Equal Opportunity Tactic: An Approach to Moderating the Differences in Ability Perception

Hercy N.H. Cheng, Winston M.C. Wu*, Tak-Wai Chan*
Department of Computer Science and Information Engineering,
*Graduate Institute of Network Learning Technology,
National Central University, Taiwan
Email: hercy@CL.ncu.edu.tw, winstonw@CL.ncu.edu.tw, chan@CL.ncu.edu.tw

Abstract: During schooling, individual ability differences are inevitable. Low-ability students, when always performing worse, may feel discouraged and frustrated during learning; high-ability and hence better-performance students may not find learning interesting as well when facing easy challenges all the time. This study proposes an equal opportunity tactic in order to moderate the differences in ability perception by manipulating the challenge of tasks for every student. A trail test was also conducted to preliminarily evaluate the influences on student behaviors.

Motivation

A classroom is a social environment where student performances are continually judged and compared by their teacher or, whether consciously or unconsciously, by the students themselves. Under such a learning environment, students with low ability often feel frustrated and discouraged when facing the same challenge as high-ability students who continually demonstrate superior performance. If a student cannot have success experience all the time, s/he might be discouraged and start to question her/his ability. In fact, many researchers indicated that performance is indeed associative with performance expectancy, self-efficacy, and perceived ability (Collins, 1982; Eccles & Wigfield, 2002; Pajares & Kranzler, 1995; Wigfield & Eccles, 2000). Thus, students who consistently fail to achieve may begin to consider themselves failures. Eventually their self-esteem may be impaired, especially in competitive environments (Kohn, 1992). Although those with better performance seem to benefit in classrooms—performing well and building confidence—such an environment is not absolutely harmless for them either. On the contrary, frequent success does not always satisfy students (Rohrkemper & Corno, 1988). When consistently faced with unchallenging tasks, such students eventually become bored and lose interest in learning. The accumulation of such experiences over years can diminish motivation and confidence and can be disastrous for personal identity in the classroom and even in the workplace. Therefore, central to this issue is the problem that the learning activities in class are always designed with the same criteria for judging the achievements of all students.

While people in the society are pursuing wealth and position, students are also pursuing high performance in a classroom. However, the education machine always asks students to meet the curricular requirements without taking care of their affective statuses. The phenomenon of individual difference actually reflects the imperfection of the current education system. Identical teaching process is actually one of the social inequalities and ignores students' rights to pursue joyful learning. It is our responsibility to provide a fair learning environment where every student can develop the ability and build confidence to face real and unfair situations in their future life.

Objective

Students spend almost twelve hours a day in classrooms where their perceived abilities are shaped from daily performances. This study therefore takes a classroom as a design unit and focuses on how to design a tactic for providing equal opportunity of achieving. Equal opportunity of achieving, or equal opportunity, means that all students regardless of their abilities could have success experience by turns, while occasional failure experience is also acceptable. However, this is not to say that even opportunity is a way to equalize their performances and take away the happiness. Rather, equal opportunity forms a hope that success is possible if students are willing to invest their efforts. In a classroom activity, the actual abilities of the students may be diverse. However, if all of them could have successful experience, the difference of their ability perception is likely moderated. Even if equal opportunity of success also implies that failures are possible, occasional failures can arouse attentions of those students who get consecutive success and keep them back to concentrate on the learning task rather than repeating what the teacher taught without thinking. Students require thwarted attempts to learn (Rohrkemper & Corno, 1988). Therefore, in a classroom with equal opportunity of achieving, every student should meet both successes and failures.

Equal opportunity is apparent in many games of chance such as a lottery, in which every player expects to eventually win, however slim the chances. The authors, nevertheless, do not propose adopting these games as learning activities. In a previous project, the authors designed and investigated *EduBingo* (Cheng, Deng, Chang, & Chan, 2007), a bingo-like game of chance in which students are required to match an arithmetic problem with the correct answer in a table. The winner is the first to establish a line of answers in the table; therefore, in order to win the game, students require good math skills as well as luck. In a sense, all students have an equal chance of winning if they can solve the question correctly in a reasonable time. As a result, although most students in the experiment became engaged in playing and practicing, some high-performing students began to lose interest and to exhibit mischievous activity. They reported feeling bored because winning or losing depended on luck rather than ability. The luck factor undermines their interests in learning. Although luck causes students to attribute losses to the rules of the game itself rather than to their own ability, it also reduces their motivation to excel. Therefore, for effective learning, a learning activity should recognize achievement through skill and effort rather than luck.

In a classroom with equal opportunity of achieving, students should be able to tackle challenging learning tasks that require their skills and efforts. In other words, their ability should match the challenge of the task. For this purpose, manipulating the challenge of learning tasks is needed. In sum, the objective of this study is to design *equal opportunity tactic* (EOT) to moderate differences in ability perception. For simplicity, in the remainder of this article, the authors take a competitive learning game, *AnswerMatching* (Chiang, 2006; Wu el al., 2007), as an example of how to manipulate the challenges. The game is an epitome of social environments such as classrooms. It is expected that this study would encourage researchers and designers to develop various approaches to this issue.

Equal Opportunity Tactic

Equal opportunity tactic manipulates challenges in a learning task for every student so that everyone could have equal or approximately equal opportunity of success. To define challenges, this study refers to the framework of challenge design in a previous project (Cheng et al., 2007), which has identified four types of challenges, namely, task difficulty, task complexity, resources, and opponents. In a conventional competition, a participant competes with other opponents, who provide challenges for the participant. Such challenges are dependent on the number and abilities of virtual or human opponents of participants, including collaborators, if any. Restated, opponents with higher abilities provide higher challenges. Accordingly, success usually depends on the abilities of players. Several researchers indicated that competing with other human learners brings positive effects (Julian & Perry, 1967; Malone & Lepper, 1987; Yu, 2001; Yu, Chang, Liu, & Chan, 2002; Whittemore, 1924) because of its well-structured activity with clearly defined goal for participants. However, competition also brings negative effects (Deci, Beley, Kahle, Abrams, & Porac, 1981; Kong, 1992), upset or anxiety, for example.

According to the definition, an opponent with equal ability provides equal opportunity of success. In order to manipulate challenges in a competition, one of the ways is changing opponents into the participants with equal or similar abilities. However, it is not feasible for a teacher to match students in a classroom owing to the diversity and dynamics of ability development (Cheng et al., 2007). Fortunately, computers can automatically estimate ability and assign students with similar abilities. Besides, if a low-ability student finds himself getting special helps, he may feel more discouraged. Computers can also assign anonymous opponents to every student. The generalized procedure of EOT is an iterative process consisting of three main steps: ability estimation, challenge manipulation, and performance update. The tactic therefore should be implemented for personal computers.

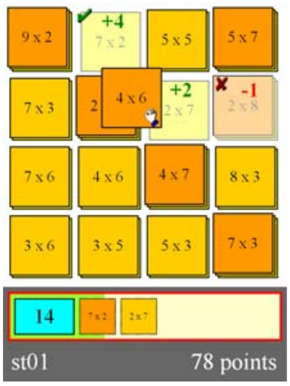

Figure 1. Game design of AnswerMatching.

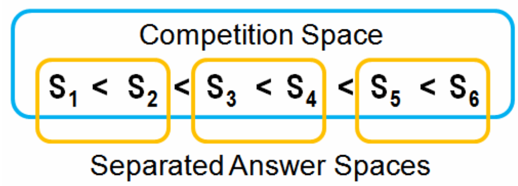

Figure 2. Challenge manipulation.

Original learning activity

In AnswerMatching, the goal of a student is to get the highest score by matching a question with one or more correct answers as soon as possible. In this study, there are ten questions, which were composite numbers, which are positive integers having at least one positive factor other than one and itself; the corresponding answers were multiplication of two numbers. For instance, if the question was 14, then the correct answers would be 2×7 and 7×2.

Figure 1 shows the interface of AnswerMatching. When a question was shown, they had to calculate it, if needed, and then find the answer cards from sixteen decks in a candidate answer space. Each deck comprised of cards having the same candidate answer, but with different scores. To simplify the example, only two students were paired to compete with each other. If a student grabbed the first card in a correct deck within a given time constraint, he received 4 points; otherwise, he received 2 points for grabbing the second correct card. However, if the student matched a question with a wrong answer card, his score was deducted by 1 point as a penalty. Because the candidate answer space was shared with an anonymous opponent, a student could see their opponent taking correct answers away without knowing the opponents. However, it was likely that a student just grabbed those cards his opponent had grabbed. To prevent such hitchhiker behavior, the system was designed to randomly take away wrong answer cards as well.

EOT design

The EOT moderates differences in ability perception by manipulating the challenges of learning tasks to meet the abilities of individual students. As mentioned earlier, the EOT consists of three steps as follows.

Step 1: Ability estimation

In the first step, the system computes everyone’s ability by an estimation formula, which produces a relative value of ability. In this game, the ability of students was determined by *procedural fluency*, which is defined as “skill in carrying out procedures flexibly, accurately, efficiently, and appropriately (National Research Council, 2001, p. 116).” In this study, the operational definition of procedural fluency is a pair of *accuracy* and *efficiency*, which can be expressed by the following formulas (1) and (2).

$$\text{Accuracy} = \frac{N_{CorrectAttempts}}{N_{AllAttempts}} \quad (1)$$

$$\text{Efficiency} = \frac{N_{CorrectAttempts}}{T_{AllAttempts}} \quad (2)$$

Given the definition of accuracy and efficiency, the ability of a student can be estimated by the expected score, as shown in formula (3). In this formula, a, e and n, which denote a student’s previous performance, are stored in the database as accuracy, efficiency, and the number of attempts, respectively; e_M denotes the average efficiency of all students. Because at the very beginning the student models are empty, the system treats all students as the same and set their data (a, e, n) as a zero triplet. After the first round, the system may have the initial data to estimate their abilities.

$$E(\text{Score}) = \left\{ a\left[4\left(\frac{e}{e + e_M} \right) + 2\left(\frac{e_M}{e + e_M} \right) \right] - (1 - a) \right\} \times n \quad (3)$$

For investigating the challenge of opponents rather than task difficulty, this study selected students whose accuracy was at least 80%. Given the nature of competition, slower students rarely scored higher than faster students. In the process of answering, they may have perceived whether their opponents always calculated faster than they did. If they scored lower in the activity over a period of time, they may hopelessly believe that they will never win in the future and thus lose their interests in the activity.

Step 2: Challenge manipulation

In the second step, the system adjusts student challenges to their estimated abilities. As mentioned earlier, an opponent with equal or similar ability provides an appropriate challenge and equal opportunity of success. Therefore, the system pairs every two students with nearest abilities in a separated answer space (see Figure 2). If the number of students is odd, the system lets the lowest-ability student answer the questions without opponents

Step 3: Performance update

In the third step, the system records the most recent student performances—accuracy, efficiency and the number of attempts—during the activities and then updates the values in the database. The purpose of this step is to approximate students’ abilities dynamically and precisely. However, in the following experiment, student performances were not updated dynamically. Instead, a pre-experiment was conducted to collect their data and assign opponents in advance. One week later, the students competed against the same one throughout the experiment. This would simplify the difficulty of analyzing the interaction data.

Preliminary Evaluation

The main purpose of the quasi-experiment was to explore the influences of EOT, in which students with similar abilities were paired for competition. It was expected that the findings could help further design of EOT for providing equal opportunity in practice.

Subjects

Before the experiment, the authors visited a three-grade class in advance and conducted three rounds of AnswerMatching by using PDAs to collect student data of basic multiplication performance. Although students were informed that they would compete with an opponent, they actually played the game separately. However, none of students noticed it because the system randomly took the wrong answers away. Finally, twelve students (six boys and six girls) with average accuracy higher than 80% were selected. Although all students were to participate in the experiment, the subsequent analysis and discussion focused only on the twelve subjects.

Method

The twelve subjects were randomly divided into EOT and comparison groups by using *block randomization* technique according to their estimated abilities. In EOT group, the subject with the 1st, 3rd, and 5th highest ability were required to compete against those with the 2nd, 4th, and 6th highest ability, respectively. Conversely, in the comparison group, the 1st, 2nd, and 3rd highest-ability subjects were assigned to compete with the 4th, 5th, and 6th highest-ability subjects, respectively. Table 1 summarizes the difference in ability for every pair.

Table 1: Subject assignment.

Group	EOT group						Comparison group					
Student	EOT1	EOT2	EOT3	EOT4	EOT5	EOT6	CMP1	CMP4	CMP2	CMP5	CMP3	CMP6
Gender	M	F	M	M	F	M	F	M	M	F	F	F
Estimated Ability	81.28	75.21	68.52	65.77	52.39	51.41	84.49	55.26	77.11	54.21	67.66	50.00
Difference	6.07		2.75		0.98		29.23		22.90		17.66	

A week later, the activity was repeated in the same classroom. After a warm-up round, all students, including the twelve subjects played six rounds (denoted by R1 to R6) of AnswerMatching within two classes (80 minutes). In each round, students were required to answer ten questions (denoted by Q1 to Q10). For each question, they were given 30 seconds to find two to four answers. Each round thus required about 5.5 minutes, and the students were given a 2-minute break between every round. Every question consisted of a composite number in the multiplication table and sixteen candidate answers. The students were required to find thirty answers in total. Thus, according to the game rules, the highest possible score was 120. Although the ten questions were the same in all rounds, the questions were presented in a different sequence, and the answer choices were also shown in a different order. Before the activity, all students were asked to review the rules and were informed that their scores would range from 60 to 120 if they could find the answers correctly. They were also told that they would be competing against an opponent. However, the identity of their opponent was not disclosed to prevent preconceptions about their opponents. During the process, two researchers led the activity, and two technical supports helped students when they encountered technical problems. Unfortunately, the PDAs used by the following four subjects temporarily crashed during the game: CMP1 from Q3 to Q6 in R1, EOT2 from Q8 to Q10 in R5, EOT3 from Q4 to Q7 in R4, and EOT6 from Q2 to Q10 in R2.

The data logs of every answer were automatically collected by the system. After every round, students were prompted to predict their scores of the following round. Higher predictions implied higher *expectancy for success* (Wigfield & Eccles, 2000) and more positive affective status. Because the students were not required to predict their scores, four predictions were not collected. Additionally, students were videotaped throughout the activity. At the end of the experiment, students were asked to complete a questionnaire about their feelings and perceptions of the game and their opponents. One week after the trial test, the authors visited the class again and interviewed all pairs of participants. After playing a round to refresh their memory, the interviewer first asked them how they felt about each other before disclosing that they actually competed with each other. This disclosure was intended to clarify their impression on each other and their opinions about such arrangement.

Results

Before the experiment, all students appeared excited to play a computer game. Once the game started, they immediately became quietly engaged in finding answers. Nevertheless, in addition to on-task behaviors, informal actions and statements provided valuable data in this research. For example, when the students successfully found all answers before the time constraint, they usually talked about how many points they had scored so far. Further, many students, including the subjects, enjoyed comparing their scores throughout the test, which demonstrated their concern about the outcome and their achievement. Their behaviors were visibly affected by the progress of their scores. Every row of Figure 3 represents the results about scores for one pair. The first chart on each rows shows the scores (darker line) and predictions (lighter line) of one subject in the pair throughout the six rounds. The third chart combines their scores for comparison. The fourth chart shows the accumulating score differences from the first question to the tenth question in every round.

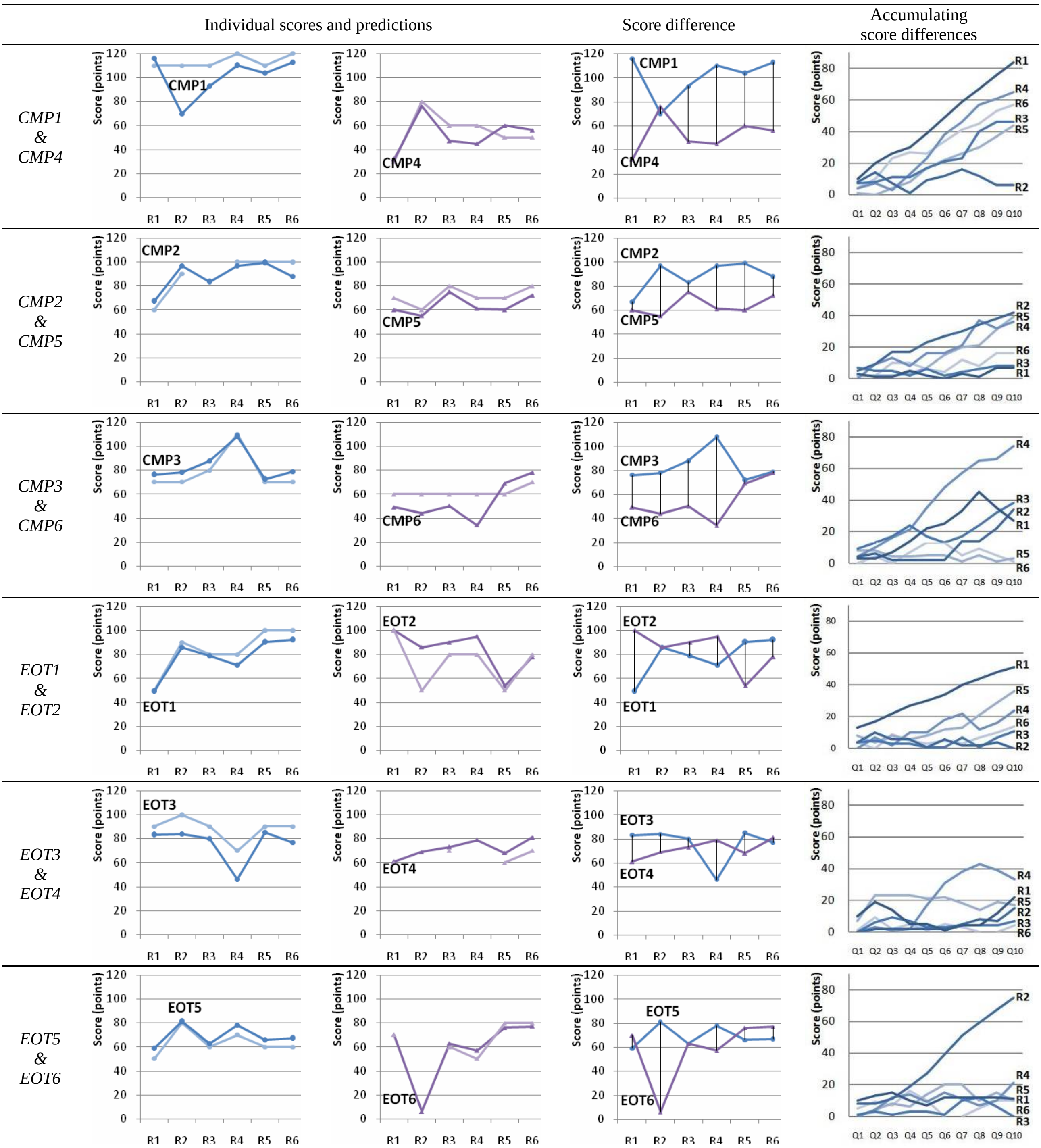

Figure 3. Results about the scores.

Accumulating Score Difference

Figure 4 further illustrates the average accumulating score differences between every pair from the first question to the tenth question. There is a steep rise for the pair CMP1-4, showing that CMP1 consistently grabbed the first answer card and scored higher than CMP4. The rises of the other two CMP pairs are relatively mild. However, although the average ability differences of all EOT pairs were smaller than those of CMP pairs, the score differences of EOT pairs were still visibly increases, which were similar to the patterns of CMP2-5 and CMP3-6. The result revealed that the current design of EOT could not effectively reduce the score difference.

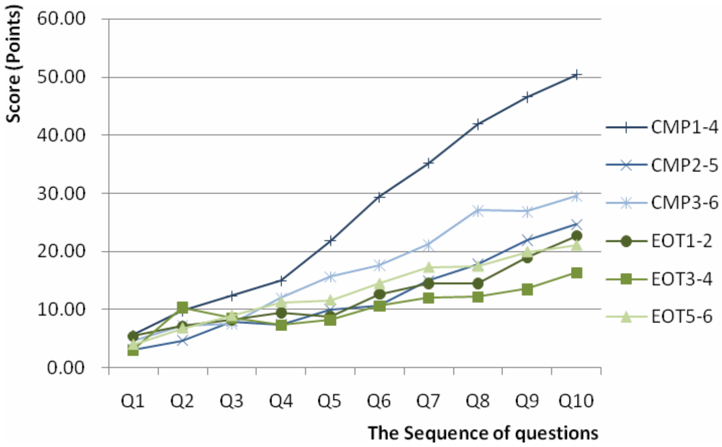

Figure 4. Average accumulating score difference.

The qualitative results of comparison group

The high-ability student CMP1 was paired to compete with medium-ability student CMP4. Because CMP1 was faster and more accurate, she usually received outstanding scores. When answering a question, she always expressed her latest scores out loud. Although her PDA had crashed in R2, resulting in a lower score, she was apparently unaffected and continued to tell others her scores. Her predictions and responses to the questionnaire showed that she was very confident and had a sense of superiority. However, her opponent, CMP4, was often upset with his scores; for instance, at the end of R1, he said "*I only [received] 32 points.*" When he had a successful experience in R2 because of the system problem, he happily stood up and told the teacher "*I [received] 76!*" In most rounds, however, his final scores were lower than 60. After his opponent was disclosed in the interview, CMP4 complained, "*No wonder I got such bad grades that time,*" and wished for other opponents; however, CMP1 was happy with the arrangement. Interestingly, CMP4 referred to his scores as "grades", which indicated his perception that the scores represented his ability.

CMP2 was also a high-ability student. When competing against a low-ability opponent, CMP2 was visibly satisfied and excited about his scores. For instance, when he scored 97 points in R2, he happily gestured the "victory" sign. He appeared to be very concerned about his scores; he was unsatisfied when he scored lower than the others, even after getting a high score in R6. Although CMP5 was a low-ability student, she was excited when she found the first cards several times in R1 and R3, the rounds with smaller score differences. However, in R4, because she consistently snatched only the second card, she murmured, "*I'm [my score is getting] lower and lower.*" Finally she appeared to lose all interest in R5 and R6. After the activity, she reported that her opponent was superior; conversely, CMP2 considered himself much better than the others.

A medium-ability student, CMP3, was also paired to compete with a low-ability student. At first, CMP3 appeared to play the game without excitement before R3. However, in R4 and subsequent rounds, she began to gesture and moved excitedly. She admitted that she could not find all answers and did not consider herself superior to the others. Another student, CMP6, was a quiet girl who seldom spoke to her classmates during the experiment. In the first four rounds she scored much lower than the others. Although she eventually improved her ability in R5 and R6 and received scores comparable to CMP3, she reported feeling very nervous during this activity.

The qualitative results of EOT group

The first pair in the EOT group was two high-ability subjects, EOT1 and EOT2. Because EOT1 exhibited lower efficiency in the beginning, he always snatched the second cards in R1. Thus, the score difference between EOT1 and EOT2 began to increase dramatically. The system failed to estimate his ability precisely, which resulted in a negative learning experience. At the end of this round, he received a disappointing score and hopelessly predicted he would never improve. However, because he made a substantial progress in terms of accuracy and efficiency in R2, his ability was comparable to that of EOT2. Thereafter, his performance began to improve, and his predictions after every round were always slightly higher than his score, which revealed his belief that he could perform better. Subject EOT2 was a girl who often compared her scores with other students, especially the highest-performing student CMP1, after she found all answers for a question. She thus felt somewhat inferior and had low expectation of her future scores despite her improved performance. Finally in R6, she was unsatisfied with her score and was observed lightly pounding her desk because she could not outperform CMP1.

The second pair included the medium-ability students EOT3 and EOT4. The scores of EOT3 were better than those of EOT4 in the first five rounds except the round in which the crash occurred (R4). However, in R6, EOT3 was finally overtaken by his opponent owing to his gradually declining accuracy. Even though he did not score higher than 90 points, his expectancies were high, ranging from 90 to 100 points. He reported that his scores were "*so-so*" because he "*had never gotten a grade more than 100 points*," suggesting that he set a high goal which he never reached during the game. Conversely, his opponent, EOT4, felt that he "*was making progress in every round.*" After knowing his opponent in the interview, he commented, "*No wonder I [mine] was grabbed all the time*." Notably, his comments differed from the complaint of CMP4, which indicated that EOT4 was unconcerned with the actual outcome; rather, he was concerned more about the process and admitted that his opponent had comparable ability.

The EOT5 and EOT6 students were a low-ability pair in EOT group. At first, EOT5 expressed a lack of confidence in memorizing the multiplication table. In R1 and R2, EOT5 sometimes knocked her desk when she could not find the answers. Luckily for her, the PDA used by her opponent crashed in R2. She then began to wave her arms in excitement after achieving a higher score at the end of the round. After R3, she was able to find more answers and began to tell others about her scores and to compare her scores with those of her neighbor (CMP2, the high-performance student). She attributed her improvement in later rounds to her improved accuracy even though her ability and scores had not actually increased. Her opponent EOT6 always compared his scores with his neighbor (CMP1, the high-performing student). For example, after he answered Q1 in R4 and watched her screen, CMP1 was bragged about her improved score. At the beginning of R6, when he realized he had scored as high as CMP1, he was visibly happy. However, when Q10 started, he slapped his desk and said "*[I am] beaten by you.*" After the trial test, he reported feeling nervous about making mistakes and being too slow to grab the cards. However, he had clearly felt a sense of achievement after improving from 50 to 77 points.

Discussion

Although the subjects were unaware of the identity of their opponents, apparently mixing the EOT group with the comparison group in the same classroom could greatly influence the emotion of the EOT group. For example, the two highest-performing students, CMP1 and CMP2, tended to excitedly share their final scores and progress with the others. The subjects CMP1 and CMP2 may have set a high standard of achievement for the other students to emulate. In addition to the three subjects with lower ability in CMP group, EOT2, EOT5, and EOT6 were also frustrated and lost hope of catching up. Despite the fact that the students with bad performance were playing a game rather than testing, their perceived abilities seemed lower and lower. When researchers attempt to conduct a rigorous experiment in the future, the situations should be avoided. Even so, there are still several implications for designing EOT.

Although there was no evidence that the perceived ability in game would influence the perceived ability in learning, the trial test is still a good case to investigate how EOT influenced students. For example, the average score difference between every EOT pair was less than that between every CMP pair, which likely provides more opportunities of success. Conversely, the high-ability subjects in the comparison group still received substantially higher scores than their opponents. Even a small success can provide a sense of achievement and positive experience. If well-designed, EOT could provide every student with a sense of achievements satisfaction.

Most subjects in EOT group reported that they could perceive whether their scores were improving, even if their scores varied up and down. For example, EOT1, EOT4, and EOT6 believed they were making progresses, but EOT2 felt his performance was worsening. A possible reason is that the system did not dynamically estimate and update the abilities of the students after every round. The experiment has showed that the abilities were always different and dynamic in a classroom. Accurately estimating ability was the key to improvement in the EOT model. A future study may design and investigate a dynamic EOT model. Additionally, the sense of superiority in the high-ability students may have resulted from the eventual lack of challenge, which suggests that they also required a mate better than them. In retrospect, this problem could have been remedied by adding comparable virtual opponents to the system.

Conclusion

The objective of this study is to design equal opportunity tactic to moderate the difference of perceived abilities by manipulating the challenges of learning tasks. In this study, EOT is implemented by assigning comparable opponents. In fact, EOT can be designed in the other ways. First, assigning every student a different set of appropriate questions can provide equal opportunity. Accordingly, high-accuracy students can solve new, harder and more complex problems while low-accuracy students can continue practicing familiar questions at the same time. Such manipulation technique is often used in individual learning and self-paced learning. However, in a social environment such as classrooms, students may become aware that they are being tested differently. Those students who receive harder questions could feel the activity is not fair at all. Second, the time constraint for solving the same task can be reduced when the efficiency of an individual student increases. High-efficiency students can be given less time to solve the same tasks than low-efficiency students. Different time constraint on solving the same task can provides equal opportunity as well. Such technique is seldom used to increase challenges in learning, but often adopted in digital games, for example, the Tetris game.

Although this study cannot prove that the classroom could be changed by EOT, the issue around its designing could be of interest to the research community. The aforementioned learning activity, AnswerMatching, is a revealing model of a highly competitive social environment. By manipulating the challenges, EOT creates a learning environment where they face appropriate challenges and acquire equal opportunity of achieving. In a sense, EOT attempts to separate actual ability from performance, which is usually mixed with ability in tests and homework. On one hand, students perceive their abilities only by the performances they earned. The performances form learning experiences away from anxiety and boredom, eventually shaping perceived ability. On the other hand, the teachers should be able to inspect their actual abilities from their portfolios—not only procedural abilities but also their knowledge or affective statuses.

Finally, when EOT is applied to a classroom activity, it is expected that all students can be engaged in accomplishing their learning goals with a belief that everyone is the best. Further, they can have real success experience building their confidence and pushing them to invest more efforts next time. More importantly, they will not be frustrated by occasional failures; rather, they are more confident of facing their faults and future challenges.

References

Cheng, H. N. H., Deng, Y. C., Chang, S. B., & Chan, T. W. (2007). EduBingo: design of multi-level challenges of a digital classroom game. In T. W. Chan, A. Paiva, and D. W. Shaffer (Eds.), *The First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning* (pp. 11-18). Los Alamitos, CA: IEEE Computer Society.

Chiang, M. C. (2006). *AnswerMatching: A Small Group Competitive Digital Game for Practicing Arithmetic with Asymmetrical Competition Strategy*. Master Thesis, National Central University, Jhongli, Taiwan.

Collins, J. (1982). Self-efficacy and belief in achievement behavior. *American Educational Research Association.* New York.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*, 109-32.

Deci, E. L., Beley, G., Kahle, J., Abrams, L. & Porac, J. (1981). When trying to win: Competition and intrinsic motivation. *Personality and Social Psychology Bulletin*, *7*, 79-83.

Julian, J., & Perry, F. (1967). Cooperation contrasted with intra-group and inter-group competition. *Sociometry*, *30*, pp. 79-90.

Kohn, A. (1992). No contest: the case against competition. NY: Houghton Mifflin.

Malone, T. W., & Lepper, M. R. (1987). Making learning fun: A taxonomy of intrinsic motivations for learning. In R. E. Snow, and M. J. Farr (Eds.), *Aptitude, Learning, and Instruction, III: Conative and Affective Process Analysis* (pp. 223-253). Hillsdale, NJ: Lawrence Erlbaum Associates.

National Research Council. (2001). *Adding It Up: Helping Children LearnMathematics*. Washington, D.C.: National Academy Press.

Pajares, F., & Kranzler, J. (1995). Self-efficacy beliefs and general mental ability in mathematical problem-solving. *Contemporary Educational Psychology*, *26*, 426-443.

Rohrkemper, M., & Corno, L. (1988). Success and Failure on Classroom Tasks: Adaptive Learning and Classroom Teaching. *The Elementary School Journal*, *88*(3), 269-312.

Whittemore, I. C. (1924). The influence of competition on performance: an experimental study. *Journal of Abnormal and social Psychology*, *19*, 236-253.

Wigfield, A., & Eccles, J. S. (2000). Expectancy-Value Theory of Achievement Motivation. *Contemporary Educational Psychology*, *25*, 68-81.

Wu, W. M. C., Cheng, H. N. H., Chiang, M. C., Deng, Y. C., Chou, C. Y., Tsai, C. C., & Chan, T. W. (2007). AnswerMatching: A Competitive Learning Game with Uneven Chance Tactic. In T. W. Chan, A. Paiva, and D. W. Shaffer (Eds.), *The First IEEE International Workshop on Digital Game and Intelligent Toy Enhanced Learning* (pp.89-96). Los Alamitos, CA: IEEE Computer Society.

Yu, F. Y. (2001). Reflections upon cooperation-competition instructional strategy: Theoretical foundations and empirical evidence. *The National Chi Nan University Journal*, *5*(1), 181-196.

Yu, F. Y., Chang, L. J., Liu, Y. H., & Chan, T. W. (2002). Learning preferences towards computerised competitive modes. Journal of Computer Assisted Learning, *18*(3), 341-350.

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