Empowering Learners to Choose the Difficulty Level of Problems Based on Their Learning Needs

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ABSTRACT

Research has found that increasing learner control offers several benefits, including increased motivation, attitude, and learning. The goal of the present study was to determine how prior math achievement influences students' selection of the difficulty level of problems within *Math Pursuits*, a hypermedia learning program. *Math Pursuits* was designed to help children understand mathematics by discovering how it relates to the world around them. The program presented each learner with an adjustable level of challenge, along with the necessary scaffolding to support success. The researchers hypothesized that students with lower math skills would choose to start with a lower difficultly level; whereas, students with higher math skills would begin the program by choosing a question with a higher level of difficulty. Results supported these hypotheses. This research also examined the motivational framework guiding students' selection of problem difficulty.

Keywords: Hypermedia, learner-controlled instruction, mathematics education, problem solving.

1. INTRODUCTION

"Complex learning should not only aim at developing complex skills, but also at promoting self-regulated learners who are able to effectively select their own learning tasks" [1, p. 400-401]. In order to promote this type of learning, researchers have been examining the effects of adding learner control options to hypermedia programs, in lieu of the more traditional system-controlled approach. Research has found that increasing learner control offers several benefits for learning. For example, Cordova and Lepper found that adding control elements to a learning game increased students' motivation and, in turn, improved their learning [2]. More recently, Kopcha and Sullivan suggested that providing increased learner control may lead to increases in motivation, achievement, performance, and attitudes for learners with high prior knowledge [3]. By personalizing the nature and sequence of navigation for individual learners, there may also be a reduction in cognitive load. This reduction may promote greater learning [1].

On the other hand, learner-controlled instruction may be more suitable for some types of learners than others. For example, Shin, Schallert, and Savenye suggest that students with higher prior knowledge are better suited to make learner-controlled choices [4]. Kopcha and Sullivan echo this finding, citing that children with higher degrees of knowledge have a deeper understanding of their particular learning preferences [3]. Students with lower levels of prior knowledge may need more guided instruction, allowing them to move quickly and more easily through the program. Kopcha and Sullivan recommend "designing learner-controlled environments so that more control is provided to learners as the learners' level of knowledge increases" [3, p. 283]. This recommendation is supported by the research findings of Merrill [5] and Corbalan et al. [1].

Much of the research on learner control has focused on the learners' path through the instructional content; however, there has been comparatively little research on learners' selection of the difficulty level of the problems that they choose to solve within a hypermedia program. The goal of the present study was to determine how prior math achievement influences the learners' own selection of the difficulty level of problems within a hypermedia program.

Additionally, this study sought to understand the motivational goal framework of students with specific navigational patterns within *Math Pursuits*. Much research has been conducted on the motivational frameworks that guide students' choices in learning [6, 7, 8, 9]. Two primary frameworks have received much attention by researchers: the mastery-goal orientation and the performance-goal orientation. Ames suggests that "a mastery goal elicits a motivational pattern that is associated with a quality of involvement likely to maintain achievement behavior, whereas a performance goal fosters a failure-avoiding pattern of motivation" [6, p. 262].

Morrone and Pintrich expand this thinking by suggesting that within each orientation, students may adopt an approach or avoidance tendency and that such differences yield very distinct strategies in learning [8]. Students who operate under a mastery approach framework focus their efforts on learning and meeting self-selected standards of success. Those who follow a mastery avoidance tendency apply their strategies to avoid "misunderstanding or not mastering the task" [8, p. 433]. A framework utilizing the performance approach is evident in students whose "primary focus is on performing better than others"; whereas, the performance avoidance tendency yields a framework geared toward avoiding poor performance [8, p. 433]. Morrone and Pintrich speculate that each tendency results in different strategy use in learning tasks. "Specifically, students with performance approach goals may employ very effective strategies to help them achieve their goals, and these strategies may lead them to become more involved in a given task than students with performance avoidance goals" [8, p. 433]. This motivational goal framework was used as a lens to qualitatively analyze the navigational patterns of students' self-selected, problem-difficulty levels.

2. CONCEPTUAL FRAMEWORK AND LEARNING ENVIRONMENT

In order to examine students' selection of problem difficulty and how their motivational goals influence these choices, a hypermedia program, *Math Pursuits,* was developed specifically for this research. The goal of the *Math Pursuits* program is to help children understand mathematics by discovering how it connects to the world around them. Through an adjustable level of challenge, along with the necessary scaffolding, *Math Pursuits* is designed to provide help to students who need additional support and challenge those who master the concepts quickly. Through an iterative research cycle, including focus groups with students, researchers have learned that students desire increased control over their learning experience. As a result, the *Math Pursuits* program has evolved into a learner-controlled, individualized instructional environment, providing the learners with direct control over how they progress through their learning experience. By providing the learners control over their instructional experience, this unique environment allows the learners to make decisions about how to best meet their own specific learning needs, thus, creating an optimal level of challenge.

An optimal challenge occurs when the level of challenge and the level of the students' skills are in balance. As a result, students become fully focused and invested in the task, thereby creating a state of flow [10]. According to Csikszentmihalyi, the necessary elements to create flow are clear goals and rule performance, immediate feedback, need for concentration, and a feeling of control [10].

The tools necessary to produce the optimal challenge for each individual learner are incorporated into *Math Pursuits*. For example, the video-based problems within *Math Pursuits* challenge students with a goal of solving a mathematical problem. These video-based problems also present students with meaningful problems that are engaging and encourage student concentration. See Figure 1 for a screen shot of a problem within the *Math Pursuits* program.

Figure 1. Video-Based Problem

Scaffolding features embedded into *Math Pursuits* are designed to provide immediate feedback to learners as they progress through the program. For example, "hints" provided by the system help guide the learner toward successfully solving each problem. In addition, a collection of help tools are available for the learner to use, including a read-aloud option for those who struggle with reading and tutorials aimed at refreshing learners' knowledge of the specific mathematical concepts presented.

In order to give students a sense of control, they are provided with a set of missions or problem-solving areas from which they can choose. In addition to selecting a specific mission, students are also able to choose the difficulty level of the problem that they want to solve. For each mission, there are a series of problems rated easy, medium, or hard. See Figure 2 for the key provided to the students on the problem-difficulty levels.

Figure 2. Key of Problem Difficulty

The difficulty levels of the questions were determined from the average of the ratings by two experts in the field: a math teacher and a math intervention specialist. Discrepancies were resolved by a third rater, a math education scholar.

Each problem, when successfully answered, awards the students with a varying number of points. More difficult problems are worth more points in the program. Thus, a student could answer more easy and medium questions to complete a mission or solve just a couple of challenging questions. The students are empowered to make decisions regarding which problem to select based on ongoing system feedback on the accuracy of their solutions.

The researchers hypothesized that students with strong mathematical skills and prior knowledge would choose more challenging questions; whereas, students with less solid mathematical skills would begin their session with easier problems.

3. METHODOLOGY

Participants and Setting

Participants were 40 high school students (grades 10 and 11) from a large urban city in the Midwest. These students were selected because they were participating in a summer institute designed to encourage them to become math teachers. The students used this program as a review of concepts learned in earlier grades in preparation for how they might teach this material to their students.

The student population was predominately female (75%). Approximately 43% of the students did not complete the demographic portion of the survey. Of the remaining students, the ethic breakdown was 41% Black, 32% White, 4% Hispanic, 14% Asian, and 9% Multiracial. The age range was 15 – 17 years old.

Data Sources

There were two data sources: a math achievement test and computer log files of students' navigational paths.

Math Achievement: Students took a pretest to measure their math achievement prior to the *Math Pursuits* intervention. The test included 24 multiple-choice questions: 8 computation and the 16 word problems. These questions were based on standardized test questions, but specific to the content that was tested by the software. Several experts validated this test. The reliability for this test was 0.78.

Based on these test scores, students were grouped into three achievement levels: low, medium, and high, representing the lowest 30th, middle 60th and highest 30th percentile of scores, respectively. A lenient cut-off criterion, based on Geary, Hoard, Byrd-Craven, and Nugent's cut-off levels for determining mathematical disability in children [11], was chosen because the *Math Pursuits* program was designed for students with a wide range of abilities.

Computer Log File: Computer log files recorded students' progress as they worked in the program. These log files recorded the choice of problem difficulty and the navigational pattern that students used within the program. In addition, these log files provided the researchers with data on the number of attempts each participant required to correctly answer each question.

Procedure

The present study served as a pilot for the *Math Pursuits* program. One week prior to working with the *Math Pursuits* program, students completed the math pretest. Then, the students used the *Math Pursuits* program over a 3-day period. Each day, the students were given instruction for 10 minutes on a specific problem-solving area: multiplication, division, and multistep operations, and 35 minutes to work in the program. On the first day of the intervention, the students received little instruction on how to navigate through the software in order for the researchers to assess how user friendly the directions were in the program. The researchers also wanted to determine if the students could pick up on the concept of individualized instruction within a learner-control framework from the directions within the software program. On the second day, the researchers debriefed the students and gave explicit directions about how the students could make educated choices about the level of difficulty of the problems that they could choose.

This study focused on the problem-difficulty selection and the navigational paths from days two and three of the study, as these days reflected the students' full knowledge and application of how to utilize the learner-controlled features of the program.

4. RESULTS

Quantitative Analyses

Division Mission: Within the division mission, 75% of students identified as having low prior knowledge chose to begin with an easy question; the remaining 25% of students began with a medium question. Of those who began at the easy level, 100% chose to increase their challenge to medium for their second question. Regarding students identified as having high prior knowledge, 36% began at the easy level; whereas, 64% chose to begin the division mission with either a medium or hard question, 28% and 36% respectively. Of those who began at the hard level, 50% chose to maintain that level for their second question, while 50% reduced their challenge to medium. Of those that began at the medium level, 67% chose to increase to a hard level, and the remaining stayed at a medium level.

When looking at the students' use of system-provided feedback on the accuracy of their answers, the majority of these students were able to use the feedback to make decisions about what problems to choose. Within the division mission, 63% of students with low prior knowledge and 73% of students with high prior knowledge used system feedback to choose their next problem to solve.

Multistep Mission: When working within the multistep mission, 55% of the students identified as having low prior knowledge began with an easy question, 18% began with a medium question, and 27% began at the hard level. All of the students who began at the easy level choose to proceed to the medium level for their second question. For students with high prior knowledge, 25% chose to begin with a question rated easy, and the rest of the students were split evenly between choosing medium and hard questions. Of the students who began the mission at the hard level, 75% chose to follow with another hard question; whereas, 25% dropped to a medium-rated question.

With regards to the use of system feedback within the multistep mission, the majority of students in both high and low prior knowledge groups were able to utilize feedback when making choices regarding problem difficulty. Within the multistep mission, 55% of students with low prior knowledge and 81% of students with high prior knowledge used system feedback to choose an appropriate level of difficulty for their second question.

Qualitative Analyses

A qualitative analysis of the data from the division and multistep operations missions revealed two types of navigational patterns that students chose as they worked in the *Math Pursuits* program. The primary patterns that emerged appear to be related to students operating under two different, well-substantiated goal orientation frameworks: mastery-goal orientation and performance-goal orientation [6, 7, 8, 9].

Performance-Goal Orientation: Students guided by a performance-goal framework yielded navigational patterns that were indicative of an attempt to avoid failure or obtain a self-determined acceptable grade. By earning points on easier questions, students were quickly able to complete the mission, rather than attempting to challenge themselves with more difficult questions, even with the possibility of earning more points. Students, who successfully answered challenging questions, then subsequently chose easier questions, might be doing so in order to maintain a "grade." The approach and avoidance tendencies [8] were exemplified here by students whose goals reflected a desire to outperform others or to avoid failure, respectively.

An example of the performance-goal framework might be that of the work of Student A. He was a student with high prior knowledge who answered all six questions in the division mission, however, only six of the nine questions in the multistep mission. This student navigated the missions with no discernable pattern, beginning the division mission with an easy question, following with a medium, then a hard question. He returned to medium for his fourth and fifth questions and finished with a hard question. In the division mission, Student A required only one attempt to obtain the correct answer on five of the six questions. Working through the multistep mission, he began with two hard questions, answering them easily, then followed with two medium questions. He completed his mission with an additional hard question, which required two attempts to correctly answer and a then medium question. This pattern might be reflective of a motivation to only earn the points necessary to complete the mission. The randomness of the navigational pattern might suggest that Student A was not invested in learning, per se, but rather in maintaining grade consistency, avoiding failure, and earning points quickly.

Student B, a student with low prior knowledge, was representative of the avoidance, performance-goal orientation. She followed the pattern: easy, medium, hard for both missions. Within the division mission, she answered only five of the six questions, requiring three attempts on three questions to obtain the correct answer. Within the multistep mission, Student B answered all the questions, again requiring between one and three attempts to successfully answer each question. This pattern might be indicative of a student who did not want to take chances in her performance and preferred to slowly increase her level of difficulty until she was confident in her ability to succeed.

Mastery-Goal Orientation: Several students' patterns in problem-difficulty selection were indicative of a mastery-orientation framework. These students appeared to have a desire to earn points, not at a fast pace, but rather based on hard work and mastery of the content. The approach or avoidance tendencies described by Morrone and Pintrich [8] were evidenced by students' intrinsic desire to learn or a desire to avoid misunderstanding of the material.

Such a navigational pattern was illustrated in the performance of Student C, a student with low prior knowledge, who navigated the division mission with an easy, medium, hard pattern, answering five of the six questions. Within the multistep mission, Student C started with a hard question, followed by an easy, then six medium questions, and completed the mission with two hard questions, answering all nine questions. This navigational pattern might be indicative of this students' desire to challenge himself with further content, while avoiding the misunderstanding that may occur with high-level questions and earning more points than required to complete each mission.

The navigational pattern of Student D, a student with high prior knowledge, appeared to utilize the mastery-goal framework as well. She answered all questions in both missions, continuing to work beyond the number of points required to complete each mission. Within the multistep mission, this student followed the navigational pattern: hard, medium, easy in question choice. This student appeared to enjoy learning for her own sake not primarily focusing on earning points and obtaining a self-determined appropriate grade. This pattern might be related to the mastery-goal orientation approach.

5. DISCUSSION

Initial quantitative and qualitative analyses of this data suggested that students with high prior knowledge might initially choose more challenging levels of difficulty and maintain a more challenging level throughout their learning experience. This is in opposition to students with lower prior math knowledge, who tended to begin with a lower level of challenge and then increase their challenge level based on system feedback.

In designing *Math Pursuits*, the researchers made efforts to provide the necessary scaffolding, in the form of help functions, system feedback, and "hints" for success within the program. These features were designed to assist those students in need of guidance, as well as those who are able to perform well without assistance [12]. With this scaffolding, the majority of learners, regardless of prior knowledge, were able to make good choices in selecting the difficulty level of problems within the *Math Pursuits* hypermedia program. This finding supported the recommendation of Kopcha and Sullivan that learner-controlled systems should provide all students, especially those with low prior knowledge, the necessary scaffolding and adequate instruction to achieve success [3].

Although the majority of students were able to use system feedback to make informed choices regarding the level of difficulty of the next problem to choose within the program, there were still some students who ignored this system feedback. For the more challenging topic of multistep operations, this tended to be more of an issue for students with lower prior knowledge. This was in line with previous findings from an earlier iteration of studying the *Math Pursuits* software where students were asked to rate the difficulty level of the problems they were attempting to solve. There was no correlation found between how a student rated the difficulty level of a problem and the number of attempts it took him / her to get the problem correct. This suggested that some students might not be able to correctly identify the difficulty level of a problem they were working to solve. This inability to use feedback on the accuracy of their solution as a method to judge the difficulty level of a problem might provide some indicator as to why some students appeared to jump prematurely to a more difficult problem when they had not mastered the skills at the easier level. Students who were unable to distinguish between difficulty levels might not see a purpose in staying at an easier level before moving on to a more difficult level. Thus, some students do not seem to grasp the need for mastery of basic skills before scaffolding into more difficult skills.

One possible solution to helping students pay more attention to the system feedback might be to provide suggestions to the students about the difficulty level of the problem that they should select next. For example, the system could offer the following suggestion if a student incorrectly answered a question: "It appears you may be having difficulty, you might want to consider choosing an easier-rated question for your next problem to solve." Such a model of instruction would continue to provide the learner with control over their instructional experience, while simultaneously assisting them in decision-making that may enhance their learning. Future research should examine if providing learners with information about potential navigational paths affects the learners' choice of problem difficulty.

Limitations

This study had a few limitations. One limitation was that the study was conducted with a limited number of total students. This limited the statistical analyses that could be conducted to isolate the differences between the scores of students with high and low prior knowledge. The number of students was also limited by number of student absences. This may have been the result of the timing of the study, which was conducted over the summer when absences tend to be higher due to vacations and other commitments. On the day of the division mission, 5 students were absent, and on the day of the multistep mission, 1 student was absent. The study was also conducted with a convenience sample of high school students. Therefore, generalizations to other students at other age levels and in other areas of the country are limited.

There were other limitations as a result of the inherent nature of design-based research where the software is an iterative prototype of the final product. For example, one limitation was a technical issue with the computer log files. On the day that the students completed the division mission, there were 7 students who were missing pretest scores and were eliminated from the analysis. For the multistep mission, there were 2 students missing pretest scores. Another limitation with using a software prototype was that the students discovered software bugs and issues while using the software. These issues may have affected students' confidence, which in turn could affect their ability to make decisions, while using the software.

Future Research

Given the limitations of this study, future research should be conducted with larger samples at other schools to enable the researchers to assess statistical differences between students with high and low prior knowledge and to determine whether these findings are generalizable to other populations of students. It would be particularly interesting to see if these research results could be replicated with younger students, who might not be as capable to make these types of informed decisions.

While the data presented in this paper support this study's hypotheses, they, in turn, raise questions about students' motivation for choosing particular problems within the hypermedia program. Gaining a better understanding of students' choices will help the researchers design functionality in the software to help students make informed decisions to challenge themselves at the appropriate level. Future research should examine the motivational framework and goals that guide learners in their self-selection of problem difficulty. This may be best accomplished via interviews with participants aimed at gaining a better understanding of the overall goal framework that drives students' motivation.

6. REFERENCES

[1] G. Corbalan, L. Kester, and J.J.G. van Merrienboer, "Towards a Personalized Task Selection Model with Shared Instructional Control", **Instructional Science,** Vol. 34, No. 5, 2006, pp. 399-422.

[2] D. I. Cordova and M.R. Lepper, "Intrinsic Motivation and the Process of Learning: Beneficial Effects of Contextualization, Personalization, and Choice", **Journal of Educational Psychology,** Vol. 88, No. 4, 1996, pp. 715-730.

[3] T.J. Kopcha and H. Sullivan, "Learner Preferences and Prior Knowledge in Learner-Controlled Computer-Based Instruction", **Educational Technology Research and Development,** Vol. 56, No. 3, 2008, pp. 265-286.

[4] E.C. Shin, D.L. Schallert, W.C. Savenye, "Effects of learner control, advisement, and prior knowledge on young students' learning in a hypertext environment", **Educational Technology Research and Development,** Vol. 42, No. 1, 1994, pp. 33-46.

[5] M.D. Merrill, "Instructional Strategies and Learning Styles: Which Takes Precedence?", In R.A. Reiser and J.V. Dempsey (Eds.), **Trends and Issues in Instructional Technology**, Upper Saddle, NJ: Merrill Prentice Hall, 2002.

[6] C. Ames, "Classrooms: Goals, Structures, and Student Motivation", **Journal of Educational Psychology,** Vol. 84, No. 3, 1992, pp. 261-271.

[7] C. Ames and R. Ames, "Systems of Student and Teacher Motivation: Toward a Qualitative Definition", **Journal of Educational Psychology,** Vol. 76, No. 4, 1984, pp. 535-556.

[8] A. Morrone and P. Pintrich, "Achievement Motivation", In G.C. Bear and K.M. Minke (Eds.) **Children's Needs III: Development, Prevention, and Intervention,** Bethesda, MD: NASP Publications, 2006.

[9] C.S. Dweck, "Motivational Processes Affecting Learning", **American Psychologist,** Vol. 41, No. 10, 1986, pp. 1040-1048.

[10] M. Csikszentmihalyi, **Finding Flow: The Psychology of Engagement with Everyday Life,** New York: Basic Books, 1997.

[11] D.C. Geary, M.K. Hoard, J. Byrd-Craven, L. Nugent, C. Numtee, "Cognitive Mechanisms Underlying Achievement Deficits in Children with Mathematical Learning

Disability", **Child Development,** Vol. 78, No. 4, 2007, pp. 1343-1359.
[12] P. Federico, "Hypermedia Environments and Adaptive Instruction", **Computers in Human Behavior,** Vol. 15, No. 6, 1999, pp. 653-692.

7. AUTHORS' NOTE

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