

The Design and Development of an Online Database-Driven Peer Assessment Tool
Using Division Rule Theory

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Abstract

Peer assessment has been adopted as a means of fair and equitable measurement of individual contributions to group work (Cheng & Warren, 2000; Conway & Kember, 1993; Gatfield, 1999; Goldfinch & Raeside, 1990; Lejk & Wyvill, 2001; Lejk, Wyvill, & Farrow, 1996) and it usually requires a certain mechanism or formula to quantify peer assessment criteria. The problem, however, is that it leads to circumstances where a student can be strategic and be easily able to obtain a higher score by simply giving lower scores to other members within a group. The need is to find a new mechanism and the purpose of this study is to develop an Online Database-Driven Peer Assessment Tool (ODDPAT) using the Division Rule mechanism as its core computational algorithm. This developmental study used modified Collaborative Create-Adapt-Generalize (CAG) model (Hicks, Potter, Snider, & Holmes, 2004) as its design and developmental framework. The process of design, development, and evaluation of the entire project was documented. Three experts were interviewed and detailed analysis of data was discussed. Finally, recommendations were made for its implementation and future research.

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Chapter 1: Introduction

Background and Rationale of Study

Living in the modern society we are often faced with challenges that involve complex and intractable problems. It is believed that collaboration is one of the essential social skills required to tackle these problems. Since this kind of social skill is not inherent, it needs to be learned (Jacques, 1984).

Collaborative learning is a structured interaction, which requires a small group of learners to work together to accomplish a common goal. It puts more emphasis on the process, social interaction during which learners try to coordinate and cooperate with each other to achieve a shared goal (Artz & Newman, 1990; Panitz, 1997).

For the last few decades a tremendous amount of research has been done on collaborative learning and a variety of instructional strategies are introduced and practiced in educational settings across multi-disciplinary fields. The benefits of collaborative learning include promoting critical thinking skills, helping learners actively involve in the learning process and achieving higher learning outcomes; developing social interaction skills and responsibility, embracing diversity of perspectives and fostering learning communities; building self-esteem and developing positive attitudes (Panitz, 1997).

Hence, school districts, state departments of education, and national research organizations have been encouraged to implement collaborative learning methods of instruction into curriculum design and have gradually developed national standards for assessment (Webb, 1995). Collaborative learning approaches have been widely accepted as effective teaching and learning tool, which help ease the grading burden on faculty and in return allow prompt feedback to the students (Turner, 1983).

Despite its merits however, concerns have been addressed in relation to the methods of assessing group work. It is difficult to award grades to individuals in a group. According to a survey conducted by Lejk et al. (1996), assigning the same grade to each member of a group was found to be the most widely practiced instructional method for assessing group work. Many faculty are often hostile to group projects because many students have expressed fear that their individual efforts are not sufficiently awarded based on the extent of contributions to the group work (Sergi, 2007). Loddington (2008) believed that “a lazy student might benefit from the efforts of teammates or particularly diligent students may have their efforts diluted by weaker team members” (p.4-5).

As a result, education has attempted to use various instructional methods to distinguish individual rewards based on individual efforts to group work. One typical strategy for group work is to assign each group member to a sub-task to work on first and then to merge their partial results into the final group output (Dillenbourg, 1999). However, this type of group work disrupts the spirit of group work – collaboration. Another approach is to have a faculty member to observe the entire group activity in order to observe the process of group work. However, it is not feasible for large classes due to the high expenses and time required. In addition, many group activities occur outside of the classroom. A third approach is to have students in a group assess each other on the basis of their individual contributions to the group work. This type of instructional method is known as peer assessment (PA) (Goldfinch & Raeside, 1990).

Peer assessment is a process where groups of individuals rate their peers (Falchikov, 1995). In other words, it is “an arrangement in which individuals consider the amount, level, value, worth, quality or success of the products or outcomes of learning of peers of similar status” (Topping, 1998, p. 250).

Peer assessment has been adopted as a means of fair and equitable measurement of individual contributions to group work and has proven to be an acceptable, valid, reliable and practical strategy for higher education courses (Cheng & Warren, 2000; Conway & Kember, 1993; Gatfield, 1999; Goldfinch & Raeside, 1990; Lejk & Wyvill, 2001; Lejk et al., 1996). Peer assessment is a good instrument for assessing process (Chapman & Auken, 2001), and “to capitalize on the effectiveness of group learning and to ensure equity of marks among students, it is generally considered ideal to engage in peer assessment” (Gatfield, 1999, p. 366).

Problem Statement

In order to measure individual contributions, a certain mechanism or formula is required to quantify peer assessment criteria and these mechanisms usually employ numerical values as their rubrics. Lejk et al. (1996) identified several common peer assessment methods used to measure individual contributions to the group work. According to their survey, the “multiplication of group mark by individual weighting factor” (p. 268) method appeared to be the most widely adopted one. This method was first introduced by Goldfinch and Raeside (1990) and was subsequently modified and improved by Conway and Kember (1993) and Goldfinch (1994). This method helps teachers distribute individual scores based on their proportions - PA factor, as their contributions to the group score.

However, the problem with this type of mechanism is that it leads to circumstances where a student can be strategic and be easily able to obtain higher score by simply giving lower scores to other members within a group. In other words, individual’s score is always affected by his/her ratings towards other members of the group. As long as formula uses average of scores to determine one’s score, it always invites students to manipulate the score and play strategically. Besides studies have proved that weaker students tend to rate themselves higher whereas

stronger students tend to underrate themselves (Lejk & Wyvill, 2001), which consequently results in penalizing themselves by being overgenerous or extremely conservative (Goldfinch, 1994).

The need is to find a new mechanism that can help restrain students from getting higher scores by just simply giving lower scores to other members within a group. In addition, the mechanism should help minimize the degree of penalty to the grade by being either overgenerous or extremely conservative. This study is to introduce a new modified mechanism derived from division rule theory from Economics reported by Tideman and Plassmann (2007). This mechanism will be referred as Division Rule hereafter.

Purpose of Study

The purpose of this study was to develop an Online Database-Driven Peer Assessment Tool (ODDPAT) using the Division Rule mechanism as its core computational algorithm. Computational algorithm here means a method of calculating peer assessment ratings. This developmental study used the Collaborative Create-Adapt-Generalize (CAG) model (Hicks et al., 2004) to build a prototype of ODDPAT system based on its step-by-step design and development procedures. The review of literature has shown that there are a number of online PA tools available, but none specifically developed using the Division Rule as its computational algorithm. In order to implement this study, the researcher focused on discovery of peer assessment mechanisms, collections of peer assessment criteria and rubrics, and functionalities identified from existing online peer assessment tools. In addition, detailed documentation of developmental procedures and strategies will provide useful resources for future development of similar online PA tools in higher education environments.

Importance of Study

Based on a current review of relevant literature, no researcher has ever attempted to design and develop an online peer assessment tool incorporated with the Division Rule mechanism. In addition, integrating the Division Rule may overcome drawbacks of peer assessments addressed in the literature review such as (1) eliminating the occurrence of unfair scores caused by manipulating scores given to other members within a group (Race, 2000, 2001; Sergi, 2007; Webb, 1995); (2) also compensating the degree of penalty for being over-generous or extremely conservative in terms of rating (Goldfinch, 1994; Goldfinch & Raeside, 1990; Kilic & Cakan, 2006; Lejk & Wyvill, 2001; Lejk et al., 1996); (3) automating the data collection, collation, and calculation process so that it reduces the administrative overheads and computational work for instructors, therefore, to give students timely feedback (Conway & Kember, 1993; Luxton-Reilly, 2009). This study will extend the current literature through the description and analysis of the developmental process employed in this study to create online peer assessment tools.

Limitation of Study

The limitation of this study is that the group size has to be three. According to Tideman and Plassmann (2007), depending on the size of a group, the possible numbers of formulas are infinite. However, it is reported that this formula works best for the group size of three. Therefore, this study was conducted with the fixed group size of three. Flexible group size may provide more opportunities to implement the ODDPAT system in a variety of group composition environment, but bigger group size does not necessarily engender better group work experiences. Smaller group size, on the other hand, can increase individual accountability (Johnson &

Johnson, 1991, 1994, 2004a, 2004b; Johnson, Johnson, & Holubec, 1994; Johnson, Johnson, & Smith, 2007; Johnson, Johnson, & Stanne, 2000; Johnson & Others, 1991). In addition, the group size of three to four appeared most effective (Lou, Abrami, Spence, Poulsen, Chambers, & d'Apollonia, 1996) and “trios will often work well together sharing out tasks appropriately and arrange meeting schedules easier compared to larger groups” (Race, 2000, p. 33).

Chapter 2: Literature Review

The literature review focused on the following major areas: historical overview of collaborative learning including its theoretical underpinnings, features of collaborative learning, and basic principals; overview of peer assessment including its typology, assessment criteria, methods (mechanisms) and analysis of current existing online peer assessment tools.

The Root of Collaborative Learning

The term, collaborative learning is often associated with different terminologies such as cooperative learning, group learning or team learning. Most of times these terminologies were used synonymously and interchangeably but the researcher believed that each terminology should have its own origin and distinctive underlying meanings.

The historical roots of collaborative learning can be investigated from the perspectives of two levels: the macro and micro level. From the macro level, collaborative learning has roots in British literature while cooperative learning has roots in American literature relatively (Panitz, 1997). From the micro level, collaborative learning has roots in language, community of learning, shared cognition but cooperative learning is mostly rooted in small group theory - social interdependence (Johnson & Johnson, 2004b; MacGregor, 1990).

According to Bruffee (1984), the term, collaborative learning was first coined by a group of British secondary school teachers and its original idea was practiced by Abercrombie who conducted experimental research on medical education in the 1950s and 1960s. In her research, Abercrombie asked the whole group, instead of each individual, to diagnose the patient and discovered that, working as a group, students acquired sound medical judgment faster than working alone. She also found that students as a group developed *better* judgments than

individuals working alone. Working in groups, she hypothesized, allowed them to avoid individual biases and presupposition. She believed that this kind of social learning process was grounded in shared language and interpretations. As Davidson (1994) stated, the collaborative learning approach is based on language and learning theories, which assume learning is a process of meaning making and personal interpretation through dialogue and discussion.

In America, collaborative learning was not widely popularized until 1980s (MacGregor, 1990). MacGregor stated that educators realized the desperate needs created by, restructuring school curricula and perceived student difficulties in adapting for college classrooms due to the school's limiting the knowledge building, which was a process of development of experts or expert-like learners. According to MacGregor, those shortcomings obliged schools to seek an alternative method, the knowledge building community. Besides the constraints of educational curricula at that time, there was another major trend, which drove the transformation of classrooms into the community of learning: inspiration from the scientific research community. Alexander Meiklejohn's "Experimental College" at the University of Wisconsin, Joseph Tusman's experiment at the University of California-Berkeley, St. John's "Great Books" college and The Evergreen State College, and Kenneth Bruffee's peer-writing approach were the typical examples (MacGregor, 1990).

Features of Collaborative Learning

Collaborative Learning as Interaction

Dillenbourg (1999) speculated that in collaborative learning, learning mechanisms are likely to be triggered by the anticipation of a particular form of interaction among people. These interactions include three criteria: interactivity, synchronicity and negotiability.

Interactivity does not mean the frequency of interaction, but the quality of interaction, which have an impact on the cognitive processes of individuals in the group.

Synchronicity requires synchronous communication and it is considered as a social rule rather than a technical parameter. In other words, synchronicity is a “considerate meta-communicative contrast” (Dillenbourg, 1999, p. 9) meaning the speaker expects a corresponding response from the listener once the utterance is produced.

Negotiability entails through collaborative interaction by displaying, arguing, justifying and conversing about each individual’s point of view. Collaborative learning can be defined as “a philosophy of interaction” Panitz (1997, p. 3) and “a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem” (Roschelle & Teasley, 1995, p. 70).

Collaborative Learning as Knowledge Building

Bruffee (1993) defined collaborative learning is “a re-aculturative process that helps students become members of knowledge communities whose common property is different from the common property of the knowledge communities they already belong to” (p. 3). The common property refers to the language that students use to construct knowledge in the community. In addition he believed learning as an “interdependent sociolinguistic process” (p. 8). He further asserted that knowledge is constructed and maintained not by examining the world but by negotiating with one another in the communities of more knowledgeable peers.

Collaborative learning assumes that learning occurs among persons, not between persons and things. This assertion is also consensus with Schrage (1990) points of view, which collaborative learning is a “process of shared creation: two or more individuals with complementary skills interacting to create shared understanding that none had previously possessed or could have

come to on their own. Collaboration creates shared meaning about a process, a product, or event” (p.40). In order to have a genuine collaboration, individuals should consider themselves as equal partners and make coordinated endeavor to create shared results (Krug, 2001). Most recently advocates consider collaborative learning as knowledge building, which indicates “the gradual construction and accumulation of increasingly refined and complex cognitive and linguistic artifacts” (Stahl, Koschmann, & Suthers, 2006).

Collaborative Learning as Social Linguistics

Collaborative learning also accepts social interaction as an important component (Castle & Sydor, 2001). Shared conceptions are attained through the external mediation, the shared language. According to the definition of Gerlach (1994), “collaborative learning is based on the idea that learning is a naturally social act in which the participants talk among themselves. It is through the talk that learning occurs” (p. 8). She believed that learning occurs when individuals interact with others by sharing their ideas, which takes not only in the form of articulating their own points of view but also listening to the ones of others. Hamm and Adams (1992) further backed up this argument by addressing that “learning includes what is acquired through interaction with environment, family, community members, schools, and other institutions. Language is the vehicle where meaning is translated, verified, and made conscious” (p. 2). It is assumed that “knowledge is not some absolute entity inside or outside of us but is instead a social construct” (Bruffee, 1999, p. 92). Roschelle (1996) argued that “conversational interaction provides a means for students to construct increasingly sophisticated approximations to scientific concepts collaboratively...the crux of learning by collaborating is convergence...emphasized mutual construction of understanding” (p. 244). The focus of collaborative learning is to focus on

the creation of personal meaning and internally persuasive undertakings through dialogue and discussion (Davidson, 1994, p. 23).

Theoretical Underpinnings

The theoretical underpinnings of collaborative learning were drawn from the perspectives that reflect Socio-Cognitive, Socio-Cultural, Knowledge-Building and Participation theories.

Socio-Cognitive Perspective

Learners construct knowledge, and knowledge is a property possessed in individual's mind (Lipponen, 2002). In the light of Piaget and Vygotsky's point of view, gaining knowledge can be viewed as concept development. According to Sfard (1998), "Concepts are to be understood as basic units of knowledge that can be accumulated, gradually refined, and combined to form ever richer cognitive structures" (p. 5).

From Piaget's (1969) perspective, children acquire knowledge by interactions with objects and world through constant process of construction of knowledge. Piaget's socio-cognitive development approach contends that children learn through stages of cognitive development. He proposed three types of mechanism taking place during the process of cognitive development: assimilation, accommodation, and equilibration.

Assimilation means children adopt the new objects or events into the pre-existing knowledge. Accommodation refers that children modify pre-existing knowledge to account for new experience. Equilibration is the major developmental process, encompassing both assimilation and accommodation.

According to Lipponen, Hakkarainen, and Paavola (2004), collaboration values the disequilibrium, which was created by emerging socio-cognitive conflicts. For instance, students

in either a heterogeneous group (different levels of cognitive developments) or a homogeneous group (same levels of cognitive developments but with different points of view) can have cognitive conflicts through mutual engagement of social interactions. It entails a state of disequilibrium among individuals, which in turn forces learners to either assimilate or accommodate their prior knowledge. Based on this assumption, knowledge is considered more like a product of individual's minds rather than the shared one mutually created by a group.

Socio-Cultural Perspective

Lipponen et al. (2004) interpreted collaboration, based on the Vygotsky's ideas, that individuals acquire knowledge that they are not able to master before collaborative learning activities. In other words, collaboration offers a collaborative environment to scaffold individual's cognitive development. Vygotsky believed that students learn through a social interaction with their partners in the Zone of Proximal Development (ZPD). The ZPD is defined, by Vygotsky (1978) as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86). In other words, ZPD is the difference between what learners can do by themselves without external help and what learners can do with the capable sources. According to Driscoll (2005), individual's cognitive development and knowledge construction take place in ZPD which is composed of social interaction, scaffolding and modeling from more capable others. Another element of social interaction is the inter-subjectivity, which means the shared understanding about the task between partners demanding mutual coordinated endeavor to solve the problem.

Some scholars argued that socio-cognitive approach puts more emphasis on individual development rather than social interaction while socio-cultural perspective considers the causal

relationship between them. Social interaction is considered as the basic unit of analysis in the light of socio-cognitive perspective, while it is viewed as an enhancement for individual cognitive development change from the socio-cultural perspective (Dillenbourg, Baker, Blaye, & O'Malley, 1996).

Participation Perspective

Participation view is rooted in the situated cognition theory. Resnick (1991) argued, “every cognitive act must be viewed as a specific response to a specific set of circumstances” (p. 4). Situated cognition emphasizes cognitive activities within the social and culture context rather than isolated context. Instead of knowledge in the individual mind, participation frameworks focus on interaction and participation in particular community of practice, and learning occurs through participating collaborative activities where knowledge is co-constructed by interacting with individuals and environment (Lipponen et al., 2004). It is consistent with the notion of Bruffee (1993) who defined collaboration as “a re-aculturative process that helps students become members of knowledge communities whose common property is different from the common property of the knowledge communities they already belong to” (p. 3). Krug (2001) also defined collaborative learning as a “specialized form of participatory learning” (p. 105).

Knowledge Building Perspective

Knowledge building was first introduced by Scardamalia and Bereiter (1996). They also created the term, knowledge-building community. It can be explained in twofold: one is that knowledge-building communities should extend to other communities beyond the schools, and the “building” indicates constructing shared knowledge, a collective product. This knowledge-building idea was derived from the perspectives of viewing classroom activities as the novice practices compared to the professional scientific expert practices. That’s why Bruffee (1993) said

collaboration is a re-acculturative process, which means the process of continuous endeavors to adapt and mold ourselves to the expert enterprise. The primary criterion of knowledge-building community is knowledge advancement – much like professional scholars constantly produce new ideas through writing articles to contribute to the advancement of existing knowledge in the community. In terms of collaboration in a knowledge-building community, collaboration takes in the form of progressive discourse. For instance, in a progressive discourse, learners mutually advance the understanding of knowledge through testing empirically, discussing and debating on it. The main purpose of the progressive discourse is to consider knowledge is not inert but to view knowledge as something problematic, which needs to be explained (Lipponen et al., 2004). Since the knowledge is not the entity of individual's mind, it exists nowhere else but in the discourse. Knowledge-building discourse aims at idea improvement (Scardamalia & Bereiter, 2006).

Basic Principles of Collaborative Learning

The basic principles of collaborative learning can be synthesized from the two dominant works. One is Kagen's Positive interdependence, Individual accountability, Equal participation and Simultaneous interaction PIES principles (Kilic & Cakan, 2006); the other one is Johnson and Johnson's Five Elements (Johnson & Johnson, 1991, 1994, 2004a, 2004b; Johnson et al., 1994; Johnson et al., 2007; Johnson et al., 2000; Johnson & Others, 1991). The acronym PIES stands for Positive interdependence, Individual accountability, Equal participation and Simultaneous interaction. Johnson and Johnson's Five Elements overlap the first elements of PIES, positive interdependence and individual accountability but add face-to-face interaction, interpersonal and small group skills, and group processing. These two collections of principles share many common features such as positive interdependence, individual accountability,

simultaneous (face-to-face) interaction among which positive interdependence is the most important element for the effective CL strategies.

Positive Interdependence

The first requirement for an effectively structured cooperative learning environment is that students are aware that they “sink or swim” together. In cooperative learning situations, students have two responsibilities: one is to learn the assigned material and the other one, more importantly, is to ensure all of the group members learn the assigned material. Johnson and others (Johnson & Johnson, 1991, 1994, 2004a, 2004b; Johnson et al., 1994; Johnson et al., 2007; Johnson et al., 2000; Johnson & Others, 1991) called this dual responsibility positive interdependence. Positive interdependence is categorized into fourfold:

1. Positive goal interdependence (establishing a mutual goal for students to realize their interdependence)
2. Positive reward interdependence (supplementing goal interdependence)
3. Positive resource interdependence (providing limited resources forces students share to highlight collaborative relationships)
4. Positive role interdependence (assigning roles for high-quality learning)

Individual Accountability

Individual accountability can be obtained via assessing student’s performance individually and giving the results back to the individual and the group. The individual is responsible for contributing his or her fair share to the group’s success and should not seek a “free ride”. This can be accomplished through keeping the group size small, giving individual tests, oral examining randomly, observing and recording group activity, assigning a role, and having students to teach others.

Simultaneous (Face-to-Face) Interaction

Face-to-face interaction exists when individuals encourage and facilitate each other's efforts to complete tasks in order to reach the group's goals. Through promoting each other's success, group members build both an academic and a personal support system for each member.

Equal Participation

CL encourages all members of the group to participate equally. One of the challenging issues of managing group activities is unequal participation, which in turn leads to the problems of free riding and polling. In other words, one person does all the talking and the others just follow the lead. Equal participation guarantees that each member is able to contribute their own efforts to the group success; hence it strengthens the individual accountability and positive interdependence.

Social Skills

In order to work effectively with each other, group members are required to master the small group and interpersonal skills. This can be achieved through knowing and trusting each other, communicating accurately, supporting each other, and resolving conflict constructively. Johnson and Johnson (2004b) warn us that simply grouping socially unskilled students does not guarantee effective cooperative learning. They explain that humans are not born instinctively aware how to interact effectively with others. Interpersonal and small group skills must be taught. The more socially skillful students are, the higher achievement that can be expected within cooperative learning groups. These principles have been studied and practiced extensively in the cooperative learning field. For collaborative learning to take place, the existence of these elements determine the effectiveness of collaborative learning. This paper tries to find consensus

and synthesis based on the assumptions and beliefs of what collaborative learning is or should be.

Advantages of Collaborative Learning

A tremendous amount of research studies have been done on the effectiveness of collaborative learning. Many researchers found consensus on the effectiveness in terms of achievements (Johnson et al., 2000; Slavin, 1995). What makes CL so attractive to researchers to conduct research and so appealing to educators to implement in class? It is due to the benefits of CL brought to the use in educational settings. These benefits are condensed and amended based on the works of Panitz (2001).

Academic Benefits

1. CL helps learners promote critical thinking skills. Learners are actively engaged in the learning process by interacting with each other through representing ideas, and discussing and debating about them to build oral communication skills. Eventually it helps develop meta-cognition skills.
2. CL helps learners involve actively in the learning process. If the first benefit provides mechanisms to stimulate learning to occur, then this benefit provides an active, involved, and exploratory environment for learning to happen.
3. Better learning outcomes are achieved. Higher achievements entail a positive attitude toward the subject matter, which in turn increases learner retention and self-management skills.

Social Benefits

1. CL helps learners develop social interaction skills and responsibility for each other.
2. CL embraces diversity of perspectives among learners.
3. CL fosters learning communities.

Psychological Benefits

1. CL helps learners build self-esteem through supporting each other to accomplish higher achievement instead of competing each other.
2. CL helps learners reduce classroom and test anxiety and develops positive attitudes toward teachers.

Disadvantages of Collaborative Learning

Despite its merits, however, concerns have been expressed in relation to the methods of assessing group work. Collaborative learning itself does not lead to the group assessment since collaborative learning is considered as a means of learning (Lejk et al., 1996). A review of literature revealed that there are two major downsides for working as a group. One is the assessment of different contributions of each group member (Falchikov, 1993); the other is the free rider, an individual contributing next to nothing to the group work (Mesch, 1991).

Instructors often assign a comprehensive assignment to groups that require individual efforts and contributions to a group project. Students are concerned about the requirements of the group project and methods of assessment for group project. The process of completing a group project invariably involves each group member's effort and contribution to the final group output. Therefore, it is essential to assess group output as well as group work process and

individual grade of a group project has to reflect not only students' achievement as a group, but also each group member's contribution.

Assessing group work process can serve to control free riders and enhance students' involvement and quality of contribution to the group project. Group assessment is recommended due to the growing importance being placed on group collaboration in instruction since group assessment develops social skills and can be more comprehensive than individual assignments (Mello, 1993). However, it is difficult to award appropriate grades to individuals in a group. According to a survey conducted by Lejk et al. (1996), assigning the same grade to each member of a group was found to be the most and widely practiced instructional method for assessing group work. Many faculty are often hostile to group projects because many students criticized and feared that their individual efforts were not sufficiently awarded based on the extent of contributions to the group work (Sergi, 2007). Loddington (2008) believed that "a lazy student might benefit from the efforts of teammates or particularly diligent students may have their efforts diluted by weaker team members" (p. 4-5). Furthermore, these "free-riding" effects can demotivate other group members who do all the work and eventually lead to the entire group spiral downwards (Cheng & Warren, 2000).

As a result, educators have attempted to use various instructional assessment methods to determine individual rewards based on individual efforts to group work. One typical strategy for group work is to assign each group member a sub-task to work on first and then merge their partial results into the final group output (Dillenbourg, 1999). However, this type of group work can disrupt the spirit of group work – collaboration (Goldfinch & Raeside, 1990). Another approach is to have a faculty member observe the entire group activity in order to observe the process of group work; however this is usually not feasible for large classes due to the expense

and time required. In addition, many group activities occur outside of the classroom. A third approach is to have students in a group assess each other on the basis of their individual contributions to the group work. This type of instructional method is known as peer assessment (Goldfinch & Raeside, 1990).

Peer Assessment

Peer assessment is a process where groups of individuals rate their peers (Falchikov, 1995). In other words, it is “an arrangement in which individuals consider the amount, level, value, worth, quality or success of the products or outcomes of learning of peers of similar status” (Topping, 1998, p. 250). During the process of assessment, peers are actually collecting information about “the quality or quantity of change in a student.” (Johnson & Johnson, 2004a, p. 2)

Why Involve Students in the Assessment?

Peer assessment has been adopted as a means of fair and equitable measurement of individual contributions to group work and has proven to be an acceptable, valid, reliable and practical strategy for higher education courses (Cheng & Warren, 2000; Conway & Kember, 1993; Gatfield, 1999; Goldfinch & Raeside, 1990; Lejk & Wyvill, 2001; Lejk et al., 1996). Peer assessment is a good instrument for assessing process (Chapman & Auken, 2001), and “to capitalize on the effectiveness of group learning and to ensure equity of marks among students, it is generally considered ideal to engage in peer assessment” (Gatfield, 1999, p. 366).

According to Johnson and Johnson (2004a), one of the reasons why involving students in assessment is because of its meaning perceived by students. Assessments found more meaningful

to students when they have a significant purpose, comprehensive procedures, criteria, rubrics and direction.

Another reason is that students are the most natural resources of help for instructors because students always involve in the group process and mostly learning occurs when conducting assessments than just receiving assessments. Therefore, “it is often advisable (and necessary) to involve students in learning assessment rubrics and using them to reflect on and assess their own and their classmates’ work.” (Johnson & Johnson, 2004a, p. 11) Race (2001) believed that “when it comes to measuring individual relative contribution to group work, the only people who really know what the relative contributions are, are the students themselves” (p. 17).

Typology of Peer Assessment

In order to efficiently implement a peer assessment strategy in a collaborative learning setting, educators need to understand different types of peer assessment when designing a curriculum. Topping (1998) deserves the credit for being the first scholar to conduct massive literature review on the typology of peer assessments. Initially his typology consisted of 17 different variables (see Table 1, second column) but later these variables were categorized into four clusters (see Table 1, first column) by van den Berg, Admiraal, and Pilot (2006) and were further expanded to an inventory of peer assessment diversity reported by Gielen, Dochy, and Onghena (2011).

Table 1

Typology of Peer Assessment by Cluster, Variable, and Range of Variation

Cluster	Variable	Range of Variation
Cluster I: The function of PA as an assessment instrument	(1) Curriculum area/subject	All
	(2) Objectives	Of staff and/or students? Time saving or cognitive/affective gains
	(3) Focus	Quantitative/summative or qualitative/formative or both?
	(4) Product/output	Tests/marks/grades or writing or oral presentation or other skilled behaviors?
	(5) Relation to staff assessment	Substitutional or supplementary?
	(6) Official weight	Contributing to assess final official grade or not?
Cluster II: Interaction between peers	(7) Directionality	One-way, reciprocal, mutual?
	(8) Privacy	Anonymous/confidential/public?
	(9) Contact	Distance or face to face?
Cluster III: Composition of the feedback group	(10) Year	Same or cross year of study?
	(11) Ability	Same or cross ability?
	(12) Constellation assessors	Individuals or pairs or groups?
	(13) Constellation assessed	Individuals or pairs or groups?
	(14) Place	In/out of class?
Cluster IV: Requirement and reward	(15) Time	Class time/free time/informally?
	(16) Requirement	Compulsory or voluntary for assessors/assesses?
	(17) Reward	Course credit or other incentives or reinforcement for participation?

Note. Adapted from Gielen, Sarah, Dochy, Filip, & Onghena, Patrick. (2011). An inventory of peer assessment diversity. *Assessment & Evaluation in Higher Education*, 36(2), 137-155. doi: 10.1080/02602930903221444

Studies of peer assessment have been conducted in almost all aspects of subject areas. However, this variety has brought confusion and difficulties in selecting right ones for both educators and researchers. Topping's and van Berg et al.'s typology do not completely articulate the complex relationships and differences of peer assessments in between individual learning and group learning contexts. In order to better comprehend the peer assessments in a group work context, the following questions should be pondered: what to assess and whom to assess.

When it comes to the composition of a feedback group, it can be categorized into three types: PA for individuals, Inter-PA for groups, and Intra-PA for groups (see Table 2). Peer assessment for individuals is to assess the product of other students. The Inter-PA is to assess group product/work between groups whereas the Intra-PA is to assess the process - contributions of students within a group (Race, 2001).

Table 2

Types of Peer Assessment

Types	What to assess	Whom to assess
PA for individuals	Individual product	Individual vs. individual
Inter-PA for groups	Group product/work	Group vs. group
Intra-PA for groups	Individual contribution	Members within a group

Peer assessment in this study refers to the latter one, the Intra-PA where group work is evaluated by an instructor whereas group process is assessed by measuring individual contributions to group work.

What to Assess: Product vs. Process

Falchikov (1995) identified two types of variables when performing peer assessment in a group environment. One is to assess the product/work; the other is to assess the collaboration process. When designing peer assessment for collaborative group, the group work can be assessed between groups, but the most practical way is to conduct assessment by an instructor. On the other hand, the collaboration process should be assessed by members within a group because of appropriateness of students involvement described elsewhere in this paper.

Table 3

Types of Peer Assessment Variables

Peer assessment of product	Peer assessment of process
Peer assessment of product is where an instructor assesses group work.	Peer assessment of process is where members assess each member's contribution/performance within a group.

Johnson and Johnson (2004a) categorized five common types of assessments. Among these outcomes, 1 and 2 can be used as the criteria to assess the group product/work whereas 3 to 5 can be used as the criteria to assess individual contributions.

1. Academic learning:

What students know, understand, and retain over time. This includes declarative, procedural, schematic, and strategic knowledge acquired in a domain.

2. Reasoning:

The quality of students' reasoning, conceptual framework, use of scientific method and problem solving, and construction of academic arguments. This includes broad abilities that consist of particular complexes of cognitive processes that underlie the verbal,

quantitative, and spatial reasoning – as well as comprehension, problem solving and decision making skills within domains and more generally across domains.

3. Skills and Competencies:

Oral and written communication skills, teamwork skills, research skills, skills of organizing and analyzing information, technology skills, skills of coping with stress and adversity, conflict resolution skills. Personal, social and civic competencies need to be assessed as well as cognitive ones.

4. Attitudes:

The attitudes students develop, such as a love of learning, commitment to being a responsible citizen, desire to read, liking scientific reasoning, self-respect, liking of diversity, commitment to making the world a better place, and many others.

5. Work Habits:

The work habits students develop, such as completing work on time, using time wisely, meeting responsibilities, striving for quality work, continuously improving one's work, striving to add value to each job one does, and so forth (p. 40-41).

Peer Assessment Criteria

There are two main types of peer assessment approaches widely practiced within group environment. One is the holistic peer assessment; the other is category-based peer assessment. The holistic peer assessment allows students to assign one grade to each other members in a group while the category-based assessment provides students with a number of categories of criteria to assess each other and measure a percentage of individual contribution using some mechanisms of calculating scores (Lejk & Wyvill, 2001).

In this developmental study, the Online Database-Driven Peer Assessment Tool (ODDPAT) was built with default category-based PA criteria. The criterion-referenced procedures are critical for students to collaboratively produce a group product. The criterion-referenced evaluation was first introduced in the 1920s and popularized in the 1930s. Though there was a downtrend during the mid-90's, before long it revived due to the increased emphasis on "behavioral objectives, the sequencing and individualizing of instruction, mastery learning, and cooperative learning" (Johnson & Johnson, 2004a, p. 45).

Categories of Peer Assessment Criteria

In the following section, several worked examples of category-based peer assessment instruments were documented and items from different resources were organized into similar categories.

Six Categories of Peer Assessment. The six-category peer assessment criteria instrument was developed by Deeks and Lejk (1995) based on the work of Goldfinch (1994). The review of literature discovered a number of research studies which employed this six-category as their assessment instrument and findings resulted in positive feedback from faculty and students (Kilic & Cakan, 2006; Lejk & Wyvill, 2001; Lejk et al., 1996).

Table 4

Six Categories of Peer Assessment Instrument

Category	Items
C1	Motivation/Responsibility/Time Management Indicators: attends meetings regularly and on time, accepts fair share of work and reliably completes by the required time
C2	Adaptability Indicators: wide range of skills, readily accepts changed approach or constructive criticism
C3	Creativity/Originality Indicators: problem solver, originate new ideas, initiates team decisions.
C4	Communication Skills Indicators: proficient at diagramming/documentation/overhead project slides, effective in discussions, good listener, able presenter
C5	General Team Skills Indicators: positive attitude, encourager, supporter of team decisions, desire for consensus.
C6	Technical Skills Indicators: provides technical solutions to problems, ability to create designs on own initiative.

Note. Adapted from Lejk, Mark, & Wyvill, Michael. (2001). Peer Assessment of Contributions to a Group Project: A comparison of holistic and category-based approaches. *Assessment & Evaluation in Higher Education*, 26(1), 61-72. doi: 10.1080/02602930020022291

More categories of peer assessment criteria. The researcher discovered more peer assessment criteria from various research studies (Anderson & West, 1998; Campion & Medsker, 1993; Johnson & Johnson, 2004a; Loughry, Ohland, & Moore, 2007; Niehoff & Moorman, 1993; Taggar & Brown, 2001) which were further synthesized and organized into different categories by their distinctive themes, such as goal achievement, commitment to the group work, participation and communication, and collaboration.

Goal achievement:

- Help the group in setting goals.
- Participate in planning and organizing group tasks.
- Participate in group discussion and decision-making process in a constructive manner.
- Help the group in achieving goals.

Commitment to the group work:

- Attend group meeting regularly and arrives on time.
- Come to group meeting with preparation.
- Thoroughly completes group assignments.
- Complete group assignments on time.

Participation and communication:

- Listen attentively to the ideas and opinions of other group members.
- Explain ideas and opinions sufficiently until other group members understand.
- Provide feedback and comments to other members.
- Respond to group email in timely manner.
- Encourage group members to share ideas and support the efforts of group member.

- Communicate ideas during group meeting.
- Actively seeks and suggests solutions to problems /conflicts.

Collaboration:

- Share / exchange a great deal of relevant information and ideas in the group.
- Cooperate with group members.
- Respect other member's opinions and ideas.
- Actively participates in helping the group work together.
- Promote positive relationship in the group.
- Assist others when needed.
- Overall contribution to group effort.

Group Assessment Methods

In order to measure individual contributions, a certain mechanism or formula is required to quantify peer assessment criteria and these mechanism usually employ numerical values as their rubrics. According to the review of literature, the following eight methods were synthesized including the Division Rule mechanism from Economics.

M1. Individual weighting factor multiplied by group score (separation of process and product). This is one of the well-known mechanisms to calculate individual contributions to the group work. This mechanism was first introduced by Goldfinch and Raeside (1990) and subsequently modified by Conway and Kember (1993).

The original peer assessment form included two parts. Part 1 listed all the tasks that students were required to accomplish during the group project. Students were asked to write down the names of main contributors of each task. Part 2 listed criteria of group process skills

against which students rated their group members on five-point scale from zero (no contribution) to four (outstanding contribution).

The calculations:

Part 1 score equals the actual number of names mentioned in Part 1 form divided by the total number of possible mentions of that individual.

$$\text{Part 1 score} = \frac{\text{Number of mentions of individual}}{\text{Possible number of mentions}} \quad (1)$$

Part 2 score equals the sum of scores received from peers divided by the highest possible score.

$$\text{Part 2 score} = \frac{\text{Actual sum scored}}{\text{Highest possible score}} \quad (2)$$

PA score is calculated by combining the Part 1 score and Part 2 score each multiplied by the weighting.

$$\text{PA score} = \text{Part 1 score} \times \text{weighting} + \text{Part 2 score} \times \text{weighting} \quad (3)$$

The PA factor, the percentage of the group score, is determined by referencing the PA Factor Lookup Table – a fixed points determined prior to the peer assessment.

Table 5

PA Factor Lookup Table

PA Score	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1
PA Factor	0%	20%	40%	60%	80%	100%	110%	120%	130%	140%

Note. Adapted from Goldfinch, Judy, & Raeside, Robert. (1990). Development of a Peer Assessment Technique for Obtaining Individual Marks on a Group Project. *Assessment & Evaluation in Higher Education*, 15(3), 210-231.

Finally, an individual score is determined by multiplying group score with the PA factor.

$$\text{Individual's score} = \text{PA factor} \times \text{group score} \quad (4)$$

After practicing the mechanism with several hundred students with a variety of group projects for three years, Goldfinch (1994) refined his peer assessment formula due to the constraints of counting the names on large classes and the investigation showing no significant differences in results using only part 2 of the form. In other words, only the Part 2 is included in the peer assessment form and use the formula instead of PA factor lookup table.

Calculations:

$$\text{Part 2 score} = \frac{\text{Total scores received}}{\text{Sum of possible scores}} \quad (5)$$

$$\text{PA score} = \frac{\text{Individual's Part 2 score}}{\text{Average Part 2 score for that group}} \quad (6)$$

$$\text{PA Factor} = w\% + (100\% - w\%) \times \text{PA score} \quad (7)$$

$$\text{Individual's score} = \text{PA factor} \times \text{group score} \quad (8)$$

M2. Distribution of a pool of marks. This method, demonstrated by Habeshaw, Gibbs, and Habeshaw (1993), allows the students to use their judgment to distribute the group scores.

This kind of assessment can be more holistic if no criteria are provided.

Calculations:

The total distribution score is calculated by multiplying the group score with the number of students within a group. For example, a group with three members received a group score of 70. The total distributable score will be $70 \times 3 = 210$. Each individual has to determine how to allocate the total distribution score to other members including himself/herself as in Table 6.

Finally, the individual's score equals the mean of the total scores received.

Table 6

Example of Distribution of a Pool of Marks

	Student A	Student B	Student C
Student A gives	70	60	80
Student B gives	50	70	90
Student C gives	80	50	80

Student A receives $(70+50+80)/3 = 66$

Student B receives $(60+70+50)/3 = 60$

Student C receives $(80+90+80)/3 = 83$

M3. Group score plus or minus contribution score. This method was also introduced by Habeshaw et al. (1993) that group members assess each other's contribution as major, average or small based on various aspects of group projects. Therefore a member who makes a major contribution in all criteria will receive zero whereas one who makes small contribution will receive negative 20 as the maximum penalty. Finally, the contribution score is deducted from the group score, which becomes an individual's final score. Later (Gibbs, 1992) suggested a variation using both negative and positive scores ranging from -2 to +2 where zero becomes the average contribution.

M4. Equally shared score with exceptional instructor intervention. This method reported by Mello (1993), awards group members with the group score as their final score unless inequity of contributions is appealed by group members via comments. Lastly the instructor needs to decide whether to give the penalty or not.

M5. Splitting of group tasks and individual tasks. This method involves setting up both group tasks and individual tasks. Group tasks are assessed as a group whereas individual tasks are assessed individually (Gibbs, 1992).

M6. Relative rating (Assessment of the Information Systems Group Project). This method is another variation of M1 where group members are allowed to give 100% to those who contributed most and then rate the rest with the best measurement of contribution efforts relative to 100%. The raters are included in the ratings. When assessments are collated into a large grid, the average percentage is calculated for each group member. A weighting is calculated by dividing an individual's average with the average of all group members' averages. Finally an individual's final score is given by multiplying the group mark with the weighting (Lejk et al., 1996).

M7. Deviations from the norm. This method (Lejk et al., 1996) allows the group members to allocate an agreed percentage of contribution of each member through negotiation. Once the agreed percentage is reached, each group member's score is determined by the combination of group score and differences between allocated percentage contribution and normal contribution multiplied by the group score.

$$\text{Individual score} = GS + GS \left(\frac{\text{Allocated \%} - \text{Normal \%}}{100} \right) \quad (9)$$

GS is Group Score

Allocated % is the agreed percentage contribution

Normal % is 100% divided by the number of group member (i.e. 25% for a group of 4; 33.33% for a group of 3).

New Mechanism Derived from Division Theory

This study is to introduce a new modified mechanism derived from division rule theory from Economics (Tideman & Plassmann, 2007). The adopted formula is as follows.

$$C_i = \frac{1}{1 + r_{ki}^j + r_{ji}^k} \quad (10)$$

The C_i refers to the student i 's contribution. The r_{ki}^j is defined as the ratio of the student k 's contribution relative to the student i 's contribution which is awarded by the student j ; whereas the r_{ji}^k is defined as the ratio of the student j 's contribution relative to the student i 's contribution which is awarded by the student k . Based on the formula, it is proved that any rater's (assessors) contribution score is solely affected by the ratings from the other two members. In other words, individual raters cannot manipulate his/her contribution scores regardless of what he/she awards others including himself/herself. In this way, Tideman and Plassmann (2007) believed that it "removes a partner's temptation to increase his own share through an exaggerated estimate of his own productivity, which would be patently unfair" (p. 5).

For example, M1 mechanism leads to circumstances where students can be very subjective and more strategic by manipulating scores when rating other members within group. Individual score is affected by the PA factor and the PA factor is affected by the PA Score. In return, the individual score is controlled by the PA Score. However, it is very obvious that the average PA score is affected by scores of other members. In order for a member to get higher PA score, he/she simply lowers the "Average Part 2 score for that group" by giving lowest scores to each members of his/her group. The following tables simulate peer assessment to show how easy it is to manipulate the scores to get higher scores than other members of his/her group by

comparing results using the mechanism mentioned above. In Table 7, the student A plays an evil role and gives lowest scores to his group members. Thus the student A's PA score is 1.33

$\left\{ \frac{12}{(12+8+7)/3} \right\}$. On the other hand, in Table 8, the student A's PA score is 1.16

$\left\{ \frac{12}{(12+10+9)/3} \right\}$ when the student A gives fair ratings to his members.

Table 7

Example of Lowest Scores Given to Other Members

	From A	From B	From C	Total Received
A score	5	4	3	12
B score	1	3	4	8
C score	1	3	3	7

Table 8

Example of Fair Scores Given to Other Members

	From A	From B	From C	Total Received
A score	5	4	3	12
B score	4	3	4	10
C score	3	3	3	9

In other words, an individual's score is always affected by his/her ratings of other members of the group. As long as a formula calculates the average of scores to determine his/her own individual score, it always invites students to manipulate the data and play strategically.

In order to prove the new modified mechanism/formula is manipulation-free, strategy-proof, and objective, the same data from the simulation tables will be used. From table 7, student A's factor (share) will be $0.32 \left\{ s_A = \frac{1}{1+3/4+4/3} \right\}$ same as the one from table 8. In other words, student A's ratings of student B and C do not affect student A's overall score.

Furthermore, because this mechanism uses the relative ratio of contributions, it might help compensate for the tendencies of ratings from over-generous group members and conservative group members. The literature shows weaker students tend to rate themselves higher whereas stronger students tend to under-rate themselves (Lejk & Wyvill, 2001), which consequently results in penalizing themselves by being over generous (Goldfinch, 1994).

For example, in the following Table 9, the factor is calculated using the Division Rule mechanism. As a result, all three members received equal amount of contribution. Even though James, Joseph, and Mary awarded different scores to other two members within a group, it resulted in equal factors because this mechanism looks for the consistencies of ratings based on the relative ratios among members of a group. According to the example, Joseph gave 20-20, which can be interpreted as Paul thought James and Mary equally contributed to the group work; James gave 30-30, which again indicates that James considers Joseph and Mary spent equal amount of efforts to the group work; Mary gave 40-40, which also shows that Mary saw James and Joseph deserved equal share of the group work. Despite different attribution characteristics (Freeman & Jo, 2002) that these three individuals possess in terms of rating others (in this example, Joseph is the most conservative by giving 20-20; James was the moderate by giving 30-30; and Mary was the most generous by giving 40-40), this mechanism accurately denotes fair distribution of scores because all three agreed on equal contributions to the group work regardless of high or low scores that they received.

Table 9

Worked Example Calculated with The New Mechanism

	From James	From Joseph	From Mary	Factor
James	40	20	40	0.33
Joseph	30	60	40	0.33
Mary	30	20	20	0.33

M8. Equations of the division rule mechanism.

$$PA \text{ Factor } (PAFi) = \frac{1}{1 + r_{ki}^j + r_{ji}^k} \quad (11)$$

$$PA \text{ Final Factor } (PAFF) = \frac{\text{Sum of } PAF}{\text{No. of criteria}} \quad (12)$$

$$\text{Individual Score } (IS) = \left(\frac{2}{3} + PAFF \right) \times \text{Group Score } (GS) \quad (13)$$

Standardization:

Option 1: to set group score as the maximum grade that a student can receive when the final grade exceeds the group score. Otherwise it remains the same score as their final grade.

Option 2: to set the group score as the maximum grade and whoever has the highest final grade will obtain the group score as his/her adjusted final grade, but the rest of the members will get their final grades based on the ratio of the highest grade in their group.

$$A's \text{ grade} = \text{Group Score} \times \frac{A's \text{ Score}}{\text{Highest Score}} \quad (14)$$

Online Peer Assessment Tools

In contrast to paper-based peer assessment, online peer assessment tools might compensate for a number of drawbacks identified with the paper-based ones. These problems include data collection, collation and calculation in large classes, anonymity, limited time for reflection and timely feedback (Freeman & Jo, 2002). Furthermore, online tools improve legibility, enable the easy reuse of comments, reduce administrative overhead and minimize the administrative errors (Price & Petre, 1997).

SPARK (Self & Peer Assessment Resource Kit). SPARK is an open source web-based self and peer assessment kit developed by the University of Technology, Sydney, Australia. The assessment kit was based on a well-evaluated paper-based peer assessment system (Goldfinch, 1994). The software has been specifically developed to overcome problems with paper-based self and peer assessment such as problems with lack of anonymity, data collection, collation and calculation on the lecturers' part and, limited time for reflection and action on students' part.

Online self and peer assessment tool. The Online Self and Peer Assessment Tool was one of the learning design templates developed by the Australian Universities Teaching Committee (AUTC). The system allows the instructors to create individual scores based on the quality and quantity of their contributions.

WebPA. WebPA is an open source online peer assessment tool, which was developed and practiced by the instructors at Loughborough University in UK since 2006.

CATME (Comprehensive Assessment of Team Member Effectiveness). CATME is an online peer assessment tool, which was developed from the new instrument measuring group members' contribution based on the behaviorally anchored peer assessment factors. It's built with five pre-fixed categories including contribution to the group work; interaction with group

members; keeping the team on track; expecting quality; having relevant knowledge, skills, and abilities. It provides long version of the instruments with 87 items and short version with 33 items. This system is equipped with most powerful mechanisms of grouping techniques.

All of the PA tools mentioned above are mainly used to assess group process but each of them is equipped with a different method of calculation of PA ratings. Most of them share similar functions and features such as different interfaces for both instructors and students, team creation, given criteria, and rating period schedules (see Table 10).

Table 10

List of Common Functions and Features of Existing Online Peer Assessment Tools

PA Tools	Calculation Method	Types of Assessment	Functions & Features
SPARK	Individual weighting factor multiplied by group score (M1)	Group process	<ul style="list-style-type: none"> ▪ Built with different interfaces for instructors and students ▪ Instructors can create teams ▪ Instructors can define assessment criteria provided a small back of criteria ▪ Provides Help information and FAQ ▪ Provides schedules for rating period ▪ Supports both self and peer assessment ▪ Provides rubrics 0 - 3 (zero being no contribution; 3 being above average)
Online Self and Peer Assessment Tool	Unknown	Group process	<ul style="list-style-type: none"> ▪ Provides both self and peer assessment ▪ Administrators can create contract templates, add instructors or extra administrators, create students and teams ▪ Instructors can edit personal profile, contracts, team and view report ▪ Students can view & edit their profile, team's profile, create and view their individual contract (tasks & responsibilities) and perform weekly self and peer assessment ▪ Students can give comments about any assessments they have given and only instructors are accessible

WebPA	Individual weighting factor multiplied by group score (M1)	Group process	<ul style="list-style-type: none"> ▪ Built with different interfaces for system admins, instructors and students ▪ Instructors can import students data and create teams ▪ Instructors can define and modify assessment criteria (pre-set criteria) ▪ Training & FAQ ▪ Provides schedules for rating periods ▪ Supports both self and peer assessment ▪ Provides rubrics in the formats of Likert scale and split 100.
CATME	Modified version of Brown's method (1995).	Group process	<ul style="list-style-type: none"> ▪ Built with different interfaces for instructors and students ▪ Uses Team-maker to import student data and create teams ▪ Uses CATME BARS to create assessment forms (survey) ▪ Supports peer assessment with or without self-assessment ▪ Provides five pre-fixed categories ▪ Provides long version of instruments (87 items) and short version (33 items) ▪ Provides schedules for rating period ▪ Provides help info ▪ Provides rubrics in the format of Likert scale ▪ Featured with team scheduling ▪ Allows students to give confidential comments

Chapter 3: Design and Development

The process for the development of online database-driven peer assessment tool system involved a sequence of phases. First, a developmental design model was chosen and modified. Next, conceptual design of the system and logical design of the database were illustrated. Last, using the conceptual and logical design, the physical development of database and creation of web interface of the system were accomplished.

Research Design

This study is a design and development research study which focuses on building a prototype of online database-driven peer assessment tool incorporated with Division Rule mechanism as its core computational algorithm to measure individual contributions to group work.

Design and development research is defined as “the systematic study of design, development and evaluation processes with the aim of establishing an empirical basis for the creation of instructional and non-instructional products and tools and new or enhanced models that govern their development” (Richey & Klein 2014, p. 141). According to the recent publication of Richey and Klein (2014), design and development research has two main categories: (1) research on products and tools and (2) research on design and development models. These two categories were previously known as Type 1 and Type 2 developmental studies (Richey, Klein, & Nelson, 1996) and evidently this study falls into the first category – research on products and tools.

Design Process

In this developmental research study, a Collaborative Create-Adapt-Generalize (CAG) model (Hicks et al., 2004) (see Table 11) was adapted and modified based on the specific needs of this study. This model was used by one of research projects conducted at Virginia Tech on developing a database management system for historical inquiry. This case study began with a narrow focus with predetermined needs and developed technological frameworks in one context and later modified to adapt into additional contexts and eventually generalized into multiple contexts. This model consists of three main phases: Create, Adapt and Generalize. Each phase is divided into several procedural steps.

Table 11

Modified Version of CAG Model

Phase	Create
C1	Identify needs in content-specific terms (CST)
C2	Convert CST to technology-related terms
C3	Determine role of technology in meeting needs
C4	Design system
C5	Select appropriate technologies
C6	Develop technological framework
C7	Evaluate initial system

Note. Adapted from Hicks, D., Potter, K., Snider, R.C., & Holmes, G.A. (2004). The Collaborative design and development of a Database Management System as a Tool for Historical Inquiry. *Journal of Computing in Teacher Education*, 20(4), 167-175.

For this study however, I decided to adapt the first phase – Create Phase as the major developmental guideline for this study, which was sufficient because the developmental research studies focus on the design-develop-evaluation process. The next two phases might be considered in a future study. The modified version of CAG model as follows:

C1. Identify Needs in Content-Specific Terms (CST)

The first step was to determine whether there existed any online database-driven peer assessment tools developed using the aforementioned Division Rule mechanism as its core computational algorithm. No such database-driven peer assessment tool was found during the literature review of peer assessment tools. Therefore, this paper identified the need to develop such a system to measure individual contributions to group work. In order for the technology to play an important role in developing the system to measure individual contributions towards the group work, it was necessary to identify specific needs as they pertained to the development. The following needs were categorized:

- The system should incorporate an automated data collection and calculation of peer assessment method.
- The system should provide different interfaces for different types of users such as Admin, Instructor, and Student authenticated by credentials.
- The instructors need to be able to easily create groups and PA forms.
- The system provides intuitive report of PA results.
- The instructors need to be able to give timely feedback to students.

C2. Convert CST to Technology-Related Terms

This peer assessment tool is web-based database driven system to measure individual contributions towards the group work. Initially this tool was developed under Virginia Tech's

network environment, which required both faculty and students to use their PID credentials to access the interface. This tool supports three types of users: admin, instructor, and student. The admin has all the administrative privileges. Instructors have all the permissions to most course related operations whereas students only have the ability to view the peer assessment questions, names of their team members and his/her final grade.

C3. Determine Role of Technology in Meeting Needs

The ODDPAT assists instructors to easily create groups and assign students. The system offers both manual and automatic grouping features. By providing default peer assessment form with pre-determined criteria, even instructors with little experience in group work assessment are able to effectively implement group activities in their class. Anonymous peer assessment process with the Division Rule mechanism may encourage students to give fair and honest opinions to the contributions of their group members, which in return prohibits any free riders from obtaining grades more than they deserve. Also the automatic data collection, collation, and calculation will help instructors save their time for timely feedback to students.

C4. Design System

Once the needs were identified and the role of technology was determined, it was time to start with the design process. The Unified Modeling Language (UML) technique was adopted to guide the system interface design and database logical design process. The UML is “a graphical language for communicating design specifications for software” (Teorey, Lightstone, Nadeau, & Jagadish, 2011, p. 33). Although there are many different types of UML models (diagrams), the researcher determined to use the Use-Case modeling and Class Modeling that are both particularly useful for discussing database design issues.

The crux of use-case modeling is to grasp the concept of what a system must do and who are the target users. In other words, use cases can be viewed as behavioral (operational) requirements of a system (Bittner & Spence, 2002). The use-case model consists of three components: actors, use cases, and class. Actors literally refer to people who directly interact with the system. In this study, actors are mainly of instructors, students, and admin. Use cases illustrate the detailed description of possible ways for actors to use the system. In this case, use cases can be interpreted as dynamic functions or features of the system. A class is a set of objects with one or more attributes such as a car with attributes of a vehicle identification number and mileage (Teorey et al., 2011). It is possible to conceptualize a database table as a class. The columns in the table can be viewed as the attributes, and the rows are considered as objects of that class.

The first phase of the design process was to identify the major components of the system; the next phase was to discuss what features and functional requirements were needed which were expressed through use-case modeling; the last step was to interpret those components and features & functions into logical modeling – class modeling which showed all the data and their relationships.

This ODDPAT system consists of six major components: Users, Groups, PA Forms, Reports, Training & FAQ and Log-in/Log-off. These components will be described more in detail.

Users. The ODDPAT is required to have three different types of user groups: Admin, Instructor and Student.

Admin is a group of users that have the full privileges to manage the ODDPAT. The admin users can add/edit/delete any course related data such as course information, students' information and scores/grading, etc. When the ODDPAT system has multiple instructors teaching multiple courses at the same time, the admin group is responsible for making sure to set

appropriate permissions for instructors so that they do not accidentally delete any of their course information nor view other instructors' course information.

Instructor is a group of users that have the privileges to mostly manage any course related features such as adding/modifying/deleting any groups, assessment forms, assessment criteria and etc.

Student is a group of users that have the least privileges but well enough to be able to view their group members and perform peer assessments among their group members.

Groups. This component of the tool is where collections of groups of users are displayed. There are two major features under this component: one is to show a list of existing groups and the other is to create groups. Instructors are able to view the collections of groups under the group list, but students can only view their members assigned to a group.

In order to create a group, a user must have the admin or instructor privileges. The ODDPAT system provides a Group Assigning Wizard, which helps instructors easily create a group and assign students to a group (Figure 1 illustrates the Use-Case diagram).

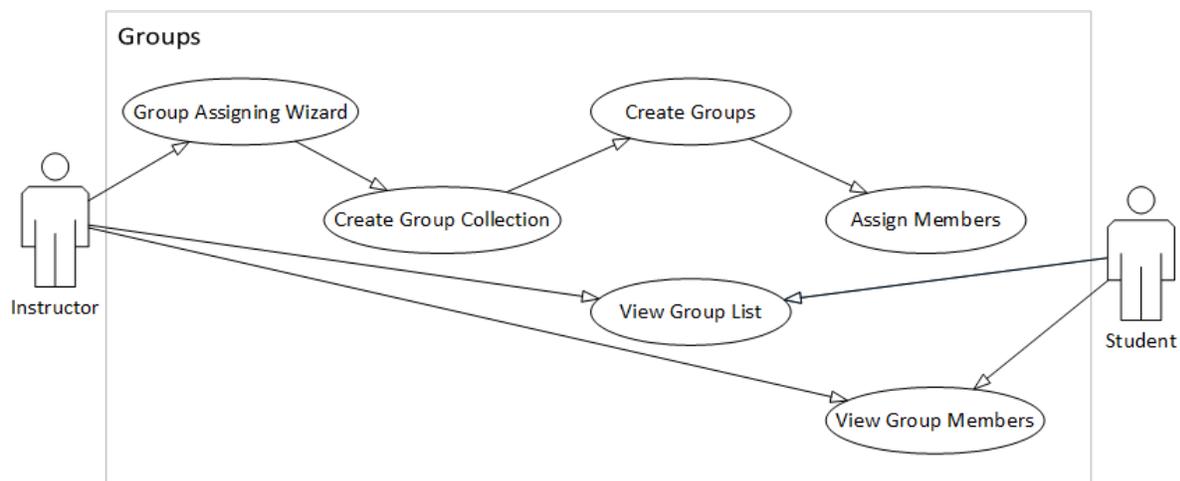


Figure 1. Use-Case Diagram for Group Assigning Wizard.

The wizard includes three steps to complete the group assigning:

- First step is to provide a collection name for groups. This should be something that can be easily identified by the instructors such as a course name or project name.

ODDPAT Group Creation Wizard

Group creation wizard helps instructor easily create group collections. These group collections later can be used for group assessments.

Step 1 of 3

Insert name for a group collection. It helps instructor identify easily when creating an assessment. A course can have one or many different combinations of group collections based on its variety of group activities. Instructors can determine whether to have one group collection for all group activities or different ones for each.
 Tip: name after a group project/assignment or course name.

Group Collection Name:

Next

Figure 2. The ODDPAT Group Creation Wizard Step 1 of 3.

- The second step is to decide the number of groups and provide the prefix of all group names for the purpose of consistency of group names. Since the ODDPAT limits the group size to three members only in one group, based on the total number of students registered in this course, the system will automatically generate maximum available numbers of groups and populate them as a dropdown menu for the instructors to select from. Instructors are allowed to choose the pre-defined the prefix as a group name such as “Group”, “Team” and etc. or instructors can choose their own prefix.

ODDPAT Group Creation Wizard

Group creation wizard helps instructor easily create group collections. These group collections later can be used for group assessments.

Step 2 of 3

There are 15 students enrolled in this course **IDT101**. Only 3 members are allowed in each group. The total number of groups you can create is 5.

Figure 3. The ODDPAT Group Creation Wizard Step 2 of 3.

- The last step is to assign students to each group. Instructors can manually assign each individual student to each group or let the system randomly assign students to groups.

ODDPAT Group Creation Wizard

Group creation wizard helps instructor easily create group collections. These group collections later can be used for group assessments.

Step 3 of 3

Group members can be assigned either manually by selecting a group individually from the drop-down menu or randomly by triggering the "Random" button. To un-assign a member from a group, just simply change that particular member's group value to "Unassigned" from the drop-down menu.

IDT101

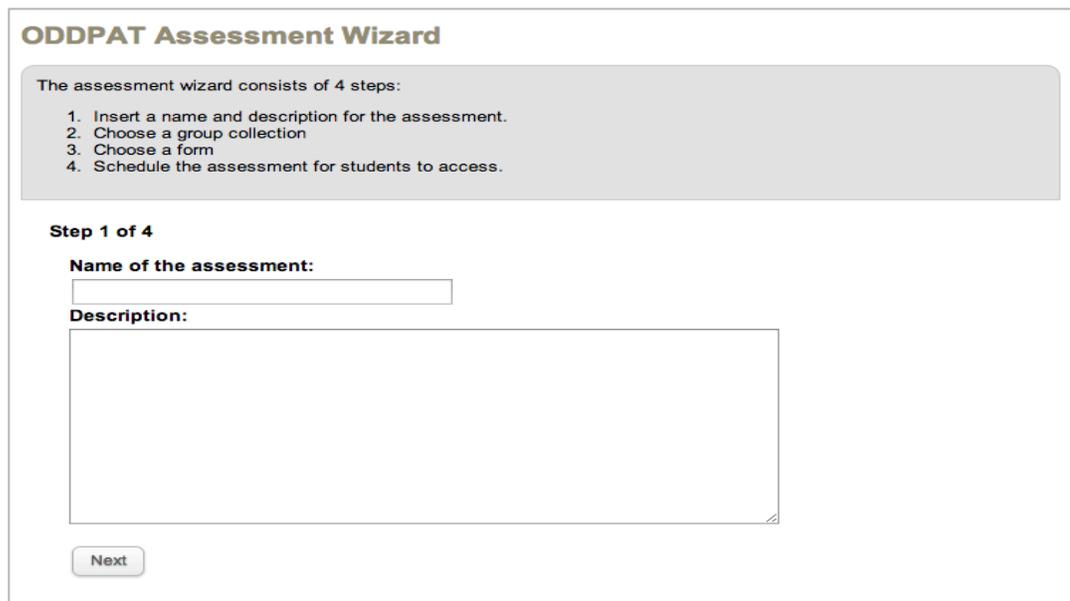
Students	Groups	Status
James [s01]	<input type="button" value="Unassigned"/> ▾	Group 01: <input type="button" value="0"/>
Robert [s02]	<input type="button" value="Unassigned"/> ▾	Group 02: <input type="button" value="0"/>
Michael [s03]	<input type="button" value="Unassigned"/> ▾	Group 03: <input type="button" value="0"/>
David [s04]	<input type="button" value="Unassigned"/> ▾	Group 04: <input type="button" value="0"/>
Richard [s05]	<input type="button" value="Unassigned"/> ▾	Group 05: <input type="button" value="0"/>
Charles [s06]	<input type="button" value="Unassigned"/> ▾	
Joseph [s07]	<input type="button" value="Unassigned"/> ▾	
Mark [s08]	<input type="button" value="Unassigned"/> ▾	
John [s09]	<input type="button" value="Unassigned"/> ▾	
Tom [s10]	<input type="button" value="Unassigned"/> ▾	
Lucy [s11]	<input type="button" value="Unassigned"/> ▾	
Mary [s12]	<input type="button" value="Unassigned"/> ▾	
Rose [s13]	<input type="button" value="Unassigned"/> ▾	
Paul [s14]	<input type="button" value="Unassigned"/> ▾	
Susan [s15]	<input type="button" value="Unassigned"/> ▾	

Figure 4. The ODDPAT Group Creation Wizard Step 3 of 3.

PA Forms. This component is the core element of the tool. It consists of two major features: assessment forms and assessment criteria. An assessment form can include at least one criterion. The system was built with a default criteria template and also provides collections of criteria resources for instructors to choose from. In addition, instructors can either customize the existing criteria or create their own from scratch. This component is also integrated with the Peer Assessment Form Wizard, which helps instructors easily create a PA form.

The wizard requires four steps:

- The first step is to provide a name and brief description for an assessment form.



ODDPAT Assessment Wizard

The assessment wizard consists of 4 steps:

1. Insert a name and description for the assessment.
2. Choose a group collection
3. Choose a form
4. Schedule the assessment for students to access.

Step 1 of 4

Name of the assessment:

Description:

Figure 5. The ODDPAT Assessment Wizard Step 1 of 4.

- The second step is to choose a collection of groups from the dropdown menu previously created by the instructors.

ODDPAT Assessment Wizard

The assessment wizard consists of 4 steps:

1. Insert a name and description for the assessment.
2. Choose a group collection
3. Choose a form
4. Schedule the assessment for students to access.

Step 2 of 4

Group Collection:

--Choose One-- ▾

Back Next

Figure 6. The ODDPAT Assessment Wizard Step 2 of 4.

- The third step is to choose the peer assessment criteria from the dropdown menu, which would be either a default criteria provided by the system or the ones customized by the instructors.

ODDPAT Assessment Wizard

The assessment wizard consists of 4 steps:

1. Insert a name and description for the assessment.
2. Choose a group collection
3. Choose a form
4. Schedule the assessment for students to access.

Step 3 of 4

PA Forms:

--Choose One-- ▾

Back Next

Figure 7. The ODDPAT Assessment Wizard Step 3 of 4.

- The last step is to schedule opening and closing date of the assessment.

ODDPAT Assessment Wizard

The assessment wizard consists of 4 steps:

1. Insert a name and description for the assessment.
2. Choose a group collection
3. Choose a form
4. Schedule the assessment for students to access.

Step 4 of 4

Opening Date:

Closing Date:

Figure 8. The ODDPAT Assessment Wizard Step 4 of 4.

Reports. This component is another essential part of the tool, which provides all the assessment scores and the final grade of each individual student. This component consists of two major features: presentation of scores & final grades and calculation algorithm for measuring individual contribution to the group work.

Presentation of scores and final grades. This is the page where instructors are able to view all the scores/grades, displayed in three different formats of tables.

Final factor table. This table displays factors based on each criteria and overall factors of each individual student. The final factor is an average of all criteria. The table is organized with students' name as its rows and each criterion as its columns (see Figure 9).

IDT101-Group Project Week 2							
Student	C1	C2	C3	C4	C5	C6	Final Factor
James	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Robert	n/a						
Michael	0.32	0.29	0.33	0.31	0.31	0.3	0.31
David	0.32	0.34	0.36	0.32	0.34	0.34	0.34
Richard	0.35	0.35	0.31	0.37	0.35	0.36	0.35
Charles	n/a						
Joseph	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Mark	n/a						
John	n/a						
Tom	n/a						
Lucy	n/a						
Mary	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Rose	n/a						
Paul	n/a						
Susan	n/a						

Figure 9. Final Factor Table on Report Page.

Scores by group table. A 3x4 table shows scores of each individual student as a group by each category. This table illustrates more detailed relationship of scores received from other members within a group. The table is structured with students' names as its rows and scores given by each student as its columns (see Figure 10). The table helps instructors understand and explain how each individual's factor is determined. The system also provides visual aids to explain how the factor is calculated (see Figure 11). By hovering over a student name on the first column of a table, color-coded cells are revealed for instructors to easily spot which scores are to be substituted as numerators and denominators into the Division Rule mechanism (see Equation 11). In this example, two green cells (Label A) indicate each score that James received from Joseph and Mary and each of those will be plugged in as denominators. The purple cells (Label B), on the other had, show each relative scores given to Mary and Joseph by the counter party.

At the bottom of each table, each relative ratio is calculated based on the bottom part of the equation r_{ki}^j and r_{ji}^k .

C1: Motivation/Responsibility/Time Management

Indicators: attends meetings regularly and on time, accepts fair share of work and reliably completes by the required time.

	From James	From Joseph	From Mary	Factor
James	40	20	40	0.33
Joseph	30	60	40	0.33
Mary	30	20	20	0.33

Figure 10. Scores by Groups Table on Report Page.

	From James	From Joseph	From Mary	Factor
James	40	20 (A)	40 (A)	0.33
Joseph	30	60	40 (B)	0.33
Mary	30	20 (B)	20	0.33

From Joseph: $20/20 = 1.00$ | From Mary: $40/40 = 1.00$

Figure 11. Visual Aids Provided to Explain the Calculation.

Final grades table. The final grades table contains the information of every student's Final Factor, Weight, Option, Ratio, Group Score, and Final Grade (see Figure 12).

- Final Factor column shows average factors received for all criteria.
- Weight is given to the peer assessment and group score. This system has a fixed weight: $2/3$ to group work and $1/3$ for group process.
- The option column indicates which type of standardization method is implemented. Option 1 is to set group score as the maximum grade that a student can receive when the final grade exceeds the group score. Otherwise it remains the same score as their final grade.

Option 2: to set the group score as the maximum grade and whoever has the highest final grade will obtain the group score as his/her adjusted final grade, but the rest of the members will get their final grades based on the ratio of the highest grade in their group.

- The ratio column shows the average of all denominators.
- The group score is the score of a group work awarded by the instructor.
- The final score is the score calculated by multiplying group score with each student's individual final factor.

Student	Final Factor	Weight	Option	Ratio	Group Score	Final Grade
James	0.33	2/3	opt2	1	85	85
Robert	n/a	2/3	opt2	n/a	80	n/a
Michael	0.31	2/3	opt2	0.89	90	80
David	0.34	2/3	opt2	0.97	90	87
Richard	0.35	2/3	opt2	1	90	90
Charles	n/a	2/3	opt2	n/a	95	n/a
Joseph	0.33	2/3	opt2	1	85	85
Mark	n/a	2/3	opt2	n/a	80	n/a
John	n/a	2/3	opt2	n/a	80	n/a
Tom	n/a	2/3	opt2	n/a	78	n/a
Lucy	n/a	2/3	opt2	n/a	78	n/a
Mary	0.33	2/3	opt2	1	85	85
Rose	n/a	2/3	opt2	n/a	78	n/a
Paul	n/a	2/3	opt2	n/a	95	n/a
Susan	n/a	2/3	opt2	n/a	95	n/a

Figure 12. Final Grade Table on Report Page.

Calculation Algorithm of Measuring Individual Contribution. Although all of the calculation jobs are done silently behind the screen, the algorithm of calculating individual contributions can be viewed as the heart of this system. In order to better demonstrate its mechanism, a worked example will be utilized (see Figure 13).

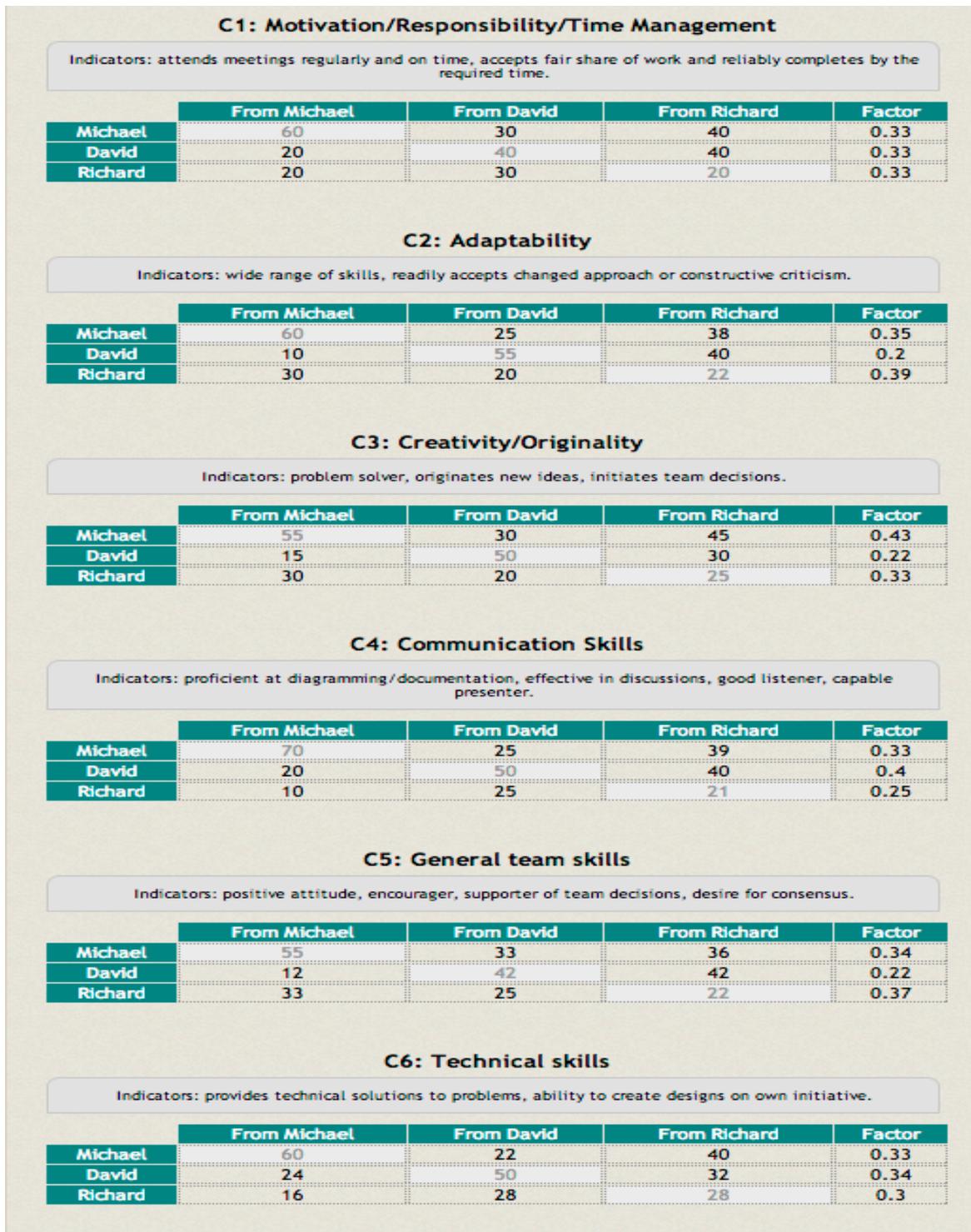


Figure 13. Worked Example.

The rows display the scores each student received, whereas the columns show the scores awarded by each student. In this example, all three students (Michael as M, David as D and

Richard as R) resulted in equal contribution in terms of the first criteria – motivation/responsibility/time management.

The nature of collaboration views group works as one whole entity (product) produced synergistically by all group members. It requires and encourages full participation of all group members. Therefore, when each student is rating other members within a group, he/she needs to decide how to distribute or split the works in terms of contributions based on criteria given. This system uses split-100 method, which was practiced by Lydia Kavanagh at the University of Queensland Australia (Wilkinson, 2008) but the concept is very similar to the Division Rule mechanism. For each criterion, the sum of scores cannot exceed 100; otherwise the system will alert the user to adjust the scores.

According to the example, each individual student's factor is calculated as following:

Michael's PA factor of the first criterion (C1):

$$\frac{1}{1 + \frac{D's \text{ score received from } R}{M's \text{ score received from } R} + \frac{R's \text{ score received from } D}{M's \text{ score received from } D}} \quad (15)$$

$$\frac{1}{1 + \frac{40}{40} + \frac{30}{30}} = \frac{1}{1 + 1 + 1} = \frac{1}{3} \approx 0.33 \quad (16)$$

David's PA factor of the first criterion (C1):

$$\frac{1}{1 + \frac{R's \text{ score received from } M}{D's \text{ score received from } M} + \frac{M's \text{ score received from } R}{D's \text{ score received from } R}} \quad (17)$$

$$\frac{1}{1 + \frac{20}{20} + \frac{40}{40}} = \frac{1}{1 + 1 + 1} = \frac{1}{3} \approx 0.33 \quad (18)$$

Richard's PA factor of the first criterion (C1):

$$1 + \frac{1}{\frac{M's \text{ score received from } D}{R's \text{ score received from } D} + \frac{D's \text{ score received from } M}{R's \text{ score received from } M}} \quad (19)$$

$$\frac{1}{1 + \frac{30}{30} + \frac{20}{20}} = \frac{1}{1 + 1 + 1} = \frac{1}{3} \approx 0.33 \quad (20)$$

Even though Michael, David, and Richard awarded different scores to two other members of their group, it resulted in equal PA factors because this mechanism looks for the consistencies of ratings based on the relative ratios among members within a group. According to the example, Michael gave 20-20, which can be interpreted as Michael thought David and Richard equally contributed to the group work; David gave 30-30, which again indicates that David considered Michael and Richard spent equal amount of efforts to the group work; Richard gave 40-40, which also shows that Richard saw Michael and David deserved equal share of group work. In spite of different attribution (disposition) these three individuals possess in terms of rating others (in this example, Michael was mostly conservative by giving 20-20; David was moderate by giving 30-30; and Richard was mostly generous by giving 40-40), this algorithm accurately denotes fair distribution of scores because all three agreed everyone equally contributed to the group work regardless of giving high or low scores.

This process is repeated for every student for every criterion. The final factor is the average of all factors: the sum of factors of all the criteria divided by the total number of criteria. Once the final factor is calculated, the final grade is determined based on the final factor, weighting, option, and group score.

$$\text{Final Grade} = \left(\text{final factor} + \frac{2}{3} \text{ weighting factor} \right) \times \text{Group score} \quad (21)$$

Michael's final PA factor: $(0.33 + 0.35 + 0.43 + 0.33 + 0.34 + 0.33)/6 = 0.35$

David's final PA factor: $(0.33 + 0.2 + 0.22 + 0.4 + 0.22 + 0.34)/6 = 0.29$

Richard's final PA factor: $(0.33 + 0.39 + 0.33 + 0.25 + 0.37 + 0.3)/6 = 0.33$

If this group scored 90 on their group work, then

Michael's final grade: $(0.35 + 2/3) \times 90 = 91.8$ (above the group score)

David's final grade: $(0.29 + 2/3) \times 90 = 86.4$

Richard's final grade: $(0.33 + 2/3) \times 90 = 90$

As you might have noticed, Michael's final grade is above the group score. It is not reasonable that a group member can score higher than the group score just simply because he/she puts more efforts than others within a group. Individual's score should never exceed the group score because the group product is considered as a group entity produced by collaborative efforts not just by one individual's contribution. Therefore, this system provides two standardized options for instructors to choose based on their circumstances and needs.

One option is to set group score as the maximum grade that a student can receive when the final grade exceeds the group score. Otherwise it remains the same score as their final grade. In this case, Michael gets 90 for his adjusted final grade and David and Richard get 86.4 and 90.

The other option is to set the group score as the maximum grade and whoever has the highest final grade will obtain the group score as his/her adjusted final grade, but the rest of the members will get their final grades based on the ratio of the highest grade in their group. For example, Michael scored 91.8 the highest among his group. Therefore he gets the group score 90 as his adjusted final grade. On the other hand, David and Richard will get their adjusted final

grades based on the ratio of Rose's actual grade. David's final grade will be $90 \times (86.4/91.8) = 85$ and Richard's final grade will be $90 \times 90/91.8 = 88$

The option two can be defined as A's grade equals the group score multiplied by the ratio of A's score to B's score expressed as a fraction. Here B's score is the highest score among his/her group.

$$A's\ grade = Group\ Score \times \frac{A's\ Score}{Highest\ Score} \quad (22)$$

Training & FAQ. This component of the tool serves as the help center where users obtain useful information about the system. Not only does it contain tutorials of how to utilize the tool, but also includes documents and examples to explain how the individual contributions are measured based on the criteria given and how instructors should interpret the results on report pages. The literature suggested that both instructors and students should have a better understanding of peer assessment concepts and practice the usage of PA tool prior to any assessments (Loddington, 2008)

Log-in/Log-off. One of the merits of using online PA tool is the guarantee of the anonymity. Literature suggests students should keep anonymous to alleviate student concerns over bias and unfair rating. In order for students to make anonymous ratings, the system needs to develop with the login feature to authenticate the user with their username and password. When a student logs in, he/she should be able to identify which groups he/she belongs to and who teammates are (see Figure 14). When a user views his/her grade, they are not allowed to see detailed individual scores received from other members among a group. Only the instructors have the privileges to be able to track detailed scores.

Welcome, James	<h2>My Groups</h2> <p>You have been assigned to these groups. Each assignment may have different group members. You should contact your group members prior to conducting any assignments. By clicking a member's name will reveal his/her email address.</p> <p>GROUP-IDT2013</p> <table border="1"> <thead> <tr> <th>Group Name</th> <th colspan="3">Members Name</th> </tr> </thead> <tbody> <tr> <td>Group 03</td> <td>James</td> <td>Mary</td> <td>Rose</td> </tr> </tbody> </table>	Group Name	Members Name			Group 03	James	Mary	Rose
Group Name		Members Name							
Group 03		James	Mary	Rose					
Home									
My Groups									
My Assessments									
Logout									

Figure 14. Interface of Group Information When a Student Logs In

Database Logical Modeling (Diagram). During the logical modeling phase, most of the classes were identified and extended based on the six major components discussed above. The Figure 14 illustrates the logical design of the database including classes with attributes and their associational relationship.

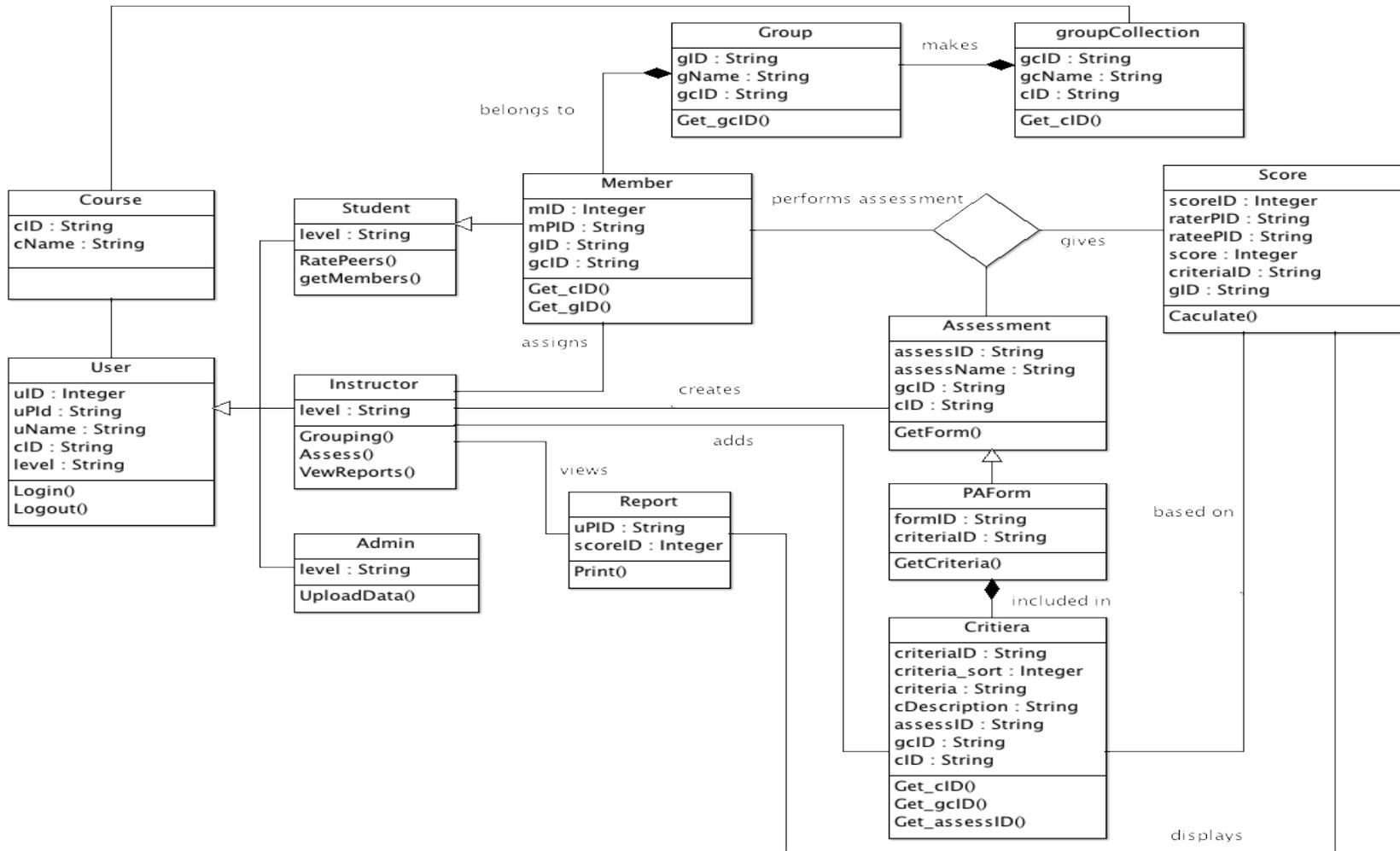


Figure 15. Database Design and Logical Model. The Users component can be identified as a User class. The User class is associated with Student, Instructor, and Admin classes by its role. The Groups component can be identified as groupCollection, Group, and Member classes. The Member belongs to Group and Group makes groupCollection. The Member class is aggregated from the Student class. The PA Forms component can be identified as Assessment, PAForm, and Criteria classes. The Assessment class is associated with PAForm class and PAForm includes many Criteria. The Reports component can be identified as Report and Score classes. The Report class is displayed based on the Score class.

C5. Select Appropriate Technologies

Based on the conceptual design of major components and functions, the next step was to develop web interfaces for users to utilize the PA tool and also construct physical database on a web server. Prior to the actual development, it was necessary to identify and determine the appropriate technologies to meet the described needs. These technologies were carefully selected based on the needs and objectives of this developmental research. These technologies are described in three categories: software, language, and server (see Table 12).

Table 12

Three Categories of Technologies

	Technology	Goal
Software	ArgoUML	Use-Case diagram for interface design and Class diagram for logical design of database.
	Aptana Studio 3	Text editor for coding and developing web pages and web applications.
	phpMyAdmin	Provides a user-friendly interface for administration of MySQL database.
Languages	PHP & MySQL	PHP is a scripting language to build web interface and MySQL is a database language to support relational database management
Server	Apache web server	A Linux server integrated with PHP 5.3 & MySQL 5.5 provides a web space to run the ODDPAT system.

ArgoUML was used to develop Use-Case diagrams and Class diagrams for both interface and database design. ArgoUML is a free open source UML modeling tool compatible for both Mac and Windows platforms.

Aptana Studio 3 was also used to build the web interface. *Aptana Studio 3* supports the latest browser technologies such as HTML5, CSS3, JavaScript, PHP, etc. to develop dynamic websites and web applications.

PHP stands for a recursive acronym for PHP: Hypertext Processor most widely used scripting language best suitable for web development (from php.net). It can be used with Dynamic HTML and easily integrated with various types of databases including MySQL (MacIntyre, 2010).

MySQL, according to Wikipedia, is “ the world’s most used open source relational database management system (RDBMS) that runs as a server providing multi-user access to a number of databases.”

phpMyAdmin was used to build the database structures. It is a free software tool written in PHP, which comes with an intuitive web-based graphical interface helps handle the administration of MySQL.

Apache web server with the support of PHP & MySQL was used.

C6. Develop Technological Framework

Based on the logical design of the database, it was necessary to transform those classes and their attributes into MySQL tables. The researcher used the phpMyAdmin to build the database and its structures.

First, a database was created and named “ODDPAT” which contains eleven database tables: assessment, course, criteria, form, groups, groupScores, members, modules, scores, userRole, and users.

Table	Action	Rows	Type	Collation	Size	Overhead
<input type="checkbox"/> assessment		4	InnoDB	utf8_general_ci	16.0 KiB	-
<input type="checkbox"/> course		1	InnoDB	utf8_general_ci	16.0 KiB	-
<input type="checkbox"/> criteria		7	InnoDB	utf8_general_ci	16.0 KiB	-
<input type="checkbox"/> form		2	InnoDB	utf8_general_ci	32.0 KiB	-
<input type="checkbox"/> groups		10	InnoDB	utf8_general_ci	16.0 KiB	-
<input type="checkbox"/> groupScores		10	InnoDB	utf8_general_ci	16.0 KiB	-
<input type="checkbox"/> members		30	InnoDB	utf8_general_ci	16.0 KiB	-
<input type="checkbox"/> modules		2	InnoDB	utf8_general_ci	16.0 KiB	-
<input type="checkbox"/> scores		162	InnoDB	utf8_general_ci	64.0 KiB	-
<input type="checkbox"/> userRole		16	InnoDB	utf8_general_ci	32.0 KiB	-
<input type="checkbox"/> users		16	InnoDB	utf8_general_ci	16.0 KiB	-
11 tables	Sum	260	InnoDB	utf8_general_ci	256.0 KiB	0 B

Figure 16. The ODDPAT Database Including Eleven Tables.

Next, each table with its fields was created.

The *assessment* table consists of nine fields: assessID, assessName, description, formID, moduleID, courseID, openingDate, closingDate, and date_created.

#	Column	Type	Collation	Attributes	Null	Default	Extra	Action
<input type="checkbox"/> 1	assessID	varchar(36)	utf8_general_ci		No	None		
<input type="checkbox"/> 2	assessName	varchar(100)	utf8_general_ci		No	None		
<input type="checkbox"/> 3	description	text	utf8_general_ci		No	None		
<input type="checkbox"/> 4	formID	varchar(36)	utf8_general_ci		No	None		
<input type="checkbox"/> 5	moduleID	varchar(36)	utf8_general_ci		No	None		
<input type="checkbox"/> 6	courseID	varchar(36)	utf8_general_ci		No	None		
<input type="checkbox"/> 7	openingDate	datetime			No	None		
<input type="checkbox"/> 8	closingDate	datetime			No	None		
<input type="checkbox"/> 9	date_created	datetime			No	None		

Figure 17. The Assessment Table Including Nine Fields.

The *course* table consists of three fields: courseID, courseName, and date_created.

#	Column	Type	Collation	Attributes	Null	Default	Extra	Action
<input type="checkbox"/> 1	courseID	varchar(36)	utf8_general_ci		No	None		
<input type="checkbox"/> 2	courseName	varchar(200)	utf8_general_ci		No	None		
<input type="checkbox"/> 3	date_created	date			No	None		

Figure 18. The Course Table Including Three Fields.

The *criteria* table consists of nine fields: criteriaID, cid_order, criteria, description, formID, assessID, moduleID, courseID, and date_created.

#	Column	Type	Collation	Attributes	Null	Default	Extra	Action
<input type="checkbox"/>	1 criteriaID	varchar(36)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	2 cid_order	int(11)			No	None	AUTO_INCREMENT	Change Drop More ▼
<input type="checkbox"/>	3 criteria	varchar(500)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	4 description	varchar(2000)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	5 formID	varchar(36)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	6 assessID	varchar(36)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	7 moduleID	varchar(36)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	8 courseID	varchar(36)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	9 date_created	date			No	None		Change Drop More ▼

Figure 19. The Criteria Table Including Nine Fields.

The *groups* table consists of four fields: groupsID, groupsName, moduleID, and date_created.

#	Column	Type	Collation	Attributes	Null	Default	Extra	Action
<input type="checkbox"/>	1 groupsID	varchar(36)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	2 groupsName	varchar(100)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	3 moduleID	varchar(36)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	4 date_created	date			No	None		Change Drop More ▼

Figure 20. The Groups Table Including Four Fields.

The *group scores* table consists of eight fields: gscoreID, score, weight, gradeOption, assessID, groupsID, moduleID, and courseID.

#	Column	Type	Collation	Attributes	Null	Default	Extra	Action
<input type="checkbox"/>	1 gscoreID	int(11)			No	None	AUTO_INCREMENT	Change Drop More ▼
<input type="checkbox"/>	2 score	int(11)			No	None		Change Drop More ▼
<input type="checkbox"/>	3 weight	int(11)			No	None		Change Drop More ▼
<input type="checkbox"/>	4 gradeOption	varchar(20)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	5 assessID	varchar(36)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	6 groupsID	varchar(36)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	7 moduleID	varchar(36)	utf8_general_ci		No	None		Change Drop More ▼
<input type="checkbox"/>	8 courseID	varchar(36)	utf8_general_ci		No	None		Change Drop More ▼

Figure 21. The Group Scores Table Including Eight Fields.

The *members* table consists of five fields: memberID, uid, groupsID, moduleID, and date_created.

#	Name	Type	Collation	Attributes	Null	Default	Extra	Action
<input type="checkbox"/>	1 <u>memberID</u>	int(11)			No	None	AUTO_INCREMENT	Change Drop More
<input type="checkbox"/>	2 uid	varchar(20)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	3 groupsID	varchar(36)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	4 moduleID	varchar(36)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	5 date_created	date			No	None		Change Drop More

Figure 22. The Members Table Including Five Fields.

The *modules* table consists of four fields: moduleID, moduleName, courseID, and date_created.

#	Column	Type	Collation	Attributes	Null	Default	Extra	Action
<input type="checkbox"/>	1 <u>moduleID</u>	varchar(36)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	2 moduleName	varchar(200)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	3 courseID	varchar(36)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	4 date_created	datetime			No	None		Change Drop More

Figure 23. The Modules Table Including Four Fields.

The *scores* table consists of eight fields: scoreID, raterPID, rateePID, score, criteriaID, groupsID, assessID, and date_created.

#	Column	Type	Collation	Attributes	Null	Default	Extra	Action
<input type="checkbox"/>	1 <u>scoreID</u>	int(11)			No	None	AUTO_INCREMENT	Change Drop More
<input type="checkbox"/>	2 raterPID	varchar(30)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	3 rateePID	varchar(30)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	4 score	int(11)			No	None		Change Drop More
<input type="checkbox"/>	5 criteriaID	varchar(36)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	6 groupsID	varchar(36)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	7 assessID	varchar(36)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	8 date_created	date			No	None		Change Drop More

Figure 24. The Scores Table Including Eight Fields.

The **user role** table consists of four fields: `role_id`, `username`, `hashed_pw`, and `uid`.

#	Name	Type	Collation	Attributes	Null	Default	Extra	Action
<input type="checkbox"/>	1 role_id	int(11)			No	None	AUTO_INCREMENT	Change Drop More
<input type="checkbox"/>	2 username	varchar(20)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	3 hashed_pw	varchar(120)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	4 uid	varchar(30)	utf8_general_ci		No	None		Change Drop More

Figure 25. The User Role Table Including Four Fields.

The **Users** table consists of seven fields: `userID`, `uid`, `name`, `email`, `courseID`, `level`, and `date_created`.

#	Name	Type	Collation	Attributes	Null	Default	Extra	Action
<input type="checkbox"/>	1 userID	int(11)			No	None	AUTO_INCREMENT	Change Drop More
<input type="checkbox"/>	2 uid	varchar(20)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	3 name	varchar(60)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	4 email	varchar(60)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	5 courseID	varchar(36)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	6 level	varchar(36)	utf8_general_ci		No	None		Change Drop More
<input type="checkbox"/>	7 date_created	date			No	None		Change Drop More

Figure 26. The Users Table Including Seven Fields.

Once the database was ready, the data entry forms were developed. The data entry forms include data (user information and course information) upload form, grouping form and PA forms. These forms were checked to see if they were functioning correctly. One of the operational problems the researcher found was the creation order of the forms. The researcher realized that some forms needed to be created prior to other forms. For example, instructors need to create a group collection first and then divide x number of groups based on the total number of students in that class and finally those students can be assigned to a group. On the other hand, in order to create an assessment form, instructors first need to add criteria and choose groups from

the group collection. Therefore, the researcher developed wizard solutions for both grouping and PA forms to ease the process.

After grouping and PA forms were tested as working flawlessly, the researcher examined the PA forms by performing the assessment from the student perspective. When the scores were submitted, the report pages were developed and tested. In order to conduct in-depth interviews, a demo version of the tool was created with pre-configured course and student information uploaded into the database.

C7. Evaluate Initial System (Survey & In-depth Interview)

Once the prototype of the tool was developed, the researcher sent a recruitment email (see Appendix A) to five faculty members among from which three expert reviewers were chosen to review the prototype. These three experts had not been exposed previously to the prototype and they were drawn from different fields and backgrounds. One expert was from computer science, the second one was from communication, and the last one was from instructional design and technology. All three experts had many years of experience in evaluating group work. The experts reviewed the prototype from the following perspectives: system visibility, system functionality and perception of the prototype including its calculation method – the Division Rule mechanism.

The review process was conducted in the following steps:

Step One. The researcher arranged a thirty-minute long face-to-face meeting with each expert. During this initial meeting, the researcher briefly introduced the prototype and explained the purpose of study. In order for the experts to gain full experience with the prototype, a “step-by-step directions for evaluating the ODDPAT system” instruction (see Appendix B) was provided to them. This rubric was developed to guide them in evaluation procedures, which

were broken down into twelve major tasks. In order for each expert to have a clean test environment, three identical versions of prototypes were created with different login credentials. In addition, each expert was provided with a unique login credential sheet (see Appendix C) and a password-protected survey link was sent via email. The survey included 14 questions regarding the interface design and system functionality (see Appendix D) and experts were required to complete the survey before the next meeting. An online demo page was also created for experts to fully understand how the Division Rule mechanism works and how it is different from a conventional calculation method (see Appendix E).

Step two. After the rubric and survey were completed, each expert was scheduled with another follow-up face-to-face meeting for an in-depth interview. Each expert was interviewed using the same 5 questions (see Appendix F) regarding the prototype and its Division Rule mechanism. Each structured interview lasted for approximately thirty minutes and its entire process was audio-recorded with onsite note taking.

Chapter 4: Results of Findings

This chapter discusses the analysis of data collected through surveys and interview questions from three experts after they reviewed the prototype. The audio-recorded interview data was all transcribed and organized into three major themes: system visibility, system functionality, and perception of the prototype and its calculation method – the Division Rule mechanism.

Expert Reviewers

Three experts reviewed the ODDPAT prototype. Two experts were from outside the instructional design and technology fields, one from computer science and the other one from communication. Both of them have built sufficient experience in evaluating group work in their subject domain areas. The third expert was from instructional design and technology field.

Analysis

In general, the overall perception on the ODDPAT prototype and its Division Rule mechanism were quite positive. All three expert reviewers recommended using this tool to assess group work. To better implement the current system for future development, the expert review data was broken down into three major themes: the interface design, system functionality and perception on the system and its Division Rule mechanism.

Interface design. The interface design looks into system in the perspective of the orientation and navigation, of visual feedback, and of ambiguity of terminologies.

Orientation and navigation. Based on the survey questionnaires, all three experts reached an agreement that the tool had no issues with its orientation, visibility, and visual feedback in terms of its interface design. All three experts concluded that this tool was easy to

use and most of its visual information was simple and clear for them to navigate smoothly and provided simple and clear information to indicate the user's current location and was easy to read and navigate. These statements are well supported by the comments from these three experts.

I think that is well designed ... it was really good because I could use it very smoothly ... the screen of the system is easy to follow (Expert I)

... quite easy to use ... I feel like it's easier, very hands-on and very easy to use for students as well as instructor ... and very straightforward and very intuitive ... enjoyed using this system ... is very easy to use, very easy to navigate (Expert II)

It was pretty clear to me. (Expert III)

Visual feedback. Although all three experts answered yes on whether each page is labeled to show its relation to others and whether there exists some form of feedback for every operator action, a few suggestions were proposed in regard of its visual feedback. Two experts noted the inappropriate wording of the visual feedback when deleting a group. "All groups have been successfully deleted" which was intended to indicate that the group collection had been deleted rather than all groups. It needed to be modified as such, "The selected group collection has been successfully deleted."

It was very easy to delete except some minor suggestions you know when I deleted a group I thought what? it says all group information was deleted, I thought oh my god no, so it will be nice to tailor, you know based on whatever it's being deleted (Expert II)

Ambiguity of terminologies. One expert raised the concern about two terms used in this system, “Forms” and “Assessments” and their relationship. In the beginning the expert did not quite perceive what they were and how they were related to each other until he went through the entire system. In the next phase of the tool development, additional descriptive text needs to be implemented to help explain what they are and how they interact.

At the first time when I went through it, I wasn't quite sure what they were 'cause I had to create a form and I wasn't sure what the form was for and I created assessment attached to the form. So it wasn't clear to me when I was doing at that moment, now later on I realized that, ok, the form contains evaluation criteria and the assessment is which you create to attach the form. It wasn't clear to me at first so I think making that more clearly for the end user. That's kind of minor (Expert III)

Furthermore, one expert suggested that the term, “Assessments” should be named something differently since it does not indicate the peer evaluation of a group project. Unfortunately, the expert was not able to recommend appropriate alternative terms for both “Forms” and “Assessments” during the interview.

In your system, an assessment seems to refer to a group assignment or project that requires peers to evaluate each other. The term “Assessments” does not allude to that. (Expert III)

One expert also identified the necessity of explanation or instruction to describe the “Assign Group Score” function. The expert recognized the importance of this function which is

used to eventually determine the final grade, but its description can be found nowhere on that page.

I'm not sure it is made clear what the 'Assign Group score' function is doing.

This page probably needs more explanation/instruction. It appears that you have to set a group score before final grades will be calculated, so it must be pretty important. (Expert III)

System functionality. In terms of system functionalities, all three experts found no major problems with basic functions such as operations of menus and buttons, login attempts for both instructors and students, being able to create, edit, delete groups, forms, and assessments, and being able to view the assessment progress, scores report and grades report.

In addition, the following functions were found and considered to be the strengths of this system.

Automated calculation. One of the significant strengths of this system is the automated calculation of peer assessment ratings. Since it has become a major interest in academic fields to incorporate group activities and be able to fairly assess individual contributions to the group work, a system with such an automated calculation would facilitate a stronger peer evaluation process.

No manual calculation is necessary. That's one of the strengths (Expert I)

So having students being able to work in groups on projects and assess each other is kind of a major interest at the institution I'm at, so it makes me excited that there's a potentially tool out there ... could automate that and help that process

and make peer evaluation stronger process ... so I think there's a big win there, a system like this. (Expert III)

Automated data collection. No calculations can be done without data being collected. Unlike paper-based peer assessment forms, this prototype collects all peer assessment ratings automatically by having students log into the system using their own individual accounts and submit their peer evaluation ratings.

One of the strengths I really like is that students can actually log on to the website and enter the grade so you save a lot of time, money printing out of evaluation forms and calculate that. So I think it's a plus (Expert II)

Automating the data collection, collation, and calculation process will tremendously reduce the administrative overhead and tedious computational work for instructors, which in return save time, money and resources.

Random assignment of group members. The system provides both random and manual assignment of group members and one expert found it very useful and assigning group members was just as easy as of a one-click of a button.

It was very straightforward to add to randomize students. I think I really like that aspect. I always like put students randomly and I think it's good that website does that without putting much work into that. (Expert II)

Multiple criteria. The provision of default criteria and the ability to create custom criteria are identified as the strength of this system. One expert stated that faculty members are more

reluctant to incorporate multiple criteria into peer evaluation process on paper-based evaluation forms than computer-based forms since it creates much work for them to analyze data.

Multiple criteria on a manual type of form will be most faculty won't do it. It would be just too much work to analyze that data but having a computer based and being able to break it down with criteria and have the calculation's done for you. I think it's a big strength of that system (Expert III)

Visual representation. Two experts really liked the visual representations of results on report pages. One expert expressed that the report pages where the results are displayed in the format of various tables and charts will help instructors understand the big picture and overall idea about the data. Another expert mentioned about the visual cues helped him understand the way calculation is done and further they will be beneficial for instructors to explain the results to students.

Keeping the results in one system ... in case that I want to evaluate the big picture ... if I try to see the trend ... There are some screen which shows the tables ... the report, yeah... that was very useful ... overall idea about what's going on in there (Expert I)

I like having the data, the charts with data, I wasn't exactly sure all the time what I was seeing but I like to having it 'cause the more I looked at it, the more it starts making sense. I like the way you cued in the charts where you can mouse over names and it would kind of show you where it was getting that calculation. I think it's very useful to see. I think it would also be useful if students came back later on, why did I get this grade, 'cause they do that all the time ... I think being able

to show them that and explain it to them and show them data I think it will be very helpful. It's a big benefit actually (Expert III)

Like any other prototype, this system also possesses some potential weaknesses in regard to system functionalities. Two experts suggested new functionalities in terms of submitting peer assessment scores. One expert suggested there should be a function that prevents instructors from deleting the assessment forms once students submit their peer assessment scores because the current system deletes all scores associated with a form when the form is deleted. Additionally the system should allow students to modify their peer assessment scores before the due date.

I noticed that when students submit their peer reviews, they cannot go back and edit them. Should they be able to edit them until the close date?

... It did not warn me that there had already been scores given using the first form. When I continued, it seemed to lose all the data I had entered ... It might help to build in functionality that prevents an instructor from changing the form associated with an assessment after scores have been entered. (Expert III)

Similarly the other expert suggested a reminder function which checks the peer evaluation submission progress and triggers the system to send an automatic notification email to both students and instructors if scores haven't been submitted at certain days prior to the due date.

I think one thing professors do need to know is what if some students forget to do that [submitting scores], how would this impact the students' grade so maybe send some alert to professor or students automatically that you need to finish it. (Expert II)

Other minor issues include the difficulty of finding the next group project on “Scores by Group” page if multiple assessments are created. It might be helpful to limit the view to only one assessment.

Perceptions on the division rule mechanism. In order to better understand the experts’ perceptions on this Division Rule mechanism, the researcher first investigated what mechanisms that these experts have been using in their subject domain areas and what challenges they have faced with when assessing group work. Based on the interview, all three experts have used different types of peer assessment mechanisms such as distribution of score (similar to the method, distribution of a pool of marks, discussed in Chapter 2), deduction of points (similar to the method, equally shared score with exceptional instructor intervention) and average of scores. Even though each expert faced different challenges, they all shared some commonalities such as free riders and the bias towards giving lower scores to other members. Having these prior experiences in mind, one expert thought the division rule mechanism was a smart idea and it made sense to her because it was similar to the approach she’s using. Another expert appreciated the fact that one’s grade is always determined by the relative ratio of the other two group members. Two experts strongly believed that this Division Rule mechanism is able to overcome some potential bias or challenges that these experts have encountered.

I think this division rule mechanism tries to eliminate the kind of subjective viewpoint or subjective decision especially about himself/herself. So I thought that make sense and it’s very reasonable... so this mechanism can overcome that kind of challenge. Definitely. (Expert I)

So, based on what I know about the Division Rule mechanism, it appears that it helps overcome some of that bias that you usually see in peer evaluation situations. (Expert III)

In general, all three experts felt positive about this Division Rule mechanism and definitely recommended this tool to assess group work. All of them pointed out that it will be very beneficial if this Division Rule mechanism is able to support a variety of group dynamics, which was considered as the limitation of this study.

Chapter 5: Discussion

This chapter discusses what and how this study contributed to the current literature. Also, detailed documentation of the design and development processes of the ODDPAT system revealed some of the lessons the researcher learned through its entire project. Finally, based on this study, I have made some suggestions for its implementation and future research.

Contributions of This Study

The benefits of collaborative learning and limitations of group assessment methods have been the driving force for the researcher to reach the point where there is an explicit need to develop an Online Database-Driven Peer Assessment tool using the Division Rule mechanism as its core computational algorithm.

The benefits of collaborative learning encouraged school districts, state departments of education and national research organizations to implement collaborative learning strategies into curriculum design and gradually developed national standards for assessment (Webb, 1995). A review of the literature revealed that peer assessment had been adopted as a means of fair and equitable measurement of individual contributions to group work and has proven to be an acceptable, valid, reliable and practical strategy for higher education courses (Cheng & Warren, 2000; Conway & Kember, 1993; Gatfield, 1999; Goldfinch & Raeside, 1990; Lejk & Wyvill, 2001; Lejk et al., 1996). Many peer assessment methods have been developed into online tools built with a variety of calculation mechanisms. However, many of these calculation mechanisms shared a common downside that would lead to circumstances where a student could be strategic and be easily able to obtain a higher score by simply giving lower scores to the other members within a group. In addition, studies indicated that weaker students tended to rate themselves

higher whereas stronger students tended to underrate themselves (Lejk & Wyvill, 2001), which consequently resulted in penalizing themselves by being overgenerous or extremely conservative (Goldfinch, 1994).

The need for this study was to find a new mechanism that could help restrain students from getting higher scores by just simply giving lower scores to other members within a group. In addition, the mechanism should help minimize the degree of penalty to the grade of whom is either overgenerous or extremely conservative.

Fortunately, the researcher discovered a new mechanism derived from the perspective of Division Rule Theory from Economics. Seeking a fair share of a profit for each participating partner from the perspective of Economics is, in many ways, equivalent to the very spirit of collaborative learning - a structured interaction, which requires a small group of learners to work together to accomplish a common goal through emphasizing on the process, social interaction during which learners try to coordinate and cooperate with each other to achieve a shared goal (Artz & Newman, 1990; Panitz, 1997). One of the most important contributions of this study was to seek the novel interdisciplinary approach by combining the theoretical perspective from economics and the methodology perspective from education. In other words, this unprecedented discovery led to the marriage between economics and education by bonding the Division Rule Theory to peer assessment of collaborative learning. This attempt itself made a significant contribution to the current literature of peer assessment in collaborative learning environment. Based on the current review of literature, no researcher has ever attempted to design and develop an online peer assessment tool with the Division Rule mechanism.

Another important contribution of this study is the fact that the ODDPAT system was developed so that both teachers and students were able to implement this tool in their classrooms.

According to the reviews from experts showed that this ODDPAT system might eliminate the occurrence of unfair scores caused by manipulation of scores, and also compensate the degree of penalty for being overgenerous or extremely conservative when students rate each other, and definitely reduce the overheads and computational work for instructors through its automated data collection, collation, and calculation process.

Lessons Learned

The researcher chose the developmental research study approach using the CAG model as its design, develop, and evaluation framework. The entire study can be broken down into three main stages: initial stage, design & development stage, and review stage.

Initial Stage

At the initial stage, the researcher needed to review the current literature about online peer assessments tools and their calculation mechanisms. After reviewing the literature, no existing tools available up to date were found using the Division Rule mechanism as its core computational mechanism. More importantly reviewing the literature helped the researcher gather common components and functionalities of existing online peer assessment tools, which later served as references at the design stage.

Design and Development Stage

This stage took the researcher more than six months because the researcher played a dual role – both designer and programmer. The most challenging part of this stage was to illustrate features and functionalities via use-case modeling and then interpret those components, features and functionalities into logical modeling – the class modeling which displays all the data and their relationships. This design process was extremely important because the elements converted

from features and functionalities had played critical roles when programming especially using an object-oriented programming language, like PHP.

In the beginning of the development stage, the researcher built a web server and its database server on his local computer in order to write, test, and debug the codes efficiently even without network connection. After the completion of scripting and interface design, all source files including the contents and structures of the database were migrated into the researcher's personal web hosting server. The migration was successful except that the researcher noticed some page loadings were extremely slow. This problem had not emerged during testing on the researcher's local machine. Later the researcher identified the problem was caused by too many nested looping queries and loading unnecessary data from the database when a page loads. The researcher had to rewrite some of the codes to optimize the performance. The speed of loading was one of the key factors to determine the optimal performance of this type of online peer assessment tool.

Review Stage

I recruited a total of three experts from different fields. I wanted to seek experts who had experience in assessing group work and among whom one expert should be from instructional design and technology field. Having those criteria in mind, I made an initial contact with five experts via recruitment emails. In result, three responded and expressed their willingness to participate in this study; one expert did not respond and one expert dropped out.

The findings from expert reviews indicated that the ODDPAT system should overcome the drawbacks of peer assessment and satisfied the needs identified in the C1 phase of this study. All three experts strongly recommended using this system to assess group work. The expert also suggested that a clear instruction or explanation of the ODDPAT system and its calculation

mechanism – the Division Rule Theory should be provided not only to the instructors but also to the students prior to the use of the system.

Implementation of Study

The actual development of the system provides an opportunity for both instructors and students to obtain hands-on experience on the system. In addition, the system can be immediately implemented as an assessment tool for group work in real classrooms. It will be more beneficial if this system can be integrated into the major course management systems like Blackboard, Scholar or Moodle since none of them has yet been built with an assessment function to truly measure the individual contribution to a group work.

Future Investigation

Several topics have been emerged for future research inquiries from this study. As mentioned elsewhere in this paper, the limitation of this study is the group size. The Division Rule mechanism limits the group size to three. All three experts recognized this limitation and suggested the system have the flexibility of dynamic group sizes as a future study. According to Tideman and Plassmann (2007), there are infinite numbers of possible formulas available if the group size is greater than three. More research should be done to narrow this research gap where to investigate the efficiency of formulas for dynamic group sizes in educational environment. The current study did not investigate the students' perception, so pilot studies may be needed in order to better understand students' perception on usage of the system.

Summary

The study drew from novel research in Economics in the development of an online peer assessment tool using the Division Rule mechanism as its core computational algorithm to overcome some drawbacks of current existing peer assessment calculation methods. The design, development, and implementation of this project will hopefully continue to serve as a catalyst for curriculum development in peer assessment of collaborative learning and eventually be implemented in major course management systems in higher education.

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Appendix A: Recruitment Email

I am conducting a dissertation research project entitled “Design and Development of Online Database-Driven Peer Assessment Tool Using Division Rule Theory”. The purpose of this developmental research is to build a prototype of Online Database-Driven Peer Assessment Tool (ODDPAT) using the Division Rule mechanism as its core computational algorithm to measure individual contribution to group work. In order for the system to be adapted and generalized into multiple contexts, it is necessary to evaluate user interface, system functionality and perceptions of faculty on the Division Rule mechanism integrated in the ODDPAT system.

You are invited to participate an online survey regarding interface design and system functionality of the ODDPAT system and an in-depth interview that is designed to collect data about perception on the ODDPAT system. The survey will take 5-10 minutes to complete and interview will take about 30 minutes. If you would like to participate in this study, please reply this email. I’d like to set up a short meeting with you to provide overview of Division Rule mechanism integrated in the ODDPAT system as well as a detailed instruction of how to use this system.

If you have any questions, please feel free to contact me at hlian@vt.edu.

Thank you for your consideration.

Sincerely,

Hongri William Lian

Appendix B: Step-by-Step Direction for Evaluating the ODDPAT System

The Online Database-Driven Peer Assessment Tool is a web-based system that is designed to measure individual contribution to the group work. In order to fully understand its functions, the following instruction including several tasks was developed to guide evaluators to explore the system.

To use the system as an instructor:

Step 1: Log into the system

Please visit URL and log into the system using the credentials provided by the researcher.

Step 2: Performing a task.

Task 1: Create a group.

Step 1: Click **Group Wizard** button on the main menu from the left pane of the web interface.

Step 2: Insert a name for a group collection (ex. IDT2013). Click **Next** button.

Step 3: Select the number of groups (ex. 5) from the dropdown menu and click **Next** button.

Step 4: Click **Random** button to randomly assign students to a group or manually choose a group for each student. Click **Submit** button to finish the Group Creation Wizard.

Step 5: Repeat the whole process again to create another group (ex. TEST123). This group will be used in the example of deleting a group.

Task 2: Edit group information

Step 1: Click **Group List** button on the main menu from the left pane of the web interface.

Step 2: You should be able to see a list of two group collections you've just created (IDT2013 and TEST123). The list is collapsible by clicking the header.

Click **Edit** button of "IDT2013" from the list to access the edit page. The **Edit** button is positioned on the right side of each header.

Step 3: In the "Group Assign Edit" page, you can modify "Group Collection Name" and re-assign group members. The **Random** button is also available to ease the process.

Rename "Group Collection Name" as GROUP-IDT2013.

Step 4: Click **Update** button when it's done.

Task 3: Delete a group collection

Step 1: Click **Group List** button on the main menu from the left pane of the web interface.

Step 2: Click **Delete** button of "TEST123" from the list to delete the group collection. Deleting a group collection will remove the group collection name and its grouping information (member assignments).

Step 3: Click **Done** button to return to the "Group List" page.

Task 4: Create an assessment form

Step 1: Click **Create Form** button on the main menu from the left pane of the web interface.

Step 2: Insert a PA Form Name (ex. FROM-IDT2013). Click **Next** button to return to “**Form List**”.

Task 5: Edit an assessment form/Add Criteria to the form

The system is built with a default assessment form with pre-determined category-based criteria. This default form is protected and cannot be modified.

Step 1: Click **Edit** button on the right side of the PA form you’ve just created.

In the “**Form Edit**” page, you can modify the “**Form Name**”, “**Criterion Name**” and its “**Description**”. Use **Add more** button to add more criteria.

Step 2: Insert a criterion and its description

Ex)

Criterion 1: Time Management

Description: Indicators: attends meetings regularly and on time.

Step 3: Click **Submit** button to return to the form list page.

Step 4: Click **Edit** button again to add another criterion.

Step 5: Click **add more** button to add a criterion.

Ex)

Criterion 2: Communication Skills

Description: Indicators: effective in discussion, good listener, and capable presenter.

Step 6: Click **Save** button to finish.

Step 7 (optional): Click the “FORM-IDT2013” header to verify the entry.

Task 6: Delete an assessment form

Step 1: Click **Forms List** button on the main menu from the left pane of the web interface.

Step 2: Click **Delete** button to delete an assessment form.

Task 7: Create an assessment

Step 1: Click **Assess Wizard** button on the menu from the left pane of the web interface.

Step 2: Insert a name for the assessment (ex. IDT101-Group Project) and provide a brief description for this assessment. Click **Next** button.

Step 3: Choose a group collection (ex. GROUP-IDT2013) from the dropdown menu. Click **Next**.

Step 4: Choose a PA form (ex. FORM-IDT2013) from the dropdown menu. Click **Next**.

Step 5: Select an “**Opening**” and “**Closing**” date of the assessment when students are allowed to access the assessment. Pick a date in between a week range. Click **Done** to finish.

Task 8: Edit an assessment

Step 1: Click **Assessment List** button on the main menu from the left pane of the web interface.

Assessments are displayed into three different categories: **Active**, **Pending** and **Closed**. The **Active** tab shows a list of currently available assessments; the **Pending** tab shows a list of future available assessments; and the **Closed** tab shows the past due assessments.

Step 2: Click **pencil icon** to edit an assessment.

Step 3: Update the “Assessment Name”, “Group Collection”, “Assessment Form” and “Dates”.

Task 9: Delete an assessment

Step 1: Click *Assessment List* button on the main menu

Step 2: Click the *X* icon to delete an assessment.

Task 10: Score Entry Scenarios

Step 1: Go to “**Group List**” page and print/write down all three members’ id of Group 01.

You will need to log in using each member’s credentials to simulate the data entry.

Step 2: Logout the system if you’re currently logged in as an instructor.

Step 3: login the system with a student’s credentials.

Step 4 (optional): Click *My Groups* button to verify group members.

Step 5: Click *My Assessments* button to view the Assessment List

Step 6: Click the “**Assessment Name**” (Ex. IDT101-Group Project) to start the assessment.

Step 7: Assign 20 to each member (exclude yourself) for each criterion.

Step 8: Click *Submit* button when it’s done.

Step 9: Repeat Step 3 – Step 8 (login as a second member and assign 30 instead).

Step 10: Repeat Step 3 – Step 8 (login as a third member and assign 40 instead).

Step 11: logout when all data entry is done.

Task 11: Assign group score

Step 1: Log back in as an instructor using the instructor’s credentials.

Step 2: Click *Assessment List* button on the main menu from the left pane of the web interface.

Step 3: Under **Active** tab, click “**page icon**” on the right side of an assessment list.

Step 4: In “**Group Scores**” page, award a group score to the **Group 01** (ex. 80).

Step 5: Select Option 2 from the “Standardize the Final Grade” section.

Step 6: Click *Save* when it’s done.

Task 12: View Report

Step 1: Click *Assessment Progress* button to view the score submission process. Check mark indicates the assessment is completed whereas the cross mark indicates the assessment is incomplete.

Step 2: Click *Scores Report* button to view the scores by either factors or groups.

Scores by Factors: to show the final factor including each individual factor for each criterion of each student.

Scores by Groups: to mouse over each student name will reveal the visual aid how each factor is calculated as a group.

Step 3: Click Grades Report to view the overall information including **Final Factor**, **Weight**, **Option**, **Group Score** and each student’s **Final Grade**.

Appendix C: ODDPAT Login Credentials

[demo1]

Name	Username	Password
Instructor	instructor	monday
James	s01	monday
Robert	s02	monday
Michael	s03	monday
David	s04	monday
Richard	s05	monday
Charles	s06	monday
Joseph	s07	monday
Mark	s08	monday
John	s09	monday
Tom	s10	monday
Lucy	s11	monday
Mary	s12	monday
Rose	s13	monday
Paul	s14	monday
Susan	s15	monday

* * all usernames and passwords are lower cases.

[demo2]

Name	Username	Password
Instructor	instructor	january
James	s01	january
Robert	s02	january
Michael	s03	january
David	s04	january
Richard	s05	january
Charles	s06	january
Joseph	s07	january
Mark	s08	january
John	s09	january
Tom	s10	january
Lucy	s11	january
Mary	s12	january
Rose	s13	january
Paul	s14	january
Susan	s15	january

* * all usernames and passwords are lower cases.

[demo3]

Name	Username	Password
Instructor	instructor	morning
James	s01	morning
Robert	s02	morning
Michael	s03	morning
David	s04	morning
Richard	s05	morning
Charles	s06	morning
Joseph	s07	morning
Mark	s08	morning
John	s09	morning
Tom	s10	morning
Lucy	s11	morning
Mary	s12	morning
Rose	s13	morning
Paul	s14	morning
Susan	s15	morning

* * all usernames and passwords are lower cases.

Appendix D: Online Survey Consent Form and Questions

URL: https://virginiatech.qualtrics.com/SE/?SID=SV_bl5iNikUjZFJIJT

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY**Consent for Participants in Research Projects Involving Human Subjects****Design and Development of Online Database-Driven Peer Assessment Tool Using Division****Rule Theory**

I am conducting a research project entitled “Design and Development of Online Database-Driven Peer Assessment Tool Using Division Rule Theory”. The purpose of this developmental research is to build a prototype of Online Database-Driven Peer Assessment Tool (ODDPAT) using the Division Rule mechanism as its core computational algorithm to measure individual contribution to group work. In order for the system to be adapted and generalized into multiple contexts, it is necessary to evaluate user interface, system functionality and perceptions of faculty on the Division Rule mechanism integrated in the ODDPAT system.

This survey will take about 5-10 minutes to complete. Your return of this survey is implied consent. There are no direct benefits to you for participation in this study. No promise or guarantee of benefits has been made to encourage you to participate. Any information obtained in this study will remain confidential and will not be disclosed. You are free to withdraw from this study at any time without penalty. You may choose to not respond to any research questions that you choose.

Sincerely,

Hongri Lian (hlian@vt.edu)

Survey Questions

I. Interface Design

A. Orientation

Does the tool provide clear information display features that indicate the user's current location within the content?

Yes

No (Please explain) _____

B. Visibility

Is the information on the screen easy to read?

Yes

No (Please explain) _____

Is it easy to find the needed information on the screen?

Yes

No (Please explain) _____

Does every display begin with a title or header that describes screen contents?

Yes

No (Please explain) _____

C. Visual Feedback

In multi-page data entry screens, is each page labeled to show its relation to others?

Yes

No (Please explain) _____

Is there some form of system feedback for every operator action?

Yes

No (Please explain) _____

Is there visual feedback in menus or dialog boxes about which choices the cursor is on now?

Yes

No (Please explain) _____

II. System Functionality

Did all the buttons and menus function correctly?

Yes

No (Please explain) _____

Were you able to login as an instructor and student on every login attempt?

Yes

No (Please explain) _____

Were you able to create/edit/delete a group and assign members to each group?

Yes

No (Please explain) _____

Were you able to create/edit/delete an assessment form and add criteria to the form?

Yes

No (Please explain) _____

Were you able to create/edit/delete an assessment?

Yes

No (Please explain) _____

Were you able to view the assessment progress report, scores by factors, scores by group, final grade of individual student?

Yes

No (Please explain) _____

Appendix E: Demo Page

Demo Page

This demo page is provided for the review purpose only. This page compares two group assessment methods: the Division Rule Method and the Conventional Method. The Division Rule method is derived from the Division Rule Theory in Economics. The conventional method was first introduced by Goldfinch and it became one of the most popular methods used in the group assessment literature. Both of their equations and calculations are illustrated and detailed elements of group assessments are listed in a table at the bottom.

	From A	From B	From C
A's Score	<input type="text"/>	<input type="text"/>	<input type="text"/>
B's Score	<input type="text"/>	<input type="text"/>	<input type="text"/>
C's Score	<input type="text"/>	<input type="text"/>	<input type="text"/>
	100.0%	100.0%	100.0%

Submit Reset

Division Rule Method

$$C_i = \frac{1}{1 + r_{ki}^j + r_{ji}^k}$$

$$A[factor] : \frac{1}{1 + \frac{b2c}{b2a} + \frac{c2b}{c2a}} =$$

$$B[factor] : \frac{1}{1 + \frac{a2c}{a2b} + \frac{c2a}{c2b}} =$$

$$C[factor] : \frac{1}{1 + \frac{a2b}{a2c} + \frac{b2a}{b2c}} =$$

Conventional Method

$$PA\ Score = \frac{Individual\ PA\ Total}{Average\ PA\ Total}$$

$$PA\ factor = w\% + (100\% - w\%) \times PA\ Score$$

$$PAScore(A) : \frac{a2a + b2a + c2a}{100} =$$

$$PAScore(B) : \frac{a2b + b2b + c2b}{100} =$$

$$PAScore(C) : \frac{a2c + b2c + c2c}{100} =$$

Student	Final Factor	Cons. Rate	Weight	Group Score	Final Grade
A	n/a	n/a	2/3	80	n/a
B	n/a	n/a	2/3	80	n/a
C	n/a	n/a	2/3	80	n/a

Student	PA Score	PA Factor	Weight	Group Score	Final Grade
A	n/a	n/a	2/3	80	n/a
B	n/a	n/a	2/3	80	n/a
C	n/a	n/a	2/3	80	n/a

Figure 27. Demo Page For Expert Review Purpose Only.

Appendix F: Interview Questions

1. Do you have any experiences in evaluating group work? If so, can you please describe the methods or techniques you used to assess group work?
2. Have you faced with any difficulties in assessing group work? If so, can you describe them?
3. Can you please describe the strength or weakness of this Division Rule mechanism? To what extent do you think this mechanism helps overcome the challenges of assessing group project? What is your overall perception on this Division Rule mechanism?
4. What are the strength and weakness of this system? Can you please discuss changes might be made to this system that would improve its effectiveness?
5. Do you recommend this method to assess group work?

Appendix G: Interview Consent Form

Informed Consent

Title of Project: Design and Development of Online Database-Driven Peer Assessment Tool Using Division Rule Theory

Principal Investigator(s): Hongri Lian

1. Purpose of the Study: The purpose of this developmental research is to build a prototype of Online Database-Driven Peer Assessment Tool (ODDPAT) using the Division Rule mechanism as its core computational algorithm to measure individual contribution to group work. In order for the system to be adapted and generalized into multiple contexts, it is necessary to evaluate user interface, system functionality and perceptions of faculty on the Division Rule mechanism integrated in the ODDPAT system.

2. Procedures to be followed: You will be asked to answer to four questions regarding your perceptions on ODDPAT system. The interview will take about thirty minutes. The interview will be audio recorded.

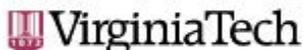
3. Discomforts and Risks: There are no more than minimal potential risks to participants.

4. Benefits: The participants receive no compensation for participation in this study, therefore the benefit is minimal to individual participants. However, data can inform possible improvement of this group assessment tool that support group assessment in various group activities.

5. Duration/Time: It will take about thirty minutes.

6. Statement of Confidentiality: Your participation in this research is confidential. The data collection methods do not ask for any information that would identify who the responses

Appendix H: IRB Approval



Office of Research Compliance
 Institutional Review Board
 North End Center, Suite 4120, Virginia Tech
 300 Turner Street NW
 Blacksburg, Virginia 24061
 540/231-4606 Fax 540/231-0969
 email irb@ut.edu
 website <http://www.irb.ut.edu>

MEMORANDUM

DATE: May 16, 2013
TO: Hongri Lian
FROM: Virginia Tech Institutional Review Board (FWA00000572, expires April 25, 2018)
PROTOCOL TITLE: Design and Development of Online Database Driven Peer Assessment Tool Using Division Rule Theory
IRB NUMBER: 13-491

Effective May 15, 2013, the Virginia Tech Institutional Review Board (IRB) Chair, David M Moore, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at:

<http://www.irb.vt.edu/pages/responsibilities.htm>

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As: **Expedited, under 45 CFR 46.110 category(ies) 6,7**
 Protocol Approval Date: **May 15, 2013**
 Protocol Expiration Date: **May 14, 2014**
 Continuing Review Due Date*: **April 30, 2014**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

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Date*	OSP Number	Sponsor	Grant Comparison Conducted?

* Date this proposal number was compared, assessed as not requiring comparison, or comparison information was revised.

If this IRB protocol is to cover any other grant proposals, please contact the IRB office (irbadmin@vt.edu) immediately.