them, CS Instructor 2 recognized that they over-emphasized the basics not giving enough time to the other topics they felt were important.

From the results of the balance of representation, ED Instructor 1 identified two changes they could make to their course to address the under-represented learning objective. They suggested incorporating more reading assignments into the reflections. They would also change the type of assignments to more synthesis than just reflection.

(6) **ED Instructor 1**: “No wonder students say the course is repetitive!”

ED Instructor 1 mentioned that students described their course as repetitive, the results of the alignment process provided them with evidence to support the student’s feedback. They had intentionally redesigned their course so that students could acquire reflection skills and had scaffolded the curriculum with various activities to promote reflection. From viewing the content in the content matrix, ED Instructor 1 could easily identify the components that were repetitive. As highlighted in Figure 7.1, ED Instructor 1’s content matrix highlighted that all of the reflection activities addressed all of the learning objectives. On all 8 of the reflective activities, students were exposed to the same learning objectives. The content matrix provided visual proof of the repetitiveness of the reflective activities.
The balance of representation results provided CS Instructors 1 and 2 evidence of which learning objectives they put too much emphasis on. Both had over-represented learning objectives. They were going to reduce some homework questions for some of the over-represented learning objectives and use those questions to address some of the under-represented learning objectives.

(7) CS Instructor 2: “I will remove some of the labs and add more homework for the under-represented stuff”.

CS Instructor 2 (quote 7) also referred to the content matrix to make decisions about how to modify their course to address the under-represented and over-represented learning objectives. Looking at the content matrix CS Instructor 2 could pinpoint which assignments to remove and where to add new assignments to address the imbalance.

7.1.2 Balance of representation as a metric for alignment

After the completion of the alignment process using the tool, the participants were interviewed in a post-study interview. They were asked “what is curriculum alignment”? All of the participants described balance of representation in their definition of alignment. Referring to “the balance of
topics over all of the course”, “over emphasis or under emphasis of learning objectives”, or “make sure there is proper balance of representation in relation to different levels of bloom’s taxonomy”. CS Instructors 1, 2 and ED Instructor 1 used the results of the balance of representation to identify changes to make to their course. Both CS instructors went back to the content matrix and identified assignments to remove, and where to add more assignments.

(8) CS Instructor 1 “Look at the very high-level learning objectives to make sure I have more assignments”

Evidence from the quote above, CS Instructor 1 recognized that learning objectives with higher-order level of cognitive skill may require more content to help students reach higher level of mastery. For example, compared to other learning objectives with level 5 cognitive skill in the same topic, “Understand chaining functions” had no final exam questions and few homework questions compared to the level 4 “Understand how parameters, arguments, returning values work” and other level 5 learning objectives from other topics. CS Instructor 1 decided to incorporate more homework questions to address the learning objective.

Although ED Instructor 2 did not provide any changes to make to their course based on the results of the balance of representation, it did provide them with insights on what they emphasize when teaching. They disagreed with the findings of one of the learning objectives being over-represented.

(9) ED Instructor 2: “It has to be that way because it’s a basic skill they’re required to master”.

After a discussion about the skills required to meet the learning objective, ED Instructor 2 recognized that they had mis-labelled the level of cognitive skill required for the learning objective.
They had labelled the learning objective as a lower level of cognitive skills, while they were expecting a higher level of mastery.

Similarly, CS Instructor 2 had disagreed with the findings that some of the learning objectives related to basics were over-represented.

(10) CS Instructor 2: “They need to practice these skills, so of course there should be more content on them!”

Like ED Instructor 2, CS Instructor 2 mentioned that there has to be a lot of content on the basics so students can master them. It was a foundational course with foundational concepts that students had to master. They felt that students needed to spend time on the basics so that they can master them. After further reflection, CS Instructor 2 decided to remove some homework questions and stick to the programming practice. They recognized that the homework questions did not necessarily help students master the basics but programming practice was more applicable. CS Instructor 2 realized that basic or foundational learning objectives did not have to be a low order cognitive skill, they recognized that a deeper understanding of the learning objective was needed demonstrating mastery of the topic. They changed the level of cognitive skill of one of their basics learning objectives, increasing the level of mastery the students were required to demonstrate. The results from the alignment report helped the instructors re-evaluate the level of cognitive skill for the learning objectives or modify the number of assignments for the learning objective.

There was a common misconception amongst CS Instructors that foundational concepts or basics had to be of a lower level of cognitive skill because they are introductory or basic. Many of the over-represented learning objectives were of low-level cognitive skill (levels 1 or 2), however the
instructors expected the students to achieve a higher level of cognitive skill to master the concept. As a result, the instructors had a lot of content covering those learning objectives, resulting in an over-represented learning objective. This misconception may be a result from not fully understanding Bloom’s taxonomy and lack of experience developing learning objectives.

7.1.3 Autonomy over the design of the course

The adoption of the changes the participants identified for their course was greatly dependent on the autonomy the participant had over the course. ED Instructor 1 had complete autonomy over their course and was going to apply the changes immediately so that they would take effect the next time they teach the course. CS Instructor 1 had some autonomy over their course, they were going to make some of changes they identified for the next time they teach the course. On the other hand, CS Instructor 2 and ED Instructor 2 had limited autonomy over the design of their courses. They both taught courses that were managed by a course coordinator, dictating the content of the course to ensure that all of the course instructors taught from a similar syllabus.

ED Instructor 2 was going to make changes to the ethics portion of their course but could not apply any of the other changes before consulting with the course coordinator. Similarly, CS Instructor 2 could not apply the changes to their course for the Fall or Spring semesters before consulting the course coordinator. They have more autonomy in the summer and would apply all of the changes to their summer course.

(11) CS Instructor 2: “It would be good to apply this process across all of the sections teaching the course.”

CS Instructor 2 (quote 11) recommended applying the alignment process to all of the sections teaching their course. They felt it would be helpful to evaluate the alignment of the different
versions of the same course and to compare results. They felt that this activity would help the course coordinator identify the common misalignments amongst all of the courses as well as highlighting individual misalignments in each version of the course.

7.2 AlignET and CAAP’s Difficulty of Use

I wanted to examine the instructor’s views on the difficulty of using the alignment process and AlignET to evaluate the alignment of their course. By observing the instructors go through the process I noticed critical incidents, times when instructors were hesitant or confused and at times they asked me questions for clarification. Through questions in participant observation role and interviews I concluded three common themes about the complexity of using AlignET: difficulty when formulating learning objectives, impact of instructional design knowledge, and improvements to the tool.

7.2.1 Difficulty when formulating Learning Objectives

Out of all the phases the participants seemed to struggle with phase one the most. CS Instructor 1 and 2 struggled a lot to write the learning objectives of their courses.

(12) CS Instructor 1: “I understood the concepts in the tutorial but I had no idea where to start.”

Quote 12 provides evidence that CS Instructor 1 did not know where to start after watching the tutorial on learning objectives. Similarly, CS Instructor 2 had difficulty starting the task. They understood the concept of learning objectives but could not start writing the learning objective, they were confused about where to start and what to look for when writing a learning objective. Both instructors took some time revisiting through their syllabi, learning management system (Canvas) course site as well as the instructions on how to create learning objectives (Appendix B). After asking for help, I asked the instructors “how did you come up with the content in your course”. Both instructors mentioned they had started off with a list of topics they wanted to cover.
This prompted the CS instructors to use the list of topics as a possible starting point to develop their learning objectives. CS Instructor 2 attempted to use the list of topics covered in the syllabus as a starting point. They then referred to the lecture slides to identify learning objectives. After defining some learning objectives, they asked

(13) CS Instructor 2: “What about skills I want them to learn that are not in the slides but I teach them by showing code examples.”

CS Instructor 2 added learning objectives that described skills students were supposed to acquire at the end of the course. CS Instructor 1 used a similar approach, their lecture slides had some goals and topics they were going to cover. They used these as a starting point and used the list of action verbs in the tutorial to try to formulate the learning objectives.

Both CS instructors used the verbs from Bloom’s taxonomy to write the learning objectives that were non-measurable action verbs to describe the learning objectives for their course. While the learning objectives were not accurate, that did not prevent the instructors from completing consequent phases of the process or evaluating the alignment of their course. Furthermore, the CS instructors were confused with the difference between learning objectives and goals for the class. Both were easily able to articulate their goals for their class but translating the goals to learning objectives were challenging.

(14) CS Instructor 2: “[purpose of phase one is] To learn about the goals and sub-goals of the class. Goals are each topic.”

At the end of the defining the learning objectives phase, CS Instructor 2 had developed a system for identifying the learning objectives. First they started off with the topics of the course then they drilled down to identify sub-goals, these goals became the learning objectives for the course.
ED Instructor 1’s class had a list of defined learning objectives. Similarly, ED Instructor 2 had a list of learning objectives set by the course coordinator but they did not agree with them. They spent time reformulating the learning objectives, struggling to phrase them, they were hesitant and always second guessing their wording. They used an iterative approach to develop the learning objectives, the first iteration was a modification of the original learning objectives and adding new learning objectives. In the second iteration ED Instructor 2, rephrased some of the learning objectives and decided to continue with the alignment process. In other iterations, they would revisit the learning objectives after examining some of the content to update or modify the wording. They also added learning objectives in later stages of the alignment process. ED Instructor 2 felt that the tool tutorial did not help.

(15) ED Instructor 2: “you can’t use a tutorial to teach someone to create learning objectives”.

ED Instructor 2 noted that creating learning objectives is difficult even for people with a background in instructional design and having just a few tutorials to teach how to create a learning objective was not practical.

ED Instructor 1 took the least time to identify the learning objectives, they had consulted three experienced faculty in the School of Education to help them formulate the course’s learning objectives and had guided them in the redesign of their course. Unlike the other participants, their learning objectives were all correctly formulated with clear measurable outcomes.

All of the participants hesitated when defining the level of cognitive skill of the learning objectives. The instructors with a background in instructional design (ED Instructors), had to revisit the level
of cognitive skills of the learning objectives and modify them as they were building the content matrix. The CS Instructors also made revisions to the level of cognitive skills of their learning objectives. They seemed to have the misconception that the level of cognitive skill was directly related to how advanced a topic was. They often labelled the foundational learning objectives with low level of cognitive skill and the learning objectives covering advanced topics with higher level of cognitive skill.

7.2.2 Impact of instructional design knowledge

There seemed to be little impact of knowledge of instructional design on the participants ability to complete the alignment process. All of the participants asked for clarification when building the content matrix. They were not sure how detailed they should be when filling out the matrix. Having completed the content matrix, the assessment matrix was very straightforward to complete, taking the participants less time than the content matrix. Other factors such as the number of course components, how the course was redesigned, and the degree of autonomy they had over the course impacted the time they took to complete each process. Knowledge of instructional design did not seem to impact the instructor’s ability to understand the results of the alignment process. All of the participants understood the results from alignment process and could easily identify course improvements.

Instructional knowledge played a role in the instructor’s ability to define the learning objectives correctly. CS Instructors’ learning objectives were not measurable and often used non-action verbs. Both CS Instructors had no instructional design training unlike ED Instructors, yet all participants hesitated and reviewed their learning objective’s level of cognitive skill. CS Instructor 1 faced the most difficulty when choosing the level of cognitive skill, as evidence by this quote.
CS Instructor 1: “Trying to think of the learning objective and rationalize what I want students to know is hard”.

CS Instructor 1 was not familiar with the definitions of the levels applying, creating and analyzing in Bloom’s taxonomy, often mislabeling the level of cognitive skill of their learning objectives. ED Instructor 2 noted that defining learning objectives is a difficult activity that even experienced instructors with a background in instructional design can find challenging. ED Instructor 1 highlighted that developing learning objectives is an iterative process; with each iteration the learning objectives get better.

ED Instructor 1: “You bounce ideas off each other and it’s good to have people check [learning objectives] for you.”

ED Instructor 1 recommended consulting with other faculty about the course learning objectives, to get feedback and to improve the learning objectives. CS Instructor 2 agreed that having me there as a sounding board was helpful to them. Although I did not tell the instructors how to create the learning objective, they felt that talking out loud was very helpful to them.

CS Instructor 1 felt that defining the learning objectives was a challenging that needed practice.

CS Instructor 1: “[you] need more time to think about it”

They felt that having access to Bloom’s taxonomy and taking their time to think about the learning objectives and level of cognitive skill would be helpful. They noted that this process would naturally take time because more thought needs to go into it and they would eventually get better at it.
7.2.3 Improvements to the tool

The participants found the tool structured and easy to use. They thought that the tabular entry for the content and assessment matrices was helpful. For example,

(19) CS Instructor 1: “sheets are handy, having large content in forms is not readable.”

CS Instructor 1 said that having a tabular format made it easier for them to enter the content and assessment matrices, as well as view the matrices. The instructors would view the matrices when making decisions about course improvements. The ability to switch from one phase to another to make revisions worked well.

(20) ED Instructor 1: “Helpful to be able to edit and change the content or learning objectives as I remember things”

All of the participants felt that the flexibility to move between phases and make edits was helpful. All of the participants would make revisions throughout the process: adding new learning objectives, modifying the level of cognitive skill of the learning objectives, moving content in the content matrix, or changing content in the assessment matrix.

The participants felt that the tutorials and help features could be improved. For example, in phase one (defining the learning objectives), there were many tutorials on how to write learning objectives but there was no way to verify the participant was writing measurable learning objectives. CS Instructor 1 suggested adding a parser check for the learning objectives to check for non-measurable action verbs. This feature would help the instructor write better learning objectives by scanning for a list of action verbs from Bloom’s taxonomy and highlight any objectives that do not have an action verb. CS Instructor 2 suggested including an interactive step-by-step guide for completing the learning objectives. For example, step 1, what are the big topics
you want students to learn? Instructors would enter the big topics. Step 2, for each topic think about what skills or concepts you want students to master? These steps would break down the task of writing learning objectives and provide instructors with feedback.

The participants also noted that help features were not always descriptive enough. For building the content matrix, the participants had all asked for clarification about the level of granularity needed for the content matrix. ED Instructor 1 suggested using more prompts and examples. They recommended including tips for example, “when filling out the content matrix look in the syllabus for...”. These tips would help prompt the instructor on what to look for when completing the phase.

There appeared to be two schools of thought regarding the role of the tool in supporting instructors with limited instructional design knowledge. The CS instructors felt that AlignET should help scaffold any instructional design knowledge that the user needed to complete the various phases of the process. The improvements suggested by the CS instructors help mitigate any gaps of instructional knowledge the instructor may have and help correct their learning objectives. The ED instructors had a different thought, they felt that the tool may help prompt the instructor to complete tasks in the alignment process but they did not believe that the tool would be able to limit instructional design knowledge. Both ED instructors acknowledged the difficulty of defining learning objectives and that it required experience, practice and instructional design knowledge. ED Instructor 2 felt that a tool could not replace instructional design knowledge.

7.3 AlignET’s Time Investment – The Instructors’ Perceived Effort

Effort required to complete the alignment process using AlignET is an important factor that can determine whether an instructor is likely to re-use the tool again or not. I wanted to examine the
instructor’s views on the effort required to evaluate the alignment of their course using AlignET. Through the observations and interviews I concluded three common themes amongst the instructors: time consuming but not challenging, reusing the tool again, and seeing the big picture.

7.3.1 Time consuming but not challenging

The participants felt that the alignment process using AlignET was time consuming but not challenging. CS Instructor 2 described their experience using AlignET as “not too involved”, they indicated that building the content and assessment matrix was a lot of “grunt work”.

(21) CS Instructor 1: “[It is] easy overall but just time consuming and trivial”.

CS Instructor 1 noted that the high level of granularity made the process time consuming. Both ED instructors described the tool as not too taxing.

(22) ED Instructor 2: “[it] just took a long time, not necessarily taxing”

The participants were asked their perceptions of the process after every phase of CAAP. After phase 2 building the content matrix, the participants indicated the process as time consuming or grunt work. After completing the entire process and receiving the report, the perceptions of the participants changed. CS Instructor 1 mentioned that understanding the purpose of the content matrix made the time spent not a negative aspect.

(23) CS Instructor 1: “In hindsight I see why I had to be detailed.”

They had felt that the high level of granularity made the process time consuming, but after understanding how it impacted the results, they did not mind filling out the content matrix in detail. Similarly, CS Instructor 2 referred back to the content matrix in the post alignment interview and appreciated how the matrix gave them an overview of their course.
7.3.2 Reusing the tool again

Three out of the four participants agreed that the effort required to complete CAAP using AlignET would not deter them from repeating the process using the alignment tool. CS Instructor 2 felt that the tool would be particularly helpful for large courses with multiple classes and instructors.

(24) CS Instructor 2: “[ensure that] we’re all [of the instructors are] on the same page.”

They felt that checking the alignment of the instructors’ courses would make sure that students are all learning the same content. CS Instructor 2 believed that the course coordinator for their course would benefit from applying alignment to all sections of their course.

ED Instructor 1 would use AlignET on their other courses and on service projects. They wanted to apply the process on a smaller scale to see if their service projects were aligned with the project goals.

(25) ED Instructor 1: “[The process] useful in the early stages of re-developing a course”

ED Instructor 1 also felt that the process would be helpful when redesigning a course, using the process early on in course design may be beneficial to an instructor.

CS Instructor 1 would reuse the tool when developing a course from scratch or if they had not taught a course for a while. They had found the level of detail required to build the content matrix as time consuming but they saw value in going through the content of the course one by one and in detail.

(26) CS Instructor 1: “Would use it every few years as a refresher”

They decided that they would use AlignET as a way to familiarize themselves with a course they had not taught for a while.
It seemed that knowledge of instructional design impacted the instructor’s decision to re-use AlignET. Unlike the CS Instructors, both ED instructors were not surprised by the level of detail required to complete the content matrix, they implement the steps of CAAP in different contexts when developing their courses. ED Instructor 1 mentioned that starting off with a course learning objectives is standard practice. Both ED instructors use instructional design methods when developing their courses. ED Instructor 1 saw uses for the tool on a lower level but ED Instructor 2 felt that the tool was not appropriate for an experienced instructor.

(27) ED Instructor 2: “It’s a useful activity if you have just started teaching but a more experienced instructor does not need it.”

ED Instructor 2 did not think that they would reuse the tool again, they felt it was a more appropriate tool for someone who has just started teaching. They felt that they already use other instructional design methods to ensure that the design of their course is aligned.

CS Instructor 1 and ED Instructor 1 had highlighted that an impactful use of AlignET would be during course design. Using the process to systematically check that new course components that are added are aligned. AlignET can be used to iteratively design a course. CS Instructor 2 noted that it would be simple to keep re-evaluating the re-design of a course using AlignET.

(28) CS Instructor 2: “I could just go back and edit the content matrix to see changes”

Any changes identified by the instructor could be updated in the content and assessment matrices and re-evaluate alignment to see the impact of the changes made on the alignment of the course.
7.3.3 Seeing the “Big Picture”

Some of the participants felt that completing CAAP allowed them to see their course from a different perspective. CAAP provided a visual representation of the course content and assessments, the tabular format of the content and assessment matrices were helpful to the participants.

(29) ED Instructor 1: “[I can] see how the course operates as a package.”

CAAP provided ED Instructor 1 a view of how different elements in their course meet the learning objectives. It was helpful for them to see how each learning objective was met. Similarly, CS Instructor 2 felt that AlignET gave them a “glimpse of the course” and a “full picture of what [they] teach”.

(30) CS Instructor 2: “[I can] think of class goals and how to create actual course work and tests.”

CAAP provided the instructors with an alternative method to developing and evaluating their course.

The process served as a reflective tool for the instructors, allowing them to view their course and how it connects in ways they had not considered before.

(31) CS Instructor 1: “Makes me think of the course in another way.”

CS Instructor 1 mentioned that building the assessment matrix was a beneficial activity that allowed them to understand their course.

7.4 Conclusions

In this chapter, I presented the emerging themes from the case study findings. I analyzed the instructor’s perceptions of the usefulness of the results of AlignET, the difficulty of applying the
AlignET, and the time invested to complete AlignET. The results of AlignET highlighted misalignments in each of the participant’s courses. All of the participants felt the results were helpful and allowed them to identify course improvements. The degree of autonomy the participant had over the course restricted their ability to implement the course improvement. Balance of representation was a memorable attribute amongst the participants.

Overall the participants did not perceive the process as complex or taxing. The relative advantage and benefits of the process positively influenced their perceptions of the tool. The participants were able to identify key improvements to the tool. Knowledge on instructional design did not seem to impact the participant’s ability to complete the alignment process using AlignET, all of the participants faced challenges when defining learning objectives and level of cognitive skill. While the time invested on process is not a deterrent to reuse the tool, knowledge of instructional design seemed to impact the likelihood the tool will be re-used. The process may not be helpful for experienced instructors and may be more impactful if used during course design than course evaluation.
Chapter 8: Conclusions

In this chapter I discuss the findings of the study and how they address the research questions, then I identify some of the limitations of the case study and how it may have impacted the findings. Finally, I summarize the implications of the findings and future work.

8.1 Revisiting Research Questions

I developed a computer-assisted alignment process (CAAP) that would meet the following design goals:

D.G.1. **Evaluate** the *degree of alignment* of the learning objectives, content and assessments for a course.

D.G.2. **Produce results** an instructor can use to make *informed changes* to their course

D.G.3. **Be applied** by a *single course instructor*

D.G.4. **Reduce time** required to evaluate alignment

D.G.5. Require *no knowledge of instructional design* and *no training* on the process.

The purpose of this research is to create an alignment process that meets previous design goals, to design a static wireframe mockup of an alignment evaluation tool (AlignET) to guide instructor through the alignment process, and to evaluate the practicality of the alignment process. The research answers the following questions:

*RQ.1.* Does the alignment process produce results that support instructors in making informed changes to their course?

*RQ.2.* How difficult or cumbersome is the alignment process and tool for instructors to use?

*RQ.3.* To what extent do instructors find the time invested to evaluate their course alignment to be practical?
RQ.4. What role does instructional design knowledge play in the instructor’s ability to apply the alignment process and tool?

In this section I will highlight how the case study findings have addressed the research goals.

**8.1.1 Research Question 1: Does the alignment process produce results that support instructors in making informed changes to their course?**

Yes, the CAAP provided instructors with an overview of the alignment of their course and in turn pinpointed specific changes to make to their course. Instructors recognized how the course content addressed the course learning objectives and were able to visualize the relationship between the assessments and the various course content. The visual representation of the content matrix allowed instructors to see how the course content was distributed, easily identifying gaps in their delivery methods. The instructors could easily specify course changes to make to address the gaps. Balance of representation was the most memorable attribute for the instructors, allowing them to identify learning objectives they over or under emphasized.

Three out of four participants were able to identify specific improvements to their course. An immediate improvement for all the participants was to add learning objectives to address some of the assignments with no learning objectives, or cancel some of the remaining assignments with no learning objectives. There were two major types of improvements the participants identified: varying instructional methods and redistributing class time or content.

*Varying Instructional Methods*

The content matrix showed the participants the variety of instructional methods they use. This visual representation helped the participants to recognize how to make course improvements. For
example, after recognizing that the content in the course was repetitive, An instructor suggested changing the type of assignments to include synthesis rather than just reflection. The instructor also identified two new projects (new course components) they could add to address the under-represented learning objectives.

An instructor re-evaluated the purpose of the some of the activities in the course, recognizing that a gap between their expectations from the students and the assessment methods. This instructor identified 5 assessment questions they would change, and after viewing the assessment matrix, suggested adding 3 more questions to the final about a specific topic.

*Redistributing class time or content*

The participants also found the balance of representation an easy attribute to understand, providing them with a summary of topics that were being covered more or less than others. One instructor suggested cancelling one of their homework assignments on an over-represented topic and replacing it with an assignment on an under-represented topic. This instructor also updated their learning objectives to include 2 more objectives that addressed the assignments with no learning objectives.

The CAAP presented the CS instructors with an alternative method to make course improvements. Before using the process, the CS instructors relied on their intuition and student feedback to make changes to their course. Often these intuitive changes were not reflected in the course the way the instructors expected. For example, CS Instructor 1 wanted to emphasize the topic data science in their course, they felt it was a very important topic that students needed to learn and had designed
the course to reflect that. However, the results of the alignment report highlighted that the learning objectives for data science were all under-represented. Similarly, CS Instructor 2 wanted their students to have a strong grasp of foundational concepts so that they could build on them more complex programming concepts. The results of the alignment report highlighted that the majority of the learning objectives for the foundational concepts were over-represented while the more complex programming concepts were under-represented.

There were times when the CS instructor’s intuition was correct. For example, CS Instructor 1 was not surprised by some of the results from the alignment report. They confirmed some of the misconceptions and challenging topics students faced in the introductory programming in Python class. CS Instructor 1 had identified trends in their students’ responses and common questions students asked. This led them to believe that students had misconceptions about those topics.

The process also helped instructors think about course development in a different way. The CS instructors in the study relied on their intuition and their teaching experience to develop a course. After completing the CAAP, one of the CS instructors re-evaluated the way in which they design their course. They suggested it may be more effective if they started off with a clear list of learning objectives that articulated their conscious and unconscious expectations from students. The instructor suggested using that list of learning objectives to develop the content and assessments for the course.
8.1.2 Research Question 2: How difficult or cumbersome is the alignment process and tool for instructors to use?

The participants found the tool structured and easy to use. They thought that the tabular entry for the content and assessment matrices was helpful, and the ability to switch from one phase to another to make revisions. Compared to current curriculum alignment models, the CAAP was successful in reducing the need of a panel of experts, thus making it applicable by a single course instructor. Overall the participants did not find AlignET to be difficult to use but the participants had suggestions for improvement. Some of the tutorials were not helpful, the participants suggested improvements to the tool to include more prompts, examples and more descriptive tutorials.

Although the participants did not feel that CAAP was cumbersome to use, they felt it was “grunt work” especially building the content and assessment matrices. The participants sometimes questioned the rationale behind the high level of granularity to build the content and assessment matrices. After completing the process and viewing the results the participants could see the benefit of being detailed when filling out the content and assessment matrices. This presents an important addition to the design of the alignment evaluation tool (AlignET), rationale and motivation for completing the various phases of the alignment process. The current descriptions in Appendix B do not include any rationale for the various tasks the instructor is asked to complete. It would be safe to assume that an instructor using this process voluntarily may also question the effort required to complete the content and assessment matrices with a high level of granularity. The instructor may find the task daunting and un-necessary and may stop applying using AlignET or may choose to not fill out the content and assessment matrices in detail impacting the alignment results.
Including a brief description and rationale of why the matrices need to be completed in a high-level of granularity may increase the motivation of the instructors using AlignET.

The participants had varying expectations from CAAP and AlignET. The CS instructors felt that it was the role of the AlignET to scaffold any instructional design knowledge they did not have. One CS instructor mentioned that it would be helpful if AlignET had a built-in parser that would check the learning objectives written by the user for non-measurable action verbs. They felt that the tool could help them learn instructional design. On the other hand, the ED instructors had a different vision for AlignET. They felt it would be a helpful tool if used in different contexts such as evaluating a course project. They did not believe that a tool could scaffold any instructional design knowledge. The ED instructors mentioned that defining learning objectives is a challenging task that requires experience and practice, using a tutorial would not help an inexperienced instructor in defining the learning objectives. Defining the learning objectives is a process that requires brainstorming, that even experienced instructors may consult with other experienced instructional design faculty when developing their learning objectives.

8.1.3 Research Question 3: To what extent do instructors find the time invested to evaluate their course alignment to be practical?

The participants did not think that the process was taxing, they felt that CAAP was time consuming but not challenging. Overall the participants took less than 11 hours to complete the process, this is a significant improvement from other curriculum alignment models. The process was successful in reducing the need of a panel of experts, thus reducing the overall time to evaluate alignment. A study by Polikoff et al. [105] reported applications of the Survey of Enacted curriculum taking up to 200 hours to apply. Many factors may impact the time invested to complete the CAAP, the size
of the course and the number of course components is one factor. From the case study, the instructors with the most amount of course components (lectures, assignments, homework, projects etc.) took the longest time to fill out the content matrix. Similarly, the instructors with the most number of questions on their assessments took the longest time to fill out the assessment matrix. Any curriculum alignment model requires document review, going through all of the course documents, to evaluate alignment [69]. A large number of course components or assessments questions is independent of the design process and cannot be accounted for. Another factor impacting the time to complete the CAAP may be if a course is poorly structured or aligned. It may require more thought about where to include content. This would make it more time consuming to fill out the matrices.

The case study highlighted that the relative advantage of process outweighs the time required to complete the alignment process. In some contexts, the participants felt that it was worth investing the time to evaluate their course alignment. For example, CS Instructor 1 noted that although CAAP is time consuming they would reuse it when designing a course from scratch or evaluating a course they had not taught for a while. They felt that CAAP provided a systematic approach to refamiliarize themselves with the course content, worth the time spent on the process. However, CS Instructor 1 would not use CAAP to evaluate a course after every time it was taught. They felt it was unnecessary because they were familiar with the course. The relative advantage of applying CAAP in that situation did not outweigh the time investment.

The participants highlighted different situations in which they would re-use the CAAP. Many of the participants indicated that CAAP would be helpful if it was used to design a course rather than
evaluate a course. CS Instructor 1 felt that the process would help them if they had to develop a
course from scratch. ED Instructor 2 felt that the process would be helpful for inexperienced
instructors who needed help designing a course. Other participants felt that CAAP could be helpful
in evaluating horizontal alignment of multiple sections of a course. CS Instructor 1 suggested that
the process would be helpful to a course coordinator overseeing multiple instructors for a course.
The course coordinator could use CAAP to compare the alignment of the various sections of the
course. The participants also highlighted micro-applications of CAAP. ED Instructor 1 would use
the process to evaluate the alignment of their projects, to ensure that all of the components of the
project are meeting the project goals.

8.1.4 Research Question 4: What role does instructional design knowledge play in
the instructor’s ability to apply the alignment process and tool?

I did not observe an impact of instructional design knowledge on the participant’s ability to
complete CAAP. All of the participants understood the alignment report and were able to identify
changes to make to their course. After completing the process, the participants had a better
understanding of curriculum alignment regardless of their instructional design knowledge.

Instructional design knowledge seemed to impact how well the learning objectives were
formulated. The CS instructors had limited instructional design background and their learning
objectives often contained non-measurable action verbs. This did not impact their ability to
complete the alignment process. The CS instructors were able to connect their learning objectives
to the various content in the content matrix as well as the questions on the assessments in the
assessment matrix. As a result, the process was able to generate an alignment report regardless of the accuracy of the learning objectives.

Instructional design knowledge impacted how well the instructors were familiar with Bloom’s taxonomy. All of the participants had some difficulty assigning a level of cognitive skill to their learning objectives. The ED instructors had training in instructional design and were familiar with Bloom’s taxonomy but they faced some challenges identifying the level of cognitive skill of their learning objectives and would often go back and change them in later phases of CAAP. The CS instructors were not familiar with Bloom’s taxonomy they faced challenges understanding what each level of cognitive skill meant often mis-labelling the level of cognitive skill for the learning objective. A common misconception amongst the CS instructors was that the levels of cognitive skill corresponded to how easy or challenging a learning objective was. A CS instructor would often label their foundational concepts a lower level of cognitive skill but they wanted their students to master the foundational concepts, expecting students to achieve higher levels of cognitive skill. This mis-labelling resulted in many of the basics learning objectives to be over-represented in the alignment report.

Instructional design knowledge and teaching experience will likely impact whether a participant would reuse CAAP. ED Instructor 2 felt that the tool was more suitable for an instructor with no experience. They felt that an instructor with instructional design knowledge uses instructional design processes to develop their course, resulting in an aligned course. Using CAAP to evaluate
a course would be pointless. This re-iterates the findings in section 8.2.3, using the CAAP during course design rather than course evaluation.

The CAAP reduced the need for instructional design knowledge as well as limiting the need for a panel of experts, however the process did not eliminate the need for expert discussion. After the participants had read the alignment report, I discussed the report with them asking them to identify course improvements. The discussion with ED Instructor 2 about the results of the balance of representation led them to re-evaluate the labelling for a learning objective. This suggests that while CAAP may be helpful in informing instructors about their course alignment and reducing the need for a panel of experts, there is value in having reflective discussions about the results and the possible course improvements.

8.2 Limitations

The case study had several limitations that may have impacted the findings. I used a collective case studies in order to collect rich data that would provide insights on the use of the CAAP. The observations of the perceptions of the participants regarding the difficulty of use, effort required, time required and usefulness of the process and tool are specific to the participants and are not representative of instructors with similar experiences. These experiences are not generalizable to any instructor. Case study research is time consuming to conduct and difficult to replicate. It served as an exploratory study, generating new ideas and connected that could be further tested using other methodologies.
The selection criteria used, purposive criterion sampling, may have resulted in the exclusion of participants that may have been eligible to take part in the study but were unknown to the gatekeepers. Using a different sampling method may have identified different participants, impacting the findings of the study.

8.3 Implications

This work presented various implications to Computer Science educators and Computer Science administrators. Prior research suggested that Computer Science instructors use their intuition, advice from their colleagues, discussions with students or anecdotal evidence to make changes to their courses [2, 5, 106]. The findings of this study support these findings, from the pre-alignment interviews I found that the CS Instructors relied on student feedback, student performance on assessments and their perceptions of what is wrong with the course to make course improvements. In contrast the ED Instructors relied on domain experts or an evaluation of learning objectives to make course changes. The CS instructors had no training in instructional design, unlike the ED instructors. All of the instructors had at least 3 years of experience teaching a course. This suggests that teaching experience may not be enough to use an evidence-based approach to course improvements. Knowledge of instruction design may play a role in how an instructor makes course improvements. CAAP presented instructors with an evidence-based approach to make informed changes to their course.

It is common in higher education for faculty graduating from non-education majors to have limited instructional design knowledge, and Computer Science faculty are no exception. The CAAP can be used by instructors to think about their course from different perspectives allowing them to reflect on their course and their teaching methods. Evidence from the case study showed that
CAAP helped CS instructors to develop some minimal instructional design skills that can be used during course design. For example, starting off with a complete list of learning objectives and using them to build a course. For faculty with limited instructional design knowledge CAAP may help instructors develop more aligned courses.

CAAP presented many applications, some low-level applications that would benefit CS educators such as evaluating the alignment of a project to ensure that all the components of a project are aligned as well as aligning the project with the overall course learning objectives. Another low-level application of CAAP is to evaluate the alignment of part of a course. For example, evaluating the alignment of the assessments with the course content and learning objectives. This may be particularly helpful for large courses with many course components, instead of spending many hours evaluating all of the course an instructor may choose to evaluate part of the course.

On a higher-level, CAAP may be helpful to CS administrators. The administrators may use CAAP to evaluate accreditation outcomes for the ABET. ABET requires accredited programs to have curriculum that aligns with their student outcomes. CAAP can be used to evaluate each course curriculum in a program and how they align with the ABET student outcomes. This process is done manually by departments in preparation for annual ABET review.

Course coordinators may find CAAP particularly useful when evaluating the various sections of their course. Courses with multiple instructors may be taught differently, CAAP can be used to evaluate the horizontal alignment between the various sections to ensure that the different versions of the course are in agreement with each other. Course coordinators can also use CAAP to evaluate the vertical alignment between course prerequisites and consecutive courses, to ensure that
prerequisite courses are addressing the prior knowledge students have to acquire before moving on to the next course sequence.

### 8.4 Future Work

The case study provided me with feedback and improvements to the design of the static wireframe mockup of the low fidelity alignment tool (AlignET). These improvements would be an important part of a production quality product. A suggested improvement to the tool is to add a parser to phase 1 (define learning objectives). The parser would check the learning objective entered to see whether appropriate action verbs are used. Using Bloom’s taxonomy, the tool would cross-reference the action verbs used with the level of cognitive skill selected to check if the verbs used match the level of cognitive skill.

AlignET needed to include more examples, in phase 1, a “show me an example” button could be added that displays to the user a course’s learning objectives with the level of cognitive skill for each. Similarly, in phases 2 and 3, displaying to the user a portion of a filled content and assessment matrices would be helpful. Having more examples can make the tool easier to use and might reduce the time required to complete the alignment process.

Adding more prompts in each of the phases may be helpful to the user. For example, in phase 1 if the user has not input any learning objectives and is idle for some time the tool could prompt the user by suggesting “What topics do you cover in your course? What sub-topics do you cover in your course?”. This may help provide some guidance to a user who is confused or doesn’t know where to start. Similarly, for content matrix when a user enters their first course component a
prompt could be “Did you list all of the questions and sub-questions that address this learning objective?” and give the user an example.

Further aspects of CAAP could be automated to reduce the overall time spent on the process. For example, if the course exists on a learning management system. AlignET could collect information about number of course components of a course. This could be used to create the unfilled content and assessment matrices. Departments often keep learning objectives for each of the courses on their curriculum. If the learning objectives were all kept in a standard representation, AlignET could keep a repository of all of the departments learning objectives. Importing the learning objectives for the course alignment was going to be applied to.

After developing a usable implementation of AlignET it would be beneficial to conduct a usability study to evaluate the interface and functionality of the tool. This study could serve as a pilot to test a quantitative instrument. The results from that study would help inform the design and development of a production quality version of AlignET, as well as the refinement of the instrument. It would be beneficial to evaluate the likelihood of adoption of AlignET by instructors, designing a study with instructors from different disciplines, departments, and varying teaching experiences would provide new insights on AlignET. It would be helpful to conduct a larger scale study using the quantitative instrument developed, across multiple institutions where instructors would use AlignET to evaluate the alignment of their courses. Allowing the researcher to explore other difficulties the instructors may face when using the tool and the instructor’s views on the usefulness of the tool. It would also be interesting to explore the connection between the alignment
of different course activities or assessments and how students perform on those activities and assessments.
References


[66] T. C. Hill, *Common Formative Assessments Developed Through Profesional Learning Communities (PLCs): A case study to analyze the alignment of curriculum, assessment and instruction in a Math PLC at a title I middle school in southern United States*, in *Curriculum and Instruction*. 2013, Texas A&M.


Appendices

Appendix A: Alignment Instruction Manual

Glossary of Terms:

Alignment: is the degree to which curriculum, assessments and instruction methods are in agreement with each other. Course alignment can be used by instructors to evaluate the effectiveness of their instructional content and assessments and whether they are meeting their learning objectives.

Assessment: methods or tools used to evaluate the progress of a student and their understanding of a topic.

Cognitive Skill: in this document cognitive skill refers to a level on Bloom’s hierarchy (see Appendix A1)

Learning Objectives: the skills and abilities that students should master and demonstrate at the end of a course. Learning objectives tell students what they are supposed to be learning in a course and where to direct their attention.

About the Alignment Process

The alignment process assesses the alignment between a course content, learning objectives and assessment methods. The process provides definitions on how to evaluate the degree of alignment between:

• learning objectives and content
• learning objectives and assessment methods
• assessment methods and content

The alignment process is made up of four iterative stages: defining the learning objectives for the course, building a content matrix, building an assessment matrix and evaluating the alignment.

The Alignment Process

1. Identify Learning Objectives

List the course’s learning objectives. If your course does not have any learning objectives refer to Appendix A2 to write learning objectives for the course.

For each learning objective identify the level of cognitive skill required for your student to achieve the learning objective (refer to Appendix A1).

2. Build the Content Matrix

Identify the components of your course. What is the work students need to complete for grades? For example: lectures, assignments, quizzes, exams or labs. These are your course components. These will be the column headers of your content matrix columns. The learning objectives for the course will be the row headers in the matrix. See example below.
Round 1
In this process you will be mapping the course components that address a learning objective. For each learning objective:
- Go through all of your course content and list the course components where the learning objective is addressed.
- Try and be detailed as possible, list the question numbers or specific portions in the labs, this will be helpful when you will verify this information.

Round 2
In this process you will verify the course components that address the learning objective. For each learning objective:
- Go back to the course content listed and verify that the correct learning objective is listed.
- Try and be detailed as possible, list the question numbers or specific portions in the labs, this will be helpful when you will verify this information.

3. Build the Assessment Matrix
In this phase you will go through all of your assessment tools, mapping them to the learning objectives and the corresponding course components in an assessment matrix. The column headers of your assessment matrix are assessment, question, learning objective, and course content with similar cognitive skill. The row headers in the matrix are every assessment tool you have in the course. See example below.

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Question</th>
<th>Learning Objective</th>
<th>Course Content with Similar Cognitive Skill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 2</td>
<td>Q3</td>
<td>To apply inheritance</td>
<td>Reading 12, 14, Reading Quiz 6 (Q3, Q12)</td>
</tr>
</tbody>
</table>

Round 1
In this process you will be mapping the course components that address a learning objective and have similar cognitive skill as the assessment question. For each assessment tool:
- For each question on the assessment tool;
  - Identify the learning objective that the question evaluates (you can use your content matrix for help).
• For that learning objective: go through all of your course components in the content matrix, list the course components where the course component has similar cognitive demand as the question.

**Round 2**
In this process you will verify the course components that address a learning objective and have similar cognitive skill as the assessment question.
For each assessment tool;
• For each question on the assessment tool;
• Identify the learning objective that the question evaluates (you can use your content matrix for help).
• For that learning objective: go through all of your course components in the content matrix, list the course components where the course component has similar cognitive demand as the question.

**4. Evaluate the Degree of Alignment**
In the last phase you will evaluate the degree of alignment of your course using 4 attributes: structure of knowledge, depth of knowledge, range of knowledge, and balance of representation. For each of the attributes you will assign a value on a scale (full, acceptable, insufficient) except for balance of representation you will use (over-represented, balanced, under-represented). The definitions of the scale values are included below, this is a guide, use your judgement and expertise.

**a. Structure of knowledge**
*Definition:* Structure of knowledge compares what students are expected to know, as defined in the learning objectives, and what is assessed in the assessment tool.

*How to evaluate structure of knowledge?*
Check that every question in the assessment matrix has at least one corresponding learning objective.

*Insufficient* alignment is when there are no learning objectives for an assessment question
*Acceptable* alignment is that at least one learning objective exists for each assessment question.
*Full* alignment is when there is more than one learning objective for an assessment question.

**b. Depth and the Range of knowledge**
*Definition:* Depth of knowledge consistency compares the level of complexity of the content as defined by the learning objectives to what is measured by the assessment. Range of knowledge correspondence compares “the span of knowledge required by the learning objectives in a subject area to that of the assessments” [28].

*How to evaluate depth and range of knowledge?*
Both are evaluated by cross-referencing the course content listed in the content matrix and assessment matrix. The goal is to find “broken links” between both the content and assessment matrices. Each entry in the assessment matrix is cross referenced to the content matrix. A broken link is course content not in the assessment matrix but on the content matrix. This may
mean that the level of cognitive demand of the content does not match that in the assessment matrix.

_Insufficient_ alignment is when none of the course content in the assessment matrix is cross-referenced in the content matrix.
_Acceptable_ alignment is when a few course content in the content matrix is not matched in the assessment matrix.
_Full_ alignment is when all the course content in the assessment matrix is cross-referenced in the content matrix.

c. **Balance of Representation**

_Definition:_ Balance of representation evaluates the emphasis given to topics in the learning objectives and the emphasis the same topics are given in the assessments.

_How to evaluate balance of representation?_ We re-evaluate the content matrix considering the following criteria:
• Is there a variety of instructional methods for the learning objectives? Are there any gaps?
• Is there an assessment tool for each learning objective?
• Compared to the other learning objectives of similar cognitive demand, is there more or less content?

Based on the three criteria:
_Under-represented_ alignment is if there is not a variety of instructional methods for each learning objectives, there is none or no more than one assessment tool for each learning objective, there may gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is less content in the content matrix.
_Balanced_ alignment is if there a variety of instructional methods for each learning objectives, there is at least one assessment tool for each learning objective, there may be a few gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is similar content in the content matrix.
_Over-balanced_ alignment is if there a variety of instructional methods for each learning objectives, there is more than one assessment tool for each learning objective, there may be no gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is much more content in the content matrix.
Appendix A1: Bloom’s Taxonomy

Bloom’s taxonomy defines six levels of learning: remembering, understanding, applying, analyzing, evaluating and creating.

1. **Remembering** is the foundational cognitive skill and refers to the retention, recall and retrieval of information like facts or definitions.
2. **Understanding** is where students can explain ideas and concepts by explaining, summarizing, classifying, interpreting or complaining.
3. **Applying** is where the knowledge learned is used in a new context.
4. **Analyzing** is breaking the concept into parts and identifying how these parts connect, relate to the overall structure.
5. **Evaluating** is where a student can justify decisions and make judgments.
6. **Creating** is the highest cognitive skill where students build on the lower skills, putting elements together to create a new idea or product.

The taxonomy is hierarchical, to reach a higher more complex level, mastery of the lower level is needed first. Learning objectives can be written using Bloom’s taxonomy making them more meaningful. Learning objectives can be mapped to the different levels of Bloom’s taxonomy, depending on the levels of cognition you want your students to achieve.
Appendix A2: How to Write Course Learning Objectives based on Bloom’s Taxonomy

Bloom’s taxonomy defines six levels of learning: remembering, understanding, applying, analyzing, evaluating and creating (defined in Appendix A1). To write course learning objectives using Bloom’s taxonomy please follow the guidelines:

- Learning objectives must be measurable. Refer to the table below for measurable verbs.
- Use only 1 verb per learning objective.
- Make sure the verb used for the learning objective is the highest level you want the student to achieve.
- Keep your learning objectives clear and concise.

<table>
<thead>
<tr>
<th>Bloom’s Level</th>
<th>Key Verbs (keywords)</th>
<th>Example Learning Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create</td>
<td>design, formulate, build, invent, create, compose, generate, derive, modify, develop.</td>
<td>By the end of this lesson, the student will be able to design an original homework problem dealing with the principle of conservation of energy.</td>
</tr>
<tr>
<td>Evaluate</td>
<td>choose, support, relate, determine, defend, judge, grade, compare, contrast, argue, justify, support, convince, select, evaluate.</td>
<td>By the end of this lesson, the student will be able to determine whether using conservation of energy or conservation of momentum would be more appropriate for solving a dynamics problem.</td>
</tr>
<tr>
<td>Analyze</td>
<td>classify, break down, categorize, analyze, diagram, illustrate, criticize, simplify, associate.</td>
<td>By the end of this lesson, the student will be able to differentiate between potential and kinetic energy.</td>
</tr>
<tr>
<td>Apply</td>
<td>calculate, predict, apply, solve, illustrate, use, demonstrate, determine, model, perform, present.</td>
<td>By the end of this lesson, the student will be able to calculate the kinetic energy of a projectile.</td>
</tr>
<tr>
<td>Understand</td>
<td>describe, explain, paraphrase, restate, give original examples of, summarize, contrast, interpret, discuss.</td>
<td>By the end of this lesson, the student will be able to describe Newton’s three laws of motion to in her/his own words</td>
</tr>
<tr>
<td>Remember</td>
<td>list, recite, outline, define, name, match, quote, recall, identify, label, recognize.</td>
<td>By the end of this lesson, the student will be able to recite Newton’s three laws of motion.</td>
</tr>
</tbody>
</table>

Table from https://tips.uark.edu/using-blooms-taxonomy/
Appendix B: Help Features in AlignET

Details of the information and help features displayed to the user in the static wireframe mockups and the explanation provided to the user for each.

*What is Alignment?*
Read out to user:
Alignment is the degree to which curriculum, assessments and instruction methods are in agreement with each other. Course alignment can be used by instructors to evaluate the effectiveness of their instructional content and assessments and whether they are meeting their learning objectives.

*Information button: What are the course components?*
Read to the user:
What is the work students need to complete for grades? For example: lectures, assignments, quizzes, exams or labs. These are your course components.

*Information button: Tell us more about your course?*
Read to the user:
For each course component you just defined how many do students need to complete in the course? For example: 14 lectures, 11 labs, 3 projects, 2 exams.

*Information button: How many exams?*
Read to the user:
For the summative assessments of your course, these may be final exams or mid-term projects. Ways in which you are evaluating your students’ learning. How many questions are there on each of those assessments? For example: 20 questions on the final exam, 15 requirements on the mid-term project labs.

*Help feature: Defining Learning Objectives*
Read out to user:
Learning Objectives are the skills and abilities that students should master and demonstrate at the end of a course. Learning objectives tell students what they are supposed to be learning in a course and where to direct their attention.

Print the following and show to the user:
How to Write Course Learning Objectives based on Bloom’s Taxonomy

Bloom’s taxonomy defines six levels of learning: remembering, understanding, applying, analyzing, evaluating and creating (defined in Appendix A1). To write course learning objectives using Bloom’s taxonomy please follow the guidelines:

- Learning objectives must be measurable. Refer to the table below for measurable verbs.
- Use only 1 verb per learning objective.
- Make sure the verb used for the learning objective is the highest level you want the student to achieve.
- Keep your learning objectives clear and concise.

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<tr>
<td>Evaluate</td>
<td>choose, support, relate, determine, defend, judge, grade, compare, contrast, argue, justify, support, convince, select, evaluate</td>
<td>By the end of this lesson, the student will be able to determine whether using conservation of energy or conservation of momentum would be more appropriate for solving a dynamics problem.</td>
</tr>
<tr>
<td>Analyze</td>
<td>classify, break down, categorize, analyze, diagram, illustrate, criticize, simplify, associate</td>
<td>By the end of this lesson, the student will be able to differentiate between potential and kinetic energy.</td>
</tr>
<tr>
<td>Apply</td>
<td>calculate, predict, apply, solve, illustrate, use, demonstrate, determine, model, perform, present</td>
<td>By the end of this lesson, the student will be able to calculate the kinetic energy of a projectile.</td>
</tr>
<tr>
<td>Understand</td>
<td>describe, explain, paraphrase, restate, give original examples of, summarize, contrast, interpret, discuss</td>
<td>By the end of this lesson, the student will be able to describe Newton’s three laws of motion to in her/his own words</td>
</tr>
<tr>
<td>Remember</td>
<td>list, recite, outline, define, name, match, quote, recall, identify, label, recognize</td>
<td>By the end of this lesson, the student will be able to recite Newton’s three laws of motion.</td>
</tr>
</tbody>
</table>

Table from https://tips.uark.edu/using-blooms-taxonomy/

If user still confused show the following videos:

- https://www.youtube.com/watch?v=g_Xm5IljYKQ
- https://www.youtube.com/watch?v=qt2f_bunk1o
Information button: Topics
Read out to the user:
To make it easier to view and sort the learning objectives. Please group the learning objectives by topic. You can pick any word or phrase that best describes the general topic the learning objective is addressing.

Information button: Learning Objective
Read out to the user:
Learning Objectives are the skills and abilities that students should master and demonstrate at the end of a course. Learning objectives tell students what they are supposed to be learning in a course and where to direct their attention.

Information button: Cognitive Skill
Read out to the user:
Learning Objectives are the skills and abilities that students should master and demonstrate at the end of a course. Learning objectives tell students what they are supposed to be learning in a course and where to direct their attention.

Print the following sheet and show to the user.
**How to Define the Level of Cognitive Skill for a Learning Objective**

Bloom’s taxonomy defines six levels of learning: remembering, understanding, applying, analyzing, evaluating and creating.

7. *Remembering* is the foundational cognitive skill and refers to the retention, recall and retrieval of information like facts or definitions.

8. *Understanding* is where students can explain ideas and concepts by explaining, summarizing, classifying, interpreting or complaining.

9. *Applying* is where the knowledge learned is used in a new context.

10. *Analyzing* is breaking the concept into parts and identifying how these parts connect, relate to the overall structure.

11. *Evaluating* is where a student can justify decisions and make judgments.

12. *Creating* is the highest cognitive skill where students build on the lower skills, putting elements together to create a new idea or product.

The taxonomy is hierarchical, to reach a higher more complex level, mastery of the lower level is needed first. Learning objectives can be written using Bloom’s taxonomy making them more meaningful. Learning objectives can be mapped to the different levels of Bloom’s taxonomy, depending on the levels of cognition you want your students to achieve.

If user still confused show the following videos:

- [https://www.youtube.com/watch?v=Qfp3x_qx5IM&t=14s](https://www.youtube.com/watch?v=Qfp3x_qx5IM&t=14s)
- [https://www.youtube.com/watch?v=OOy3m02uEaE](https://www.youtube.com/watch?v=OOy3m02uEaE)
Help feature: Content Matrix
Read to the user:
The content matrix is a mapping of the course components of your course, for example: lectures, assignments, quizzes, exams or labs and which learning objective they meet. Try and be detailed as possible, list the question numbers or specific portions in the labs.

Help feature: Assessment Matrix
Read to the user:
The assessment matrix is a mapping of a) the questions on the assessment and which learning objective they are evaluating, and b) the course content with similar cognitive skill and which learning objective they meet.

Information button: Content with Similar Cognitive Skill
Read to the user:
Here list the course content where students have practiced concepts being evaluated by the assessment question. How have you prepared them for this assessment question? Did they have similar practice problems as a homework assignment? Try and be detailed as possible, list the question numbers or specific portions in the labs.
Appendix C: Template Alignment Report

To evaluate the degree of alignment between: learning objectives and content, learning objectives and assessment methods, and assessment methods and content we will use four of Webb’s content focus attributes: depth of knowledge, range of knowledge, balance of representation and structure of knowledge. Each of these attributes is assigned a value on a scale: full, acceptable and insufficient except balance of representation is assigned balanced, under-balanced or over-balanced.

Structure of knowledge: <<scale>>

Structure of knowledge compares what students are expected to know, as defined in the learning objectives, and what is assessed in the assessment tool.

<<list of assessment questions that do not correspond to a learning objective>>

How was this value assigned?

This value was evaluated by checking that every question in the assessment matrix has at least one corresponding learning objective. Acceptable alignment is that at least one learning objective exists for each assessment question, insufficient alignment is when there are no learning objectives for an assessment question, and full alignment is when there is more than one learning objective for an assessment question.

Depth of knowledge: <<scale>>

Depth of knowledge consistency compares the level of complexity of the content as defined by the learning objectives to what is measured by the assessment.

<<list of course components that do not correspond to a learning objective>>
How was this value assigned?

The value of depth of knowledge is evaluated by applying traceability between the content matrix and assessment matrix. The goal is to find “broken links” between both the content and assessment matrices. Each entry in the assessment matrix is cross referenced to the content matrix. A broken link is course content not in the assessment matrix but on the content matrix. This may mean that the level of cognitive demand of the content does not match that in the assessment matrix. Full alignment is when all the course content in the assessment matrix is cross-referenced in the content matrix. Acceptable alignment is when a few course content in the content matrix is not matched in the assessment matrix and insufficient is when none of the course content in the assessment matrix is cross-referenced in the content matrix.

Range of knowledge: <<scale>>

Range of knowledge correspondence compares the span of knowledge required by the learning objectives in a subject area to that of the assessments.

<<list of broken links>>

How was this value assigned?

Range of knowledge is also evaluated by applying traceability between the content matrix and assessment matrix. Full alignment is when all the course content in the assessment matrix is cross-referenced in the content matrix. Acceptable alignment is when a few course content in the content matrix is not matched in the assessment matrix and insufficient is when none of the course content in the assessment matrix is cross-referenced in the content matrix.
Balance of Representation

Balance of representation evaluates the emphasis given to topics in the learning objectives and the emphasis the same topics are given in the assessments.

<<if learning objectives are under- or over- represented>>

All the learning objectives are balanced except for:

**Topic: <<topic name>>**

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Compared to other learning objectives with <<cognitive skill>>, <<learning objective>> has <<variety of content>>.

*How was this value assigned?*

We re-evaluate the content matrix considering the following criteria:

- Is there a variety of instructional methods for the learning objectives? Are there any gaps?
- Is there an assessment tool for each learning objective?
- Compared to the other learning objectives of similar cognitive demand, is there more or less content?

Based on the three criteria, balanced alignment is if there a variety of instructional methods for each learning objectives, there is at least one assessment tool for each learning objective, there may be a few gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is similar content in the content matrix. Over-balanced alignment is if there a variety of instructional methods for each learning objectives, there is more than one assessment tool for each learning objective, there may be no gaps in the content matrix, and
compared to the other learning objectives of similar cognitive demand, there is much more content in the content matrix. Under-represented alignment is if there is not a variety of instructional methods for each learning objectives, there is none or no more than one assessment tool for each learning objective, there may gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is less content in the content matrix.
Appendix D: Alignment Reports

ED Instructor 1’s Alignment Report

To evaluate the degree of alignment between: learning objectives and content, learning objectives and assessment methods, and assessment methods and content we will use four of Webb’s content focus attributes: depth of knowledge, range of knowledge, balance of representation and structure of knowledge. Each of these attributes is assigned a value on a scale: full, acceptable and insufficient except balance of representation is assigned balanced, under-balanced or over-balanced.

Structure of knowledge: Full
Structure of knowledge compares what students are expected to know, as defined in the learning objectives, and what is assessed in the assessment tool.

How was this value assigned?
This value was evaluated by checking that every question in the assessment matrix has at least one corresponding learning objective. Acceptable alignment is that at least one learning objective exists for each assessment question, insufficient alignment is when there are no learning objectives for an assessment question, and full alignment is when there is more than one learning objective for an assessment question.

Depth of knowledge: Full
Depth of knowledge consistency compares the level of complexity of the content as defined by the learning objectives to what is measured by the assessment.

How was this value assigned?
The value of depth of knowledge is evaluated by applying traceability between the content matrix and assessment matrix. The goal is to find “broken links” between both the content and assessment matrices. Each entry in the assessment matrix is cross referenced to the content matrix. A broken link is course content not in the assessment matrix but on the content matrix. This may mean that the level of cognitive demand of the content does not match that in the assessment matrix. Full alignment is when all the course content in the assessment matrix is cross-referenced in the content matrix. Acceptable alignment is when a few course content in the content matrix is not matched in the assessment matrix and insufficient is when none of the course content in the assessment matrix is cross-referenced in the content matrix.

Range of knowledge: Full
Range of knowledge correspondence compares the span of knowledge required by the learning objectives in a subject area to that of the assessments.

How was this value assigned?
Range of knowledge is also evaluated by applying traceability between the content matrix and assessment matrix. Full alignment is when all the course content in the assessment matrix is cross-referenced in the content matrix. Acceptable alignment is when a few course content in the content matrix is not matched in the assessment matrix and insufficient is when none of the course content in the assessment matrix is cross-referenced in the content matrix.
Balance of Representation

Balance of representation evaluates the emphasis given to topics in the learning objectives and the emphasis the same topics are given in the assessments.

All the learning objectives are balanced except for:

<table>
<thead>
<tr>
<th>Topic: Community</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Articulate different concepts and definitions of “community” and be able to provide local and global examples of each</td>
<td>Level 3: Applying</td>
<td>Under-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 3 cognitive skill, “Articulate different concepts and definitions of “community” and be able to provide local and global examples of each” has fewer reflection assignments and is not part of the final paper.

How was this value assigned?
We re-evaluate the content matrix considering the following criteria:
- Is there a variety of instructional methods for the learning objectives? Are there any gaps?
- Is there an assessment tool for each learning objective?
- Compared to the other learning objectives of similar cognitive demand, is there more or less content?

Based on the three criteria, balanced alignment is if there a variety of instructional methods for each learning objective, there is at least one assessment tool for each learning objective, there may be a few gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is similar content in the content matrix. Over-balanced alignment is if there a variety of instructional methods for each learning objective, there is more than one assessment tool for each learning objective, there may be no gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is much more content in the content matrix. Under-represented alignment is if there is not a variety of instructional methods for each learning objective, there is none or no more than one assessment tool for each learning objective, there may gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is less content in the content matrix.
ED Instructor 2’s Alignment Report

To evaluate the degree of alignment between: learning objectives and content, learning objectives and assessment methods, and assessment methods and content we will use four of Webb’s content focus attributes [1]: depth of knowledge, range of knowledge, balance of representation and structure of knowledge. Each of these attributes is assigned a value on a scale: full, acceptable and insufficient except balance of representation is assigned balanced, under-balanced or over-balanced.

**Structure of knowledge: Full**
Structure of knowledge compares what students are expected to know, as defined in the learning objectives, and what is assessed in the assessment tool.

*How was this value assigned?*
This value was evaluated by checking that every question in the assessment matrix has at least one corresponding learning objective. Acceptable alignment is that at least one learning objective exists for each assessment question, insufficient alignment is when there are no learning objectives for an assessment question, and full alignment is when there is more than one learning objective for an assessment question.

**Depth of knowledge: Acceptable**
Depth of knowledge consistency compares the level of complexity of the content as defined by the learning objectives to what is measured by the assessment.

There were 8 assignments (1A, 1B, 2C, 4C, 6B, 6C, 14A, 15A) that did not correspond to any learning objectives.

*How was this value assigned?*
The value of depth of knowledge is evaluated by applying traceability between the content matrix and assessment matrix. The goal is to find “broken links” between both the content and assessment matrices. Each entry in the assessment matrix is cross referenced to the content matrix. A broken link is course content not in the assessment matrix but on the content matrix. This may mean that the level of cognitive demand of the content does not match that in the assessment matrix. Full alignment is when all the course content in the assessment matrix is cross-referenced in the content matrix. Acceptable alignment is when a few course content in the content matrix is not matched in the assessment matrix and insufficient is when none of the course content in the assessment matrix is cross-referenced in the content matrix.

**Range of knowledge: Full**
Range of knowledge correspondence compares the span of knowledge required by the learning objectives in a subject area to that of the assessments.

*How was this value assigned?*
Range of knowledge is also evaluated by applying traceability between the content matrix and assessment matrix. Full alignment is when all the course content in the assessment matrix is cross-referenced in the content matrix. Acceptable alignment is when a few course content in
the content matrix is not matched in the assessment matrix and insufficient is when none of the course content in the assessment matrix is cross-referenced in the content matrix.

Balance of Representation
Balance of representation evaluates the emphasis given to topics in the learning objectives and the emphasis the same topics are given in the assessments.

All the learning objectives are balanced except for:

<table>
<thead>
<tr>
<th>Topic: Design Process</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use engineering tools to design and test the solution</td>
<td>Level 6: Creating</td>
<td>Under-represented</td>
</tr>
<tr>
<td>Implement dimensioning rules and principles and provide sufficient dimensions for a given part</td>
<td>Level 5: Evaluating</td>
<td>Under-represented</td>
</tr>
<tr>
<td>Articulate the solution alternatives and chosen solution in a final report</td>
<td>Level 6: Creating</td>
<td>Under-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 6 cognitive skill in the same topic, “Use engineering tools to design and test the solution” has no lectures covering the topic and no individual assignments and has only 1 group assignment that covers the learning objective. “Articulate the solution alternatives and chosen solution in a final report” has no lectures covering the topic and no individual assignments and has 3 group assignments that covers the learning objective. Similarly, “Implement dimensioning rules and principles and provide sufficient dimensions for a given part” is also under-represented because compared to other learning objectives with level 5 cognitive skill in the “design process” topic they all had group assignments however this learning objective did not.

Topic: Inventor

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop multiview drawings for a given part</td>
<td>Level 5: Evaluating</td>
<td>Under-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 5 cognitive skill, “Develop multiview drawings for a given part” has only 1 lecture and 1 individual assignment but is not practiced anywhere else.

Topic: Matlab

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use different tools in Matlab to plot</td>
<td>Level 4: Analyzing</td>
<td>Under-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 4 cognitive skill, “Use different tools in matlab to plot” has no lectures covering the topic.
### Topic: Engineering

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connect the course to the students' engineering interests</td>
<td>Level 4: Analyzing</td>
<td>Under-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 4 cognitive skill, “Connect the course to the students’ engineering interests” has only 3 individual assignments that cover the learning objective but is not addressed anywhere else.

**How was this value assigned?**

We re-evaluate the content matrix considering the following criteria:

- Is there a variety of instructional methods for the learning objectives? Are there any gaps?
- Is there an assessment tool for each learning objective?
- Compared to the other learning objectives of similar cognitive demand, is there more or less content?

Based on the three criteria, balanced alignment is if there a variety of instructional methods for each learning objectives, there is at least one assessment tool for each learning objective, there may be a few gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is similar content in the content matrix. Over-balanced alignment is if there a variety of instructional methods for each learning objectives, there is more than one assessment tool for each learning objective, there may be no gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is much more content in the content matrix. Under-represented alignment is if there is not a variety of instructional methods for each learning objectives, there is none or no more than one assessment tool for each learning objective, there may gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is less content in the content matrix.
CS Instructor 1’s Alignment Report

To evaluate the degree of alignment between: learning objectives and content, learning objectives and assessment methods, and assessment methods and content we will use four of Webb’s content focus attributes [1]: depth of knowledge, range of knowledge, balance of representation and structure of knowledge. Each of these attributes is assigned a value on a scale: full, acceptable and insufficient except balance of representation is assigned balanced, under-balanced or over-balanced.

Structure of knowledge: Full
Structure of knowledge compares what students are expected to know, as defined in the learning objectives, and what is assessed in the assessment tool.

How was this value assigned?
This value was evaluated by checking that every question in the assessment matrix has at least one corresponding learning objective. Acceptable alignment is that at least one learning objective exists for each assessment question, insufficient alignment is when there are no learning objectives for an assessment question, and full alignment is when there is more than one learning objective for an assessment question.

Depth of knowledge: Acceptable
Depth of knowledge consistency compares the level of complexity of the content as defined by the learning objectives to what is measured by the assessment.

There were 5 programming assignments (14, 19, 21, 23, 24) that did not correspond to any learning objectives. There are also, 7 homework assignments (1, 3, 5, 11, 14, 26, 45) that did not correspond to any learning objectives.

How was this value assigned?
The value of depth of knowledge is evaluated by applying traceability between the content matrix and assessment matrix. The goal is to find “broken links” between both the content and assessment matrices. Each entry in the assessment matrix is cross referenced to the content matrix. A broken link is course content not in the assessment matrix but on the content matrix. This may mean that the level of cognitive demand of the content does not match that in the assessment matrix. Full alignment is when all the course content in the assessment matrix is cross-referenced in the content matrix. Acceptable alignment is when a few course content in the content matrix is not matched in the assessment matrix and insufficient is when none of the course content in the assessment matrix is cross-referenced in the content matrix.

Range of knowledge: Acceptable
Range of knowledge correspondence compares the span of knowledge required by the learning objectives in a subject area to that of the assessments. There were no final questions on data science.

How was this value assigned?
Range of knowledge is also evaluated by applying traceability between the content matrix and assessment matrix. Full alignment is when all the course content in the assessment matrix is
cross-referenced in the content matrix. Acceptable alignment is when a few course content in the content matrix is not matched in the assessment matrix and insufficient is when none of the course content in the assessment matrix is cross-referenced in the content matrix.

**Balance of Representation**

Balance of representation evaluates the emphasis given to topics in the learning objectives and the emphasis the same topics are given in the assessments.

All the learning objectives are balanced except for:

**Topic: Data Science under-represented**

Compared to other topics students only cover data science learning objectives in 1 lecture, 2 quizzes, 1 programming assignment and 1 project. Although they are required to demonstrate high order thinking (Understand interactions between code blocks, executing out of order and introduce students how to represent results visually)

**Topic: Functions**

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand why functions exist and why they’re a useful structure</td>
<td>Level 2: Understanding</td>
<td>Under-represented</td>
</tr>
<tr>
<td>Understand chaining functions</td>
<td>Level 5: Evaluating</td>
<td>Under-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 2 cognitive skill in the same topic, “Understand why functions exist and why they’re a useful structure” has less homework questions and is not tested on the final exam. “Understand chaining functions” has no final exam questions and few homework questions compared to the level 4 “Understand how parameters, arguments, returning values work” and other level 5 learning objectives from other topics.

**Topic: Data structures**

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand key-value pairs</td>
<td>Level 3: Applying</td>
<td>Over-represented</td>
</tr>
<tr>
<td>Compare data access speeds for dictionaries and lists</td>
<td>Level 2: Understanding</td>
<td>Under-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 2 cognitive skill in the same topic, “Compare data access speeds for dictionaries and lists” has no programming assignments or final exam questions. “Understand key-value pairs” is heavily tested on the final exam compared to other level 3 learning objectives of the same topic and other topics.

**Topic: Control structures**

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understand branching code and branching logic</td>
<td>Level 5: Evaluating</td>
<td>Over-represented</td>
</tr>
</tbody>
</table>
Understand why looping structures are useful | Level 2: Understanding | Over-represented

Compared to other learning objectives with level 2 cognitive skill, “Understand why looping structures are useful” has more programming assignments, homework questions and final exam questions. “Understand branching code and branching logic” is heavily tested on the final exam compared to other level 5 learning objectives.

How was this value assigned?

We re-evaluate the content matrix considering the following criteria:

- Is there a variety of instructional methods for the learning objectives? Are there any gaps?
- Is there an assessment tool for each learning objective?
- Compared to the other learning objectives of similar cognitive demand, is there more or less content?

Based on the three criteria, balanced alignment is if there a variety of instructional methods for each learning objectives, there is at least one assessment tool for each learning objective, there may be a few gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is similar content in the content matrix. Over-balanced alignment is if there a variety of instructional methods for each learning objectives, there is more than one assessment tool for each learning objective, there may be no gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is much more content in the content matrix. Under-represented alignment is if there is not a variety of instructional methods for each learning objectives, there is none or no more than one assessment tool for each learning objective, there may gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is less content in the content matrix.
CS Instructor 2’s Alignment Report

To evaluate the degree of alignment between: learning objectives and content, learning objectives and assessment methods, and assessment methods and content we will use four of Webb’s content focus attributes: depth of knowledge, range of knowledge, balance of representation and structure of knowledge. Each of these attributes is assigned a value on a scale: full, acceptable and insufficient except balance of representation is assigned balanced, under-balanced or over-balanced.

Structure of knowledge: Full
Structure of knowledge compares what students are expected to know, as defined in the learning objectives, and what is assessed in the assessment tool.

How was this value assigned?
This value was evaluated by checking that every question in the assessment matrix has at least one corresponding learning objective. Acceptable alignment is that at least one learning objective exists for each assessment question, insufficient alignment is when there are no learning objectives for an assessment question, and full alignment is when there is more than one learning objective for an assessment question.

Depth of knowledge: Insufficient
Depth of knowledge consistency compares the level of complexity of the content as defined by the learning objectives to what is measured by the assessment.

There were 39 homework assignments (X220 – X225, X218, X219, X228, X229 – X232, X1 – X3, X5, X12, X13, Homework 6 Q1 – Q7, Homework 7 Q1 – Q10, X96 – X98, X22, X24) that did not correspond to any learning objectives. There were also 2 assessment questions that did not correspond to any learning objective (Midterm Exam Q4 and Final Exam Q4).

How was this value assigned?
The value of depth of knowledge is evaluated by applying traceability between the content matrix and assessment matrix. The goal is to find “broken links” between both the content and assessment matrices. Each entry in the assessment matrix is cross referenced to the content matrix. A broken link is course content not in the assessment matrix but on the content matrix. This may mean that the level of cognitive demand of the content does not match that in the assessment matrix. Full alignment is when all the course content in the assessment matrix is cross-referenced in the content matrix. Acceptable alignment is when a few course content in the content matrix is not matched in the assessment matrix and insufficient is when none of the course content in the assessment matrix is cross-referenced in the content matrix.

Range of knowledge: Acceptable
Range of knowledge correspondence compares the span of knowledge required by the learning objectives in a subject area to that of the assessments.

How was this value assigned?
Range of knowledge is also evaluated by applying traceability between the content matrix and assessment matrix. Full alignment is when all the course content in the assessment matrix is
cross-referenced in the content matrix. Acceptable alignment is when a few course content in the content matrix is not matched in the assessment matrix and insufficient is when none of the course content in the assessment matrix is cross-referenced in the content matrix.

**Balance of Representation**
Balance of representation evaluates the emphasis given to topics in the learning objectives and the emphasis the same topics are given in the assessments.

All the learning objectives are balanced except for:

**Topic: Basics**

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>To hand-trace the execution of a program</td>
<td>Level 2: Understanding</td>
<td>Over-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 2 cognitive skill in the same topic, “To hand-trace the execution of a program” has many questions on the exams, quizzes (in-class and out-of-class).

**Topic: Class Design**

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>To learn about packages</td>
<td>Level 2: Understanding</td>
<td>Under-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 2 cognitive skill in the same topic, “To learn about packages” has no lectures or any assessment questions.

**Topic: Input/Output**

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>To read and write text files</td>
<td>Level 2: Understanding</td>
<td>Under-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 2 cognitive skill in the same topic, “To read and write text files” has no assessment questions (in-class or out-of-class quizzes or exam questions).

**Topic: Logic**

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>To write arithmetic expressions in JAVA</td>
<td>Level 3: Understanding</td>
<td>Over-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 3 cognitive skill, “To write arithmetic expressions in JAVA” has many more assessment questions (in-class or out-of-class quizzes or exam questions).
### Topic: Object Creation

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>To understand the concepts of classes and objects</td>
<td>Level 2: Understanding</td>
<td>Over-represented</td>
</tr>
<tr>
<td>To understand the difference between objects and objects references</td>
<td>Level 2: Understanding</td>
<td>Over-represented</td>
</tr>
<tr>
<td>To be familiar with the common superclass Object and its methods</td>
<td>Level 2: Understanding</td>
<td>Over-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 2 cognitive skill, all of the learning objectives in the object creation topic are over-represented. They are heavily tested on the final exam.

### Topic: Repeating Actions

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>To understand the concepts of classes and objects</td>
<td>Level 2: Understanding</td>
<td>Over-represented</td>
</tr>
<tr>
<td>To understand the difference between objects and objects references</td>
<td>Level 2: Understanding</td>
<td>Over-represented</td>
</tr>
<tr>
<td>To be familiar with the common superclass Object and its methods</td>
<td>Level 2: Understanding</td>
<td>Over-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 2 cognitive skill, all of the learning objectives in the object creation topic are over-represented. They are heavily tested on the final exam.

### Topic: Street Skills

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>To minimize dependencies</td>
<td>Level 5: Creating</td>
<td>Under-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 5 cognitive skill and compared to the other learning objectives in “Street Skills”, “To minimize dependencies” have no course work at all that help students meet the learning objective.

### Topic: Variables

<table>
<thead>
<tr>
<th>Learning Objective</th>
<th>Level of Cognitive Skill</th>
<th>Balance of Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>To understand integer and floating point numbers</td>
<td>Level 3: Applying</td>
<td>Under-represented</td>
</tr>
<tr>
<td>To recognize the limitations of numeric types</td>
<td>Level 3: Applying</td>
<td>Under-represented</td>
</tr>
</tbody>
</table>

Compared to other learning objectives with level 3 cognitive skill, “To understand integer and floating point numbers” and “To recognize the limitations of numeric types” have no programming assignments like the other level 3 learning objectives in the same topic.

*How was this value assigned?*

We re-evaluate the content matrix considering the following criteria:

- Is there a variety of instructional methods for the learning objectives? Are there any gaps?
- Is there an assessment tool for each learning objective?
• Compared to the other learning objectives of similar cognitive demand, is there more or less content?

Based on the three criteria, balanced alignment is if there a variety of instructional methods for each learning objectives, there is at least one assessment tool for each learning objective, there may be a few gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is similar content in the content matrix. Over-balanced alignment is if there a variety of instructional methods for each learning objectives, there is more than one assessment tool for each learning objective, there may be no gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is much more content in the content matrix. Under-represented alignment is if there is not a variety of instructional methods for each learning objectives, there is none or no more than one assessment tool for each learning objective, there may gaps in the content matrix, and compared to the other learning objectives of similar cognitive demand, there is less content in the content matrix.
Appendix E: Email to Gatekeeper

Dear Dr. [insert name]:

My name is Noha Elsherbiny and I am a PhD candidate in the Computer Science department at Virginia Tech. I am emailing you because I need your help in recruiting participants for my research study. I have developed an alignment process and prototype tool, to be used by a course instructor to assess the alignment for their course and be able to make informed course improvements. I am recruiting participants to use my prototype tool, to provide me with their perceptions about the process and the tool.

I would really appreciate it if you would help me identify potential participants. I am looking for participants that have a strong background in instructional design, have taught a course and have access to all of their course material.

Thank you for your help

Noha Elsherbiny

PhD Candidate in Computer Science

Virginia Tech
Appendix F: Email to Potential Participants

Dear [insert name],

My name is Noha Elsherbin and I am a PhD candidate in the Computer Science department at Virginia Tech. I am emailing you because I am recruiting participants for my research study. I have developed an alignment process and prototype tool, to be used by a course instructor to assess the alignment for their course and be able to make informed course improvements. I am recruiting participants to use my prototype tool, to provide me with their perceptions about the process and the tool.

As the course instructor for [course], I am wondering if you would be interested in participating in my study. I am looking for participants that do not have background in instructional design but have taught a course and have access to all of their course material. The study has received IRB approval from VT (18-505), I’ve attached a copy of the IRB approval form. I am estimating the time commitment for this study is two to four hours, depending on the complexity of your course. I would be very happy to answer any questions you have about the study.

Thank you for your help

Noha Elsherbin

PhD Candidate in Computer Science

Virginia Tech
Appendix G: Protocol for Screen Meeting

Script for pre-screening phone call:
Thank you for agreeing to meet with me. I have developed an alignment process and prototype tool, to be used by a course instructor to assess the alignment for their course and be able to make informed course improvements. I am recruiting participants to use my prototype tool, to provide me with their perceptions about the process and the tool.

Today, I will be asking you a few questions to determine whether you qualify as a participant in this study. It will only take a couple of minutes. After the screening process if you agree to continue with the study, I will give you a chance to read the informed consent form. I will answer any questions you may have and I will ask you to sign the form. Do you have any questions?

Do you give me permission to conduct the screening process? Yes / No

- Name of participant
- What course would you be interested in conducting the alignment study on?
- Were you the instructor of record for that course?
- Do you have access to all of the course materials?
- Do you have any instructional design or pedagogical training?
  - If yes: please explain what instructional design or pedagogical training you have received.

Does the Participant Meet the criteria for the study? Yes / No

If yes:
Thank you for your time, you have met the criteria for this study. Are you interested in continuing with the study? Yes / No

If yes:
Please read this consent form. Let me know if you have any questions.

[answer questions]
Please sign the form. May we please set a 4 to 5 times to meet to conduct the study. It is up to you when and for how long you’d like to meet.

[record times available to meet]

Where would you like to meet? Ideally it should be a space that you’re most comfortable in and have access to your course materials

[record space to meet]

Thank you for your time and I look forward to seeing you soon.

If no:

Thank you for your time, I appreciate you taking the time to meet with me.

If no:

Thank you very much for your time today but you did not meet the criteria for participant selection for my study. Unfortunately, I can’t include you in my study. Thank you again for your interest and time.
Appendix H: Informed Consent Form

RESEARCH SUBJECT CONSENT FORM

Title: Impact of the Mis-alignment of the Learning Objective and Course Content on Student Performance

Protocol No.: 18-505

Sponsor: Un-sponsored

Investigator: Stephen H. Edwards

2202 Kraft Drive
Blacksburg, VA 24061
USA

Daytime Phone Number: 540-353-6850

24-hour Phone Number: 540-353-6850

You are being invited to take part in a research study. A person who takes part in a research study is called a research subject, or research participant.

What should I know about this research?

- Someone will explain this research to you.
- This form sums up that explanation.
- Taking part in this research is voluntary. Whether you take part is up to you.
- You can choose not to take part. There will be no penalty or loss of benefits to which you are otherwise entitled.
- You can agree to take part and later change your mind. There will be no penalty or loss of benefits to which you are otherwise entitled.
- If you don’t understand, ask questions.
- Ask all the questions you want before you decide.

Why is this research being done?

The purpose of this research is to help instructors assess their instructional strategies by looking at the course alignment and how realigning a course’s assignments and exams can make it more effective. These findings will help us to evaluate our alignment model and how instructors can use it to improve their courses.

In this study we will re-align a specific course by using an alignment model to identify the areas of the course where the curriculum, assessments and instructional activities and methods do not align. We are working with the course instructor to correct the misalignment by re-designing parts of the course.
About 2-5 subjects will take part in this research.

**How long will I be in this research?**

We expect that your taking part in this research will last 1 hour.

**What happens to me if I agree to take part in this research?**

This study relies on the perceptions of the instructors of the course. We need to record and transcribe your answers to today’s interview/focus group questions. Which we will use to evaluate the effectiveness of the alignment model we used. Your involvement consists of taking part in this interview/focus group and sharing your answers and opinions about the specific course you are teaching or planning to teach.

This consent form is simply your way of giving us permission to use your comments and feedback from today’s interview/focus group.

**What are my responsibilities if I take part in this research?**

If you take part in this research, you will be responsible to:

- Voluntarily agree to participate in this study, and confirm you are not a minor (are not under 18).
- Participate in this interview/focus group, sharing the answers or comments you are willing to allow us to use for research purposes.

**Could being in this research hurt me?**

Participation in this research will not place you at more than minimal risk of physical or psychological harm.

**Will it cost me money to take part in this research?**

Taking part in this research does not cost any money.

**Will being in this research benefit me?**

We cannot promise any benefits to you or others from your taking part in this research. However, possible benefits to you include learning how to evaluate your own course’s alignment and learning how to fix alignment problems so that your course might be more effective. Your participation may contribute to refining or improving this alignment process. Possible benefits to others include making such a course alignment process available to other educators so that they may also benefit from applying it. We expect that this research will lead to improvements in CS education. These improvements are expected to include better instructional strategies and curricula developments, so that students can perform better in corresponding courses.
What other choices do I have besides taking part in this research?

Your alternative is to not take part in the research.

What happens to the information collected for this research?

The data we collect as part of this project will be kept strictly confidential. The data collected will be anonymous, you will be given a pseudo name so that you cannot be identified. Any personally identifiable information will be stored securely, where only the investigators can access it. The investigators will use the collected data in publications, and they may make such data available to other researchers outside the project who are investigating the learning of programming. In no case will personally identifiable information be divulged to any party outside the project team.

We may publish the results of this research. However, we will keep your name and other identifying information confidential.

We protect your information from disclosure to others to the extent required by law. We cannot promise complete secrecy.

Data collected in this research might be deidentified and used for future research or distributed to another investigator for future research without your consent.

Who can answer my questions about this research?

If you have questions, concerns, or complaints, or think this research has hurt you or made you sick, talk to the research team at the phone number listed above on the first page.

This research is being overseen by an Institutional Review Board (“IRB”). An IRB is a group of people who perform independent review of research studies. You may talk to them at (800) 562-4789, help@wirb.com if:

- You have questions, concerns, or complaints that are not being answered by the research team.
- You are not getting answers from the research team.
- You cannot reach the research team.
- You want to talk to someone else about the research.
- You have questions about your rights as a research subject.

What happens if I agree to be in this research, but I change my mind later?

You are free to withdraw from this study at any time, for any reason, and without penalty.

If you decide to leave this research, contact the research team so that the investigator can remove your data from the study.
Will I be paid for taking part in this research?

You will not be paid for taking part in this research.

**Statement of Consent:**

Your signature documents your consent to take part in this research.

| Signature of adult subject capable of consent | Date |
| Signature of person obtaining consent         | Date |
Appendix I: Interview Protocol

Pre-alignment Process Interview (10 – 15 minutes)
Hello nice to see you again. Thank you for signing the consent form and agreeing to be part of my study. Today we’re going to get started. I will be asking you a few questions, noting down your answers then I will review my answers with you. Do you have any questions?

<<Answer questions>>

Let’s get started.

- Have you heard the term alignment before? In what context? Can you define alignment?
  
  Please give an example of good alignment.

- What is your teaching experience? How long have you been teaching this course?
- How have you designed this course? Why did you select these topics?
- How do you make changes to your course? Why do you use this approach?
- What pedagogical training or instructional design training have you received?

Let’s review my notes <<reviewing notes with participant>>

Thank you for your time. Would you like to continue with the next part of the study now or wait for our next scheduled meeting?

Post-phase Interview (10 – 20 minutes)
Great job on completing the <<phase>>. I would like to ask you a few questions to get your perceptions about the process you just completed, noting down your answers then I will review my answers with you.

- What do you think was the purpose of this activity? What are your perceptions?
- How difficult was it to complete the phase?
- Did you feel the activity was taxing? How?
- How has this activity informed you about your course?
- Do you have any questions for me?

<<Answer questions>>

Let’s review my notes <<reviewing notes with participant>>

Thank you for your time. Would you like to continue with the next part of the study now or wait for our next scheduled meeting?
Post-alignment Process Interview

Thank you for completing the alignment process. Here is the alignment report from the alignment tool for your course. I will give you a few minutes to review it then we can discuss it. <<wait a few minutes>>

Do you have any questions about the report?

<<Answer questions>>

I would like to ask you a few questions to get your perceptions about the whole process and the tool. I will write down your answers then I will review my answers with you.

Alignment
- Please define alignment? Please give an example of alignment.

Usefulness
- What did you think of the results of the alignment process?
- Which of the results do you agree with and which do you not agree with? Why?
- Has the alignment process changed your perceptions of your curriculum? If yes, how?
- What are some things you plan to change in the course?
- Would you use this alignment process again? Why?
- How would you use this alignment process?

Ease of Use
- How easy was it for you to follow the alignment process?
- Which phase did you struggle with the most? Why?

Time commitment
- Do you feel that following the alignment manual was laborious? Is yes, how? If no, why not?
- What phase of the alignment process do you think need to be shortened? Why? Why do you think you took x minutes to complete phase y?

Alignment Tool
- What did you think of the alignment tool interface?
What functionality would you change? Why?

What functionality would you add? Why?

Thank you for your time participating in the study, I’ve really appreciated it. If you have any questions or concerns, please feel free to email me.
## Appendix J: Observation Form

<table>
<thead>
<tr>
<th>Participant:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Time:</td>
<td></td>
</tr>
<tr>
<td>End Time:</td>
<td></td>
</tr>
<tr>
<td>Phase:</td>
<td></td>
</tr>
<tr>
<td>Observations:</td>
<td>Questions asked participant and response:</td>
</tr>
<tr>
<td>Incorrect/missing information:</td>
<td>Questions asked by participant:</td>
</tr>
<tr>
<td>Changes made to previous phases:</td>
<td>Justification:</td>
</tr>
</tbody>
</table>
Appendix K: IRB Approval

MEMORANDUM
DATE: March 31, 2019
TO: Stephen H Edwards, Noha Ibrahim Mohamed Elsherbiny
FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)
PROTOCOL TITLE: Impact of the Mis-alignment of the Learning Objective and Course Content on Student Performance
IRB NUMBER: 18-505

The Virginia Tech Institution Review Board (IRB), acknowledges the Amendment request for the above-mentioned research protocol.

This acknowledgement recognizes the item(s) identified in the Special Instructions section.

NOTE: Amendments that must be submitted to WIRB for review and approval include changes to funding, conflict of interest, ANY and ALL changes to study procedures and study documents. If your study received a Determination letter (qualified for Not Human Subjects or for an Exemption) please review the information at the end of your Determination Letter. If your study was approved by a Panel, WIRB provides guidance on making changes in their Guide for Researchers. Please refer to the section titled, Changes to Research / Additional Document Submissions in the following document:
### Appendix L: Digitized Observation Forms

<table>
<thead>
<tr>
<th>Participant:</th>
<th>CS Instructor 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Time:</td>
<td>6:06pm</td>
</tr>
<tr>
<td>End Time:</td>
<td>7:06pm</td>
</tr>
<tr>
<td>Phase:</td>
<td>1) Defining Learning Objectives</td>
</tr>
<tr>
<td>Observations:</td>
<td>Questions asked participant and response:</td>
</tr>
<tr>
<td>Participant did not have learning objectives for the course. Showed them the tutorial for defining the learning objectives. No experience with Bloom’s taxonomy had heard of it before but never seen it applied. Referred to the lecture slides, there was a list of outcomes for the lecture. They used that as a starting point to define the learning objectives. Learning objectives have non-measurable verbs and non-action verbs. Took a while to get started but once begun got faster. Second guessing – revisiting the learning objectives to re-evaluate their wording. Developed a list of learning objectives. Asked them to define level of cognitive skill. Showed them tutorial on cognitive skill. Participant was very hesitant, they asked for an elaboration on the difference between apply, create, and analyze. Participant was using their verbs in the learning objective to assign a level of cognitive skill, but the verbs don’t seem to be accurate. Stopped for 1 minute. Participant is clearly confused because their phrasing of the learning objective is incorrect. The participant recognized the problem, started assigning a level of cognitive skill (LCS). Getting faster at assigning LCS around learning objective number 33.</td>
<td></td>
</tr>
<tr>
<td>Is everything ok, why are you hesitant? Learning objective is low-level (the verb used) but I think it needs to be higher. Are you asking if the level of cognitive skill can be higher than the verb you used to describe the learning objective? Yes It’s ok, you decide what level of cognitive skill to assign.</td>
<td></td>
</tr>
<tr>
<td>Incorrect/missing information:</td>
<td>Questions asked by participant:</td>
</tr>
<tr>
<td>A lot of the learning objectives had non-measurable action verbs. Confused between create and analyze.</td>
<td>Students have difficulty between return and print functions. Do I used applying/creating?</td>
</tr>
<tr>
<td>Changes made to previous phases:</td>
<td>Justification:</td>
</tr>
<tr>
<td>None</td>
<td>N/A</td>
</tr>
<tr>
<td>Participant:</td>
<td>CS Instructor 1</td>
</tr>
<tr>
<td>-------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Start Time:</td>
<td>1:19pm</td>
</tr>
<tr>
<td>End Time:</td>
<td>3:56pm</td>
</tr>
<tr>
<td>Phase:</td>
<td>2) Create Content Matrix</td>
</tr>
</tbody>
</table>

**Observations:**

Understood the prompt for building the content matrix. Not convinced with level of detail required to build the content matrix.

Started filling the content matrix by looking at the learning objective, going to the course materials and findings course components that match.

Tried a different strategy, started with the course components and mapping it to the learning objective. “It’s faster”

Instructor seems to think that learning objectives should only be for “programming skills” not for all the skills they want students to acquire in the course. Even skills that are enforced by program requirements.

Participant uses likert scale questions on an “honor code survey” sent every 2 weeks of the semester worth 10-point bonus to teach students how to not violate honor code.

When filling the programs in the content matrix, started to get tired and bored. Offered a break.

Refused.

Completed the content matrix

**Questions asked participant and response:**

*Why did you not include Quiz 1& 3 in the content matrix?*

These are introductory, most students have seen MATLAB so these are just to introduce the course.

*Why not include Quiz 5, 11, 14, 26?*

These are ethics portion and not relevant to the course. Part of pathways requirement.

**Incorrect/missing information:**

Many course components do not correspond to a learning objective (12).

There are not learning objectives for honor code survey although it seems like an important skill they’re dedicating a bit of class time for!

**Questions asked by participant:**

*How detailed do I need to be?*

Is it necessary to be that detailed?

**Changes made to previous phases:**

Added a learning objective on tuples.

**Justification:**

N/A
<table>
<thead>
<tr>
<th>Participant:</th>
<th>CS Instructor 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Time:</td>
<td>4:09pm</td>
</tr>
<tr>
<td>End Time:</td>
<td>4:17pm</td>
</tr>
<tr>
<td>Phase:</td>
<td>3) Create Assessment Matrix</td>
</tr>
</tbody>
</table>

**Observations:**
Participant understood the prompt for filling out the assessment matrix. Was very straightforward, went to midterm and filled out the assessment matrix with minimal interruptions (very fast). Pulled up the final exam and filled out the assessment matrix very quickly. Did not hesitate at all.

**Questions asked participant and response:**
*Is this easier than the content matrix?* Not easier just I’ve done it before so I know what to expect plus it’s only 2 exams!

**Incorrect/missing information:**
None

**Questions asked by participant:**
Again, you want me to be detailed. Is there a purpose from this activity?

**Changes made to previous phases:**
None

**Justification:**
N/A
<table>
<thead>
<tr>
<th>Participant:</th>
<th>CS Instructor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Time:</td>
<td>8:18am</td>
</tr>
<tr>
<td>End Time:</td>
<td>10:15am</td>
</tr>
<tr>
<td>Phase:</td>
<td>1) Defining Learning Objectives</td>
</tr>
</tbody>
</table>

**Observations:**
- Participant did not have learning objectives for the course. After showing them the how to define learning objectives tutorial they stared at screen for 2 minutes.
- Showed me a list of the course topics, these are the list of things students need to know. From there the participant used the topics to define sub-topics and learning objectives.
- Body language: they’re very uncomfortable, fidgeting a lot and hesitant often.
- Came with a list of learning objectives.
- Asked them to define level of cognitive skill.
- Showed them tutorial on cognitive skill.
- Participant looks interested, they had never heard of it before.
- Confused between applying and analyzing.
- Remembered 5 new learning objectives, went back to add them.
- Assigning level of cognitive skill for new learning objectives was easy they did not hesitate.

**Questions asked participant and response:**
- *You seem lost, is everything ok?*
  - No idea where to start.
- *What are the takeaways from the tutorial?*
  - Learning objectives are like goals? Maybe start there.
- *You did not hesitate assigning the level of cognitive skill for these?*
  - Math and logic are difficult concepts to get, so I show students how to do it on paper, using truth tables. I cover this a lot, once they get the hang of this then Logic and Boolean expressions become very easy (participant referring to foundational concepts).

**Incorrect/missing information:**
- A lot of the learning objectives had non-measurable action verbs.

**Questions asked by participant:**
- How to define a learning objective?
- Why do I need the topic of the learning objective?
- What is level of cognitive skill?
- Is it ok if all of level of cognitive skill is 1 or 2?

**Changes made to previous phases:**
- None

**Justification:**
- N/A
<table>
<thead>
<tr>
<th>Participant:</th>
<th>CS Instructor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Time:</td>
<td>10:48am</td>
</tr>
<tr>
<td>Phase:</td>
<td>2) Create Content Matrix</td>
</tr>
</tbody>
</table>

**Observations:**

Participant understood the prompt for building the content matrix but did not know where to start. After flipping through canvas site, they decided to look at the course materials week by week.

Lectures: participant explained that they had to use iclicker questions because of course coordinator. Thinks they are time consuming.

Out of class quizzes: untimed to give students time to answer questions.

As the participant was filling out the content matrix they were speaking out loud their rationale for course design:

- Untimed assessments so students with exam anxiety can do well
- Taking time to explain first 2 weeks of lectures so students can take time to digest content
- Giving students access to many exercises for them to practice on their own time but do not count towards final grade.

Participant course is large, they were starting to get bored. “This is repetitive”. I explained the rationale for completing the content matrix “It’s nice to talk to someone”

**Questions asked participant and response:**

*Why did the 39 homework problems not in the content matrix?*

They’re practice problems to strengthen student background before moving onto another topic.

*Do you feel the course has much content?*

Yes, but that is because the course coordinator dictates what needs to be in the course. Then, I made modifications so it’s a lot. I removed some things.

**Incorrect/missing information:**

39 homework problems that did not correspond to a learning objective.

**Questions asked by participant:**

Should I include sub-question numbers?

Should I include iclicker questions, even if they’re different every time?

**Changes made to previous phases:**

None

**Justification:**

N/A
<table>
<thead>
<tr>
<th>Participant</th>
<th>CS Instructor 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Time:</td>
<td>12:29pm</td>
</tr>
<tr>
<td>End Time:</td>
<td>3:43pm</td>
</tr>
<tr>
<td>Phase:</td>
<td>3) Create Assessment Matrix</td>
</tr>
</tbody>
</table>

**Observations:**
Participant understood the prompt for building the assessment matrix. Had a strategy to fill out the matrix quickly:
- Printed out the assessments on paper.
- Started with mid-term exam
- Looked at the list of learning objectives by topic and assigned the learning objective to the corresponding question.

At times the participant hesitated because the learning objective was not the main purpose of the question.

Copying results to the google sheet
Finals exam took less time to complete than the mid-term, they were familiar with the learning objectives by then. Taking less time to copy the results to the google sheets

“Oh I covered this a lot”, when looking at the finals exam and how the learning objectives were repeated.

**Incorrect/missing information:**
None

**Questions asked by participant:**
- What do I do if the learning objective doesn’t really address the question?

**Changes made to previous phases:**
None

**Justification:**
N/A
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<th><strong>Participant:</strong></th>
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<tr>
<td><strong>Start Time:</strong></td>
<td>3:53pm</td>
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<td><strong>End Time:</strong></td>
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<tr>
<td><strong>Phase:</strong></td>
<td>1) Defining Learning Objectives</td>
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**Observations:**
Participant had learning objectives for the course. Pulled out file with learning objectives and copied and pasted them into the google sheet. Asked them to define level of cognitive skill. Participant would re-assess the level of cognitive skill but was confident when making decisions. Was familiar with level of cognitive skill. Created a list of learning objectives with level of cognitive skill.

**Questions asked participant and response:**
*This is straightforward for you? I’ve done it (defining learning objectives) before.*

**Incorrect/missing information:**
None

**Questions asked by participant:**
None

**Changes made to previous phases:**
None

**Justification:**
N/A
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<td>End Time:</td>
<td>4:37pm</td>
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<tr>
<td>Phase:</td>
<td>2) Create Content Matrix</td>
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**Observations:**
Participant understood the prompt for building the content matrix but wanted clarification on the level of detail. Explained to them. They completed the content matrix with no hesitation at all.

**Questions asked participant and response:**

*This seemed really straightforward for you?*
I had to do something similar for pathways assessment of my class a few months ago so this is easy.

**Incorrect/missing information:**
None

**Questions asked by participant:**

*How detailed do I need to be?*

**Changes made to previous phases:**

**Justification:**

Modified the level of cognitive skill of a learning objective

**N/A**
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<td>End Time:</td>
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<tr>
<td>Phase:</td>
<td>3) Create Assessment Matrix</td>
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<table>
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<tr>
<th>Observations:</th>
<th>Questions asked participant and response:</th>
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<tbody>
<tr>
<td>Participant understood the prompt for building the assessment matrix. Did not need any clarification. They completed the assessment matrix quickly and with no hesitation at all</td>
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<table>
<thead>
<tr>
<th>Incorrect/missing information:</th>
<th>Questions asked by participant:</th>
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<td>None</td>
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<tr>
<td>Participant:</td>
<td>ED Instructor 2</td>
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<td><strong>Start Time:</strong></td>
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<tr>
<td>2:17pm</td>
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<tr>
<td><strong>Phase:</strong></td>
<td>1) Defining Learning Objectives</td>
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**Observations:**
- Participant had learning objectives for the course set by the course coordinator. Did not like them.
- Familiar with learning objectives and Bloom’s taxonomy
- Participant re-formulating the learning objectives. Disagreeing with the wording in the original learning objectives.
- Participant googled Bloom’s taxonomy the list of action verbs, used them to reformulate learning objectives.
- Started off with a list of topics, for each topic
  - What is the purpose of this topic? Took notes on what they wanted students to achieve
  - Went back to action verbs to put each outcome into a learning objective
- Stopped to think, when got stuck would jump between topics
- Seemed indecisive
- Put significant time to think of the details of each learning objective.
- Came up with a list of learning objectives
- Assigning level of cognitive skill to the learning objectives.
- Would often go back and revise the level of cognitive skill for previous learning objectives
- In the end double checked their learning objectives and level of cognitive skill

**Questions asked participant and response:**

- **What are you thinking about?**
  Thinking of the best wording to describe the learning objective. It’s not easy to come up with the best action verb

**Incorrect/missing information:**
- None

**Questions asked by participant:**
- None

**Changes made to previous phases:**

**Justification:**

**None**

**N/A**
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<td>End Time:</td>
<td>11:17am</td>
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<tr>
<td>Phase:</td>
<td>2) Create Content Matrix</td>
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**Observations:**
- Participant understood prompt for building the content matrix. Did not see the need for the activity.
- Filled the content matrix by going through course content week by week.
- Most of the course work is not divided into sub-questions or tasks.
- Seemed straight forward, very minimal hesitation.
- Course did not have many course components and sub-components.
- Did not want to add 2 lectures to content matrix.
- Looking at some assignments and trying to map them to a learning objective, realized that they were missing a learning objective (repeated 6 times).

**Questions asked participant and response:**
- Why did you not add 2 lectures in the content matrix?
  Those are not significant.
- Why are there no learning objectives for 8 content?
  Those are enforced by course coordinator, to ask students to prepare for the next class. Activity each week.

**Incorrect/missing information:**
- 2 lectures, 2 assignments and 4 labs with no corresponding learning objective.

**Questions asked by participant:**
- Why are you asking an instructor to do this?
  I forgot a learning objective, can I add one?

**Changes made to previous phases:**
- Added 6 new learning objectives

**Justification:**
- N/A
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<th>ED Instructor 2</th>
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<td>End Time:</td>
<td>11:35am</td>
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<tr>
<td>Phase:</td>
<td>3) Create Assessment Matrix</td>
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</table>

**Observations:**
- Participant understood prompt for building the assessment matrix.
- They were more accepting of this activity, they seemed to understand the connection between Phase 2 and 3.
- Filled the assessment matrix by going through assessments and mapping them to a learning objective.
- Seemed straightforward, and was very fast and confident when filling out the matrix.
- Did not hesitate or make any revisions.

**Questions asked participant and response:**
- *Straight forward activity?*
  - Yes it’s the same as last one but shorter
- *Different from the previous?*
  - I understood what you wanted us to do, so this one is easy enough. It’s like checking to see assessments are correct (measuring what they should).

**Incorrect/missing information:**
- None.

**Questions asked by participant:**
- None.

**Changes made to previous phases:**
- None.

**Justification:**
- N/A.
Appendix M: Digitized Interview Notes

**Participant:** ED Instructor 1

**Date:** March 12, 2019

*Pre-alignment Process Interview*

- *Have you heard the term alignment before? In what context? Can you define alignment? Please give an example of good alignment.*
  Maybe like in values, the values of a person being in alignment with a job. Nothing in pedagogy.

- *What is your teaching experience? How long have you been teaching this course?*
  Taught in higher education institutions for four years and taught the course four times

- *How have you designed this course? Why did you select these topics?*
  I had to redesign the course so it met pathways requirements. The old version was awful it had nothing to do with community. Didn’t like the flow. Revamped the course using Bloom’s taxonomy.

- *How do you make changes to your course? Why do you use this approach?*
  Consulted with 2-3 experienced faculty in school of education. I knew what I wanted students to get out of the course. Developed the learning objectives together. It’s very helpful to have someone to “bounce ideas off each other and it’s good to have people check them for you.”

- *What pedagogical training or instructional design training have you received?*
  Went to multiple workshops and many transferrable skills.

**Date:** March 12, 2019

*Post Phase 1 Interview*

- *What do you think was the purpose of this activity? What are your perceptions?*
  To define the learning objectives for the course

- *How difficult was it to complete the phase?*
  Not at all

- *Did you feel the activity was taxing? How?*
  No it just requires some thought

- *How has this activity informed you about your course?*
  Nothing new

- *Do you have any questions for me?*
  No
**Date:** March 12, 2019  
**Post Phase 2 Interview**
- *What do you think was the purpose of this activity? What are your perceptions?*  
  Maybe to think how each part of the course addresses the learning objectives.

- *How difficult was it to complete the phase?*  
  Not at all it was straight forward after I knew what to do, plus had to do something similar for pathways assessment.

- *Did you feel the activity was taxing? How?*  
  Not at all, it makes me feel good. Helps me remember why I teach the course. “When I redesigned the course goals and revamped the course based on critical race theory”. This shows me how well the redesign is and how the course operates as a package.

- *How has this activity informed you about your course?*  
  “No wonder students say the course is repetitive!” (service learning objective). Students were complaining that the course was repetitive. I need to retool the reflection assignments, there needs to be more synthesis work. It also explains why the students were not completing the readings.

- *Do you have any questions for me?*  
  No

**Date:** March 12, 2019  
**Post Phase 3 Interview**
- *What do you think was the purpose of this activity? What are your perceptions?*  
  It shows me how the learning objectives and the assignments match. It shows me that what I do actually meets course outcomes.

- *How do you usually design your assessments?*  
  For this course, I used the learning objectives as a starting point to develop materials and then the assessments for them.

- *How difficult was it to complete the phase?*  
  Not difficult.

- *Did you feel the activity was taxing? How?*  
  Slightly taxing going through all of the course materials.

- *How has this activity informed you about your course?*  
  Again, the course is repetitive. I need to make sure that the reflections are less repetitive and incorporate maybe more readings into the reflections.

- *Do you have any questions for me?*  
  No
Date: March 18, 2019
Exit Interview (Post Alignment)

Alignment
- Please define alignment? Please give an example of alignment.
  “make sure there is proper balance of representation in relation to different levels of bloom’s taxonomy”

Usefulness
- What did you think of the results of the alignment process?
  “This is so validating! All of the hard work and time I put into redesigning my course.” Proof of the intentionality of the work. I will continue to look at the range of knowledge for the course to make sure I have varying instructional methods.

- Which of the results do you agree with and which do you not agree with? Why?
  Agreed with all of the results. It’s a helpful way to look at the course. I have nothing negative to say because everything is aligned.

- Has the alignment process changed your perceptions of your curriculum? If yes, how?
  Not changed but confirmed. “I can see how the course operates as a package. “ and areas of improvement

- What are some things you plan to change in the course?
  Need to add more synthesis work in the course. Like said before it’s repetitive so need to go through the syllabus and update. For the under-represented learning objectives will do a better job defining community throughout the panel discussions.

- Would you use this alignment process again? Why?
  Yes. It’s helpful and structured.

- How would you use this alignment process?
  “It’s useful in the early stages of re-developing a course” like for a new program I’m working on, making sure the learning objectives and course is in alignment. Could also be very helpful to use when assessing service projects, making sure the alignment of the project itself is correct.

Ease of Use
- How easy was it for you to follow the alignment process?
  It was ok, the prompts were clear.

- Which phase did you struggle with the most? Why?
  Maybe defining the cognitive skill but it was not too bad. I was also unsure how detailed I needed to be.

Time commitment
- Do you feel that following the alignment manual was laborious? Is yes, how? If no, why not?
  No not at all it didn’t take me any time
• What phase of the alignment process do you think need to be shortened? Why? Why do you think you took x minutes to complete phase y?
  I don’t think so, there’s nothing to change

Alignment Tool
• What did you think of the alignment tool interface?
  Good. “Helpful to be able to edit and change the content or learning objectives as I remember things”

• What functionality would you change? Why?
  Nothing

• What functionality would you add? Why?
  Adding examples of the instructions so it may be easier for the instructor to fill out the content and assessment matrices. Like for example when looking in syllabus look for…

Participant: ED Instructor 2
Date: March 11, 2019

Pre-alignment Process Interview
• Have you heard the term alignment before? In what context? Can you define alignment? Please give an example of good alignment.
  No noting related to teaching

• What is your teaching experience? How long have you been teaching this course?
  Taught for 6 years university level courses for chemical engineering then taught foundations of engineering four times.

• How have you designed this course? Why did you select these topics?
  Did not there is a course coordinator who decides what the course should be. Has some degree of flexibility to modify some of the assignments. Felt that ethics was an important topic but not covered well in the course so added some assignments to address ethics.

• How do you make changes to your course? Why do you use this approach?
  I use the results from the assessments, based on the students’ performance I can evaluate what needs to change. Teaching method, the assignments or labs etc. We have a roundtable meeting with the course coordinator to discuss the findings from the assessments. This way the changes are the same across all the classes.

• What pedagogical training or instructional design training have you received?
  In (home country) went through teacher development workshops and at (current institution) took four instructional design courses. Observed and was observed by other faculty.

Date: March 11, 2019
Post Phase 1 Interview
• What do you think was the purpose of this activity? What are your perceptions?
  Push me to think of the finer details of the course
• How difficult was it to complete the phase?
It’s not easy to come with wording for the learning objectives. It is a difficult task. It’s not easy to define learning objectives needs practice. “You can’t use a tutorial to teach someone to create learning objectives”.

• Did you feel the activity was taxing? How?
No not really

• How has this activity informed you about your course?
Level of cognitive skill serves as a reminder about the expectations from the course

• Do you have any questions for me?
No

Date: March 13, 2019
Post Phase 2 Interview
• What do you think was the purpose of this activity? What are your perceptions?
To make sure there is something for each learning objective and that there is something to evaluate the students.
• How difficult was it to complete the phase?
No

• Did you feel the activity was taxing? How?
The level of detail was a little much. “Just took a long time, not necessarily taxing”

• How has this activity informed you about your course?
You have to have taught the class to fill this out, it’s not possible to do if you haven’t taught the class. It provides a draft of the class, visually see the class. Showing the boundaries between learning objectives and the class.

• Do you have any questions for me?
How could this be of use for students?
<<answer: not necessarily for students but definitely for faculty which in the end impacts students. Q: Do you see a use for students?>>
Maybe as a metacognitive strategy for students to see the content distribution

Date: March 13, 2019
Post Phase 3 Interview
• What do you think was the purpose of this activity? What are your perceptions?
To make sure that the assessments and the learning objectives match.

• How do you usually design your assessments?
Look at each topic covered and always use the learning objectives, start with that. Have questions that map to each learning objective.
• How difficult was it to complete the phase?
  It was ok

• Did you feel the activity was taxing? How?
  No

• How has this activity informed you about your course?
  Making sure that the assessments and components the students are exposed to are relevant and address learning objectives. Used as a checking point to check materials.

• Do you have any questions for me?
  What happens if a question doesn’t map to a learning objective?
  <<This is a sign of a possible misalignment in the course. Q: How would you usually address this issue?>>
  Don’t usually have that problem but it would mean that you need to reframe the question to map to a learning objective. Pointless assessment question

Date: March 19, 2019
Exit Interview (Post Alignment)

Alignment
• Please define alignment? Please give an example of alignment.
  Process of relating major components of a course: content, learning objectives, assessments to make sure there is proper balance of representation in relation to the different levels of Bloom’s taxonomy. Looking at the over emphasis or under emphasis of learning objectives.

Usefulness
• What did you think of the results of the alignment process?
  It’s not surprising, the balance of representation makes sense I expected to see that. You can see the work required of students and what is taught and the gaps. Reflecting on the process you can see it when looking at the results why they are the way they are.

• Which of the results do you agree with and which do you not agree with? Why?
  Disagree with depth of knowledge results. These are assignments not to collect feedback but they’re to have them do something. “They’re not assignments like the others, the goal is to have an activity every week.”
  Disagree with over-represented learning objective: learn to use engineering tools to design and test. Need lots of content “It has to be that way because it’s a basic skill they’re required to master”.

  <<q:but why did you assign a level 2 cognitive skill if they are required to master it?>>
  I guess it makes sense to have it as analyzing or applying.

• Has the alignment process changed your perceptions of your curriculum? If yes, how?
  Revisiting the learning objectives to make sure that the wording is accurate and concise.
  Add more learning objectives for assignments with no learning objective (addressing the reflection component of the course)
• What are some things you plan to change in the course?
  Like before revisiting the learning objectives

• Would you use this alignment process again? Why?
  No, “It’s a useful activity if you have just started teaching but a more experienced instructor does not need it.”. Helpful reflection activity on how you teach but more experienced instructors use instructional design strategies to develop aligned courses. Don’t need this.

• How would you use this alignment process?
  N/A

Ease of Use
• How easy was it for you to follow the alignment process?
  Ok

• Which phase did you struggle with the most? Why?
  Still think defining the learning objectives is a hard activity and challenging task

Time commitment
• Do you feel that following the alignment manual was laborious? Is yes, how? If no, why not?
  Took a long time but you are going through a whole course it’s normal

• What phase of the alignment process do you think need to be shortened? Why? Why do you think you took x minutes to complete phase y?
  Nothing really in mind

Alignment Tool
• What did you think of the alignment tool interface?
  Ok provided a numeric representation of the course. A clean summary of the course

• What functionality would you change? Why?
  Nothing

• What functionality would you add? Why?
  Nothing

Participant: CS Instructor 1
Date: Feb 20, 2019
Pre-alignment Process Interview
• Have you heard the term alignment before? In what context? Can you define alignment? Please give an example of good alignment.
  No, sounds like a construction term for like model building. First thing comes to mind is dungeons and dragons. Nothing in CS.
• What is your teaching experience? How long have you been teaching this course?
7 years of teaching experience as instructor of record, taught online courses and regular in-person. Taught small class of 30 and large classes of up to 540 students in CS and MATH. Enjoys teaching students with no programming experience

• How have you designed this course? Why did you select these topics?
Inherited course. Kept the course the same, it’s good. It presents information logically and covers all the necessary topics. Just had to re-order lectures because the flow felt better. Also added topics related to data science, it’s really an important topic in this day and age. There are so many applications of concepts taught in class in data science. Plus it’s area of expertise (research) so enjoys teaching it and showing students ways on how to visualize data.

• How do you make changes to your course? Why do you use this approach?
Observed students’ reactions in class as well as how they do on classwork. Can tell when they’re struggling with a topic. It works!

• What pedagogical training or instructional design training have you received?
None

Date: Feb 20, 2019
Post Phase 1 Interview
• What do you think was the purpose of this activity? What are your perceptions?
To build connections between the learning objectives

• How difficult was it to complete the phase?
“I understood the concepts in the tutorial but I had no idea where to start.” “Choosing the right level of cognitive skill was hard”. Unfamiliar with Bloom’s taxonomy. “Trying to think of the learning objective and rationalize what I want students to know is hard”.

• Did you feel the activity was taxing? How?
No it was just hard

• How has this activity informed you about your course?
Made me think out loud about the effort required by students to meet the learning objectives. Thinking about the level of thought I want them to meet. Makes me think of how do I get them (students) to “evaluate” in Bloom’s taxonomy.

• Do you have any questions for me?
No
Date: March 9, 2019
Post Phase 2 Interview
• What do you think was the purpose of this activity? What are your perceptions?
Looking at all of the course and how it maps to level of cognitive skill. For this course, specific learning objectives have higher level of cognitive skill and vague learning objectives have lower level of cognitive skill
• How difficult was it to complete the phase?
  No

• Did you feel the activity was taxing? How?
  Easy overall just time consuming and trivial. This activity is good for classes with light workload, it would be much easier to apply. Or maybe not breaking up the individual questions (high level of granularity). Mapping individual questions didn’t provide more insight than by like topics. I can see myself using it if I hadn’t taught a class for a while, 5 years ago when I first starting teaching this may have been helpful but definitely not last semester’s class.

• How has this activity informed you about your course?
  The class seems balanced overall, there are some learning objectives that are vague and others which are more specific. “The blanks in the content matrix presents other opportunities to introduce content in the class”.

• Do you have any questions for me?
  No

Date: March 9, 2019
Post Phase 3 Interview

• What do you think was the purpose of this activity? What are your perceptions?
  Makes me think of the course in another way. This time I was looking at question to the learning objective. Helpful way to view the course.

• How do you usually design your assessments?
  I look at each topic and come up with question that map to things done in the class.

• How difficult was it to complete the phase?
  Better than content matrix

• Did you feel the activity was taxing? How?
  No

• How has this activity informed you about your course?
  I need to broaden the questions on the final exam, they were too compact. There needs to be more coverage on the final exam on topics that are missing. Need to come up with new questions.

• Do you have any questions for me?
  No
Exit Interview (Post Alignment)

Alignment

- Please define alignment? Please give an example of alignment.
  The strong correlation between what I want students to learn and what students actually learn and what they’re tested on. Balance of topics over all of the course, what’s over-represented and what’s under-represented?

Usefulness

- What did you think of the results of the alignment process?
  “It’s what I expected. I could tell from their results.” Saw it in the students answers to questions on the exam or in programming assignments. It provided a nice summary of the course, making them implicit of things they were not aware of.

- Which of the results do you agree with and which do you not agree with? Why?
  Not agree or disagreeing. It just provided another way to think of the class. “I never thought of metadata before”. Didn’t think of the class as learning objectives mapping to course content.

- Has the alignment process changed your perceptions of your curriculum? If yes, how?
  Yes, “I need to think carefully about what learning objectives are in my course and what do I want them to convey”. Thinking about the conscious vs. unconscious class expectations. Don’t like to use slide shows to present, so going off script may not be the best way to teach. May not always cover everything I want to.

  TEACHING STYLE: wants to modify their teaching style
  “This strategy is useful, listing all I want to cover in my course and mapping it to course work” to make sure that for example functions (under-represented) is covered in the flow of all the examples and questions.
  Need to reassess “what qualifies as learning objective” include the unconscious things.
  Need to think about “how do you learn the topics well and think about how to assess it”

- What are some things you plan to change in the course?
  “Look at the very high-level learning objectives (level 5 for chaining functions) to make sure I have more assignments”. Add more questions on the homeworks
  Think about the purpose of some of the activities and what is in the assessments. Change five assessment questions.

- Would you use this alignment process again? Why?
  Yes if I want to build on another course or if developing course from scratch. Helpful to plan curriculum development. High level of granularity is time consuming, “not very useful for a class I know”

- How would you use this alignment process?
  If inherited a course and not confident how well the course works, would apply the process.
  “Would use it every few years as a refresher” (about the course)

Ease of Use

- How easy was it for you to follow the alignment process?
  Yes
Which phase did you struggle with the most? Why?
Defining the learning objectives. “Trying to think of the learning objective and rationalize what I want students to know is hard”.

Time commitment
- Do you feel that following the alignment manual was laborious? Is yes, how? If no, why not?
  No, it’s trivial and sometimes time consuming

- What phase of the alignment process do you think need to be shortened? Why? Why do you think you took x minutes to complete phase y?
  Defining the learning objectives is hard. Bloom’s taxonomy is useful but need access to the taxonomy and “need more time to think about it”. Allowing them to go over the whole course and think about it. Helpful to have someone to talk to.

Alignment Tool
- What did you think of the alignment tool interface?
  No complaints. “sheets are handy, having large content in forms is not readable.”
- What functionality would you change? Why?
  None
- What functionality would you add? Why?
  Add a parser to phase one, so it can check for non-measurable action verbs

Participant: CS Instructor 2
Date: Feb 12, 2019
Pre-alignment Process Interview
- Have you heard the term alignment before? In what context? Can you define alignment? Please give an example of good alignment.
  Not heard before in the context of teaching. Would guess “teaching towards learning objectives” trying to hit learning objectives. Think of car wheel alignment.

- What is your teaching experience? How long have you been teaching this course?
  Nothing formal, helped friends out with their classes. First formal teaching experience when graduate teaching assistant for CS 1114. Taught the class four times.

- How have you designed this course? Why did you select these topics?
  “I wanted students to be prepared to tackle CS2114”. Looked at the goals for CS2114 as what students should be able to meet (prior knowledge). Ideally they should be able to start an internship after the class is over.

- How do you make changes to your course? Why do you use this approach?
  Didn’t like previous iterations of the course taught in the fall and spring, it was “industrial like”. Class sizes were large “I didn’t know students’ names!”

  Adaptive syllabus depending on the students (mixture of seniors and non-majors). “Want to use real word applications to make it more interesting”. Had long-term and short-term goals to
meet in the class: to pass the class but in the end can you problem solve. Goal is to teach the “rules and best practices”. “It was tough making decisions about which topics to include.”

- *What pedagogical training or instructional design training have you received?*
  None

**Date:** Feb 12, 2019  
*Post Phase 1 Interview*
- *What do you think was the purpose of this activity? What are your perceptions?*
  To learn about the goals and sub-goals of the class. Goals are each topic.

- *How difficult was it to complete the phase?*
  It was hard to start it, “What are you looking for?”

- *Did you feel the activity was taxing? How?*
  It was ok

- *How has this activity informed you about your course?*
  Nothing much

- *Do you have any questions for me?*
  No

**Date:** Feb 14, 2019  
*Post Phase 2 Interview*
- *What do you think was the purpose of this activity? What are your perceptions?*
  To understand how the course is spaced out and the intersectionality of the content. “What students should know from what I’m teaching”

- *How difficult was it to complete the phase?*
  No

- *Did you feel the activity was taxing? How?*
  It’s ok. Lots of grunt work and repetitive, going through all that stuff (course content)

- *How has this activity informed you about your course?*
  “I spend so much time teaching the basics”, lots of understanding and applying but I guess that’s normal for a beginner’s class.

- *Do you have any questions for me?*
  “What about skills I want them to learn that are not in the slides but I teach them by showing code examples?”

**Date:** Feb 21, 2019  
*Post Phase 3 Interview*
- *What do you think was the purpose of this activity? What are your perceptions?*
I think it’s to reflect on the coherence of the course. “It’s made me realize the importance of
the questions I’m asking”. It’s a “useful activity to make me reflect on things I have not
reflected on before”. What “I’ve over-prepared students for like the basics”. “There are just
things they have to know! They need to be able to use logic and think.”

“I was surprised I thought I had more” (covered more topics in the assessments), maybe need
to “spread out the topics to cover more”

• How do you usually design your assessments?
I use previous questions from previous courses, I look at what worked and what didn’t

<<how do you know what worked and what didn’t>>
Based on their responses, I can tell. I make sure that in the future the topic is covered
somewhere. To make sure they’re not guessing I’m asking short response that they have to
write on paper. No multiple choice.

• How difficult was it to complete the phase?
It’s ok, just like the other one (phase 2) it was time consuming but it’s helpful

• Did you feel the activity was taxing? How?
Not really

• How has this activity informed you about your course?
Showed me how much I focus on a few topics. Polymorphism is tested a lot.

• Do you have any questions for me?
No

Date: March 13, 2019
Exit Interview (Post Alignment)

Alignment
• Please define alignment? Please give an example of alignment.
  “When your outcomes are matching the student outcomes”. When” all paths in the class
  match”. The levels of understanding required to meet each learning objectives and the content
  should fit all of these levels. Describes the specific steps towards the aggregate

Usefulness
• What did you think of the results of the alignment process?
  “It provided a glimpse of the course” What do I test? Looking at the levels of what I test.
  Overall it provides a “full picture of what I teach”

• Which of the results do you agree with and which do you not agree with? Why?
Disagree: Over-represented learning objectives for basics. “I need to repeat the basics” “They
need to practice these skills, so of course there should be more content on them!”
reinforcing what they are learning at the beginning of the class. “You can’t compare all of the
learning objectives for level 2, they’re not the same”
I explained why the comparison is needed>
It’s over-represented because “what’s expected is not what is achieved”, ok.

Agree: Details of why under-represented, need to make changes.

- Has the alignment process changed your perceptions of your curriculum? If yes, how?
  Yea, there are things I must emphasize more in the course. “I will remove some of the labs and add more homework for the under-represented stuff”.

“There is a deficiency in my assessments”. The testing level of knowledge is not what I want it to be, there needs to be a wider variety of questions.

- What are some things you plan to change in the course?
  “I need to change my assignments; I focus too much talking about the basics”, remove some of the labs
  “I want students to achieve a level 2 cognitive skill for reading and writing files but I don’t have assignments.” I can add some homework assignments for that

I can’t implement these, I’m at the “mercy of the professor” (coordinator). There’s a lack of agency you need to be aware of.

- Would you use this alignment process again? Why?
  For [ ] no it’s too involved with too many hours

- How would you use this alignment process?
  This is great for a big class like [ ], the course coordinator should ask all the instructors of this course to apply this process and we can compare the different course alignment. “It would be good to apply this process across all of the sections teaching the course.” “To make sure we’re all on the same page.” Maybe this is not helpful for a small class, there not be many things to look at.

“I could just go back and edit the content matrix to see changes” to evaluate the impact of changes identified on the course design

Ease of Use
- How easy was it for you to follow the alignment process?
  Yeah, it was no problem

- Which phase did you struggle with the most? Why?
  Defining the learning objectives, it was very hard.

Time commitment
- Do you feel that following the alignment manual was laborious? Is yes, how? If no, why not?
  It’s grunt work, going through all of the content was very time consuming
• What phase of the alignment process do you think need to be shortened? Why? Why do you think you took x minutes to complete phase y?
   Content matrix there is so much content to go through, you have to do it but it’s grunt work!

Alignment Tool
• What did you think of the alignment tool interface?
   It worked, the tables were very helpful. If make updates to the course, “I could just take the matrices and update from the class” “It doesn’t box you in”

• What functionality would you change? Why?
  Not sure

• What functionality would you add? Why?
  Need more examples in phase 1. Show me some “samples” for CS courses.