A SIMULATION, PERSISTENCE, ENGAGEMENT AND FEEDBACK IMPACT PERFORMANCE IN A COMPUTER NETWORKING COURSE

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ABSTRACT

Information and Communication Technology tools are being rapidly adopted in the online learning environment for their learning effectiveness based upon theories of higher-order skill learning styles, problem-based learning, engagement, frequent feedback and persistence (element in motivation). In this study, 133 students used the tools of an online computer simulation, online discussion forum, and frequent quizzing in a networking computer science course. Students who persisted (at least 10 hours spent in the lab) and successfully developed higher order skills in the simulation (lab scores), fully engaged in the online discussion forum (discussion grades) and received frequent positive feedback (mean quizzes score) were examined for their results on the performance measures in the course (midterm exam, final exam, final grade). Significant results were found in the t-test, correlation and regression analysis between persistence (time spent in lab) and skill achievement in the computer lab simulation (lab scores). In addition, simulation skill achievement, discussion board engagement, and frequent feedback through quizzing impacted certain specific exams and overall performance, in general.

INTRODUCTION

The introduction of Information and Communications Technology and the increase in online education has brought about the usage of new teaching/learning tools, such as computer lab simulations and the online discussion forum, which Biriyai and Thomas (2014,111) characterize as "significant and very important components in distant interaction." In addition, instructors seek to find the most effective combination of learning activities and practices to help students persist and take control of their own learning. Professors are primarily curriculum designers and users of learning tools and activities to promote improved skills and learning for students (Mazzolini & Maddison, 2007). In the practical fields of applied and technology sciences, including computer science, computer information systems and management information science, faculty believe students need higher-order thinking skills, persistence in reaching their goals, the ability to communicate/engage with others and self-regulation of their own learning behaviors, for academic and professional success.

So how do we know that students are sufficiently developing these critical thinking and communication skills, using persistent learning behaviors, improving their self-efficacy and truly engaged in learning? In addition, what impact do these behaviors have on their performance? In addition, which online tools have been effective for higher-order learning, communications and engaging students? In the online environment, faculty often design their courses to assess various levels of skills and behaviors. This research is interested in the intersection of three Information and Communication Technology tools specifically: the computer lab simulation; the online discussion forum, and frequent online quizzing, and their impact on students' performance and higher-order skill development in an online computer networking course.

LITERATURE REVIEW

In the literature review, first is a review of different learning styles to find the best style for higher-order skill attainment. Problem Based Learning, Engagement Theory, Frequent Feedback and the concept of Persistence from Motivation Theory are then summarized with respect to online Information and Communication Technology tools used in business and the applied sciences, particularly computer science. Lastly, the research on the effectiveness of three particular tools – the computer lab simulation, online discussion forum, and frequent online quizzes - is analyzed for clues to the best combination of learning activities to develop skills and enhance student performance.

Learning Styles and Higher Order Skills Research

Rajendran & Ramachandran Veilumuthu (2010) emphasized the importance of learning styles to increase higher-order skill development in computer science and engineering courses. Learning induces a persistent, measurable, and specified behavioral change in the learner to formulate a new mental construct or revise a prior thought construct. Learning styles can be classified into four methods: 1) auditory learning – learning by hearing; 2) visual learning – learning by seeing; 3) reading/writing – learning by processing contents; and 4) kinesthetic learning or practical – learning by experimenting. The fourth learning style, kinesthetic learning or 'learning by doing', helps students to develop "logical reasoning" skills and is most aligned with tools like games, simulations, and projects.

Complex experiments, such as setting up a small business network, are difficult to do on campus in a traditional lab due to the cost and impossibility to set up the full infrastructure in a classroom or learning center on campus. In Rajendran et al.'s (2010) research, a majority of students (92%) felt that doing experiments virtually in their networking course decreased their worry about any damages they might cause, fears of wrongly connecting the equipment and offered them added convenience of experimenting without lab time and place restrictions. While nearly 90 percent of the students recommended using computer-based virtual labs with handbook instructions over textbooks, perception of faculty support varied - nearly 62 percent of them felt they needed full time guidance from a faculty member; 22 percent of them felt they didn't need any, while16 percent felt they required help on certain topics. All the students showed enthusiasm in using the virtual labs describing them as "learning through fun" (Rajendran et al., 2010, 2175).

Higher-order thinking, often called critical thinking, is a function of the interaction between cognitive strategies, meta-cognition, and nonstrategic knowledge when solving problems (O'Neill & Murphy, 2010). It is based on the concepts in the cognitive domain of Bloom et al.'s Taxonomy (1965) where some learning requires more cognitive processing than others. Higher order skills, including analysis, evaluation and application, often need different instructional practices and involve complex judgmental skills like problem solving and thinking critically (Bloom et al., 1965). Higher-order thinking is thought to be more useful and necessary for survival in the 21st century because such skills (analysis, application and synthesis) are considered more likely to be transferable to situations outside those in which the skill was initially learned (Lim & Tay, 2003; Paul, 1990).

In their computer science major, Fagin, Harper, Baird, Hadfield and Sward (2006) outline 3 examples of online tools which effectively enhanced students analytical, application and evaluation skills. For example, in the networking course, students compared Java and .NET frameworks using the Online Discussion Forum; in their first programming course, students implemented different scenarios in a simulation, analyzed the results and drew conclusions applying what they found; in the software engineering course, students critiqued open source versus proprietary software while recommending their preferences, thus enhancing their evaluation skills (also in the online discussion forum).

Persistence in Motivation Theory

Motivation is a behavioral process of forces acting on or within a person that cause the arousal, direction, and persistence of goal-directed, voluntary effort (Nevid, 2013). The components of motivation that ensure that goals are reached are: 1) *Activation* (also called arousal) or the effort one puts in to initiate motivated action or behavior (such as a student signing up for a course to learn computer networking); 2) *Persistence* - the continued and stimulated effort that a student puts in to reach a goal, overcoming a variety of obstacles (such as lack of math skills or loss of a scholarship making it difficult to pay tuition); and 3) *Intensity* - the full drive and energy that a student expends to reach a goal (work 2 part time jobs to pay for tuition or get a math tutor).

One of the most widely accepted explanations of motivation is offered by Victor Vroom (1964) in his *Expectancy Theory*, which states that people will be motivated to exert a high level of effort when they believe there are relationships between the effort they put forth, the performance they achieve, and the outcomes/rewards they receive. In an academic setting, it means if the rewards (successfully completing the course, program or degree) are not important to the student or they don't think their effort will impact their learning (studying/learning increases their performance or grade in the course), they will not put forth persistent effort towards achieving their academic goals.

Persistence, according to Comings (2007), is comprised of both intensity (the hours of instruction per month) and duration (the months of engagement in instruction). Persistence defines the phenomenon from the point of view of students who persist in learning—until they have achieved their goals. Persistence ends when the student decides to stop learning. Persistence is important because research has shown a "relationship between persistence and learning" (Comings, 2007, 24). Between 50 and 150 hours (majority say100 hours of instruction) are needed by adults to achieve an increase of one grade-level equivalent on standardized tests such as general equivalency diploma (GED), English language fluency, literacy, math skills or reading comprehension tests (Comings, Sum, & Uvin, 2000; Porter, Cuban, & Comings, 2005; Rose & Wright, 2006). Fitzgerald and Young (1997) analyzed data on 614 students comparing pretest and posttest reading scores and found a relationship between hours of instruction and learning gains for immigrants learning English.

Gegenfurtner, Quesada-Pallarès, and Knogler (2014), in their meta-analysis of simulations and cognition, show how design elements in simulation-based settings affect self-efficacy and transfer of learning. Students achieve their learning goals through playfulness and problem-based learning (Tsekleves, Cosmas & Aggoun, 2014), which increases self-efficacy and transfer of learning to new situations (Gegenfurtner et al., 2014). They conclude that gathering feedback post-training, as opposed to during the process, results in higher self-efficacy and transfer of learning. Additional studies showed improved learning outcomes when instruction fit student needs and learning styles (Beder, 1991; Quigley, 2000; Cuban, 2003). By making programs and courses more engaging (Beder, 1991; Meder, 2000), motivating (by helping students set goals), and interesting (increasing students' desire to participate) (Beder, 1991; Cuban, 2003), faculty increase students' performance.

So how do student motivation and achievement intersect? People are motivated to possess a positive self-concept. They often go to great lengths to attain positive views of the self (self-enhance) and avoid negative views of the self (self-protect) (Alicke & Govorun, 2005; Alicke & Sedikides, 2009; Sedikides, Green, & Pinter, 2004). Self-enhancement and self-protection are prevalent and pervasive motives, which often take precedence over other long-term goals (e.g., academic achievement; Crocker & Park, 2003). In their research study of 197 students, Jiang and Kleitman (2015) confirm the link of self-enhancement motivation to higher metacognitive beliefs, which in turn positively predicted higher confidence while performing a task. Using self-protection strategies increases anxiety and decreases metacognition beliefs and confidence. Kleitman and Gibson (2011) also confirmed in their study of 177 students, that academic self-efficacy and metacognitive competency beliefs, which they called "metacognitive beliefs", is a key predictor of self-confidence. Mastery goal-orientation, self-efficacy, and competence in memory and reasoning abilities predicted metacognitive beliefs and, indirectly, self-confidence. Students with stronger metacognitive beliefs were less engaged in self-handicapping behaviors, which translates into higher academic achievement.

Engagement Theory

The underlying basis of *Engagement Theory* is that students should be "meaningfully involved in their learning through interactive and worthwhile tasks" (Kearsley & Shneiderman, 1998, 20). *Engagement Theory* is based upon the theoretical perspectives of "constructivism" philosophy or the effectiveness of active learning. Research studies over the past decades have presented clear evidence on the significant impact of such pedagogical approaches on students' education with regard to academic achievement, motivation, and attitudes toward teaching and learning alike (Delialioğlu, 2012; Garrison & Arbaugh, 2007; Hmelo-Silver, 2004; Pereira et al., 2007).

Technology often can promote engagement that is difficult to achieve otherwise (Fink, 2013). Information and Communication Technology tools in online teaching and learning work as 'levers' to increase students' test scores; escalate students' collaboration and communication skills; and increase students' motivation and engagement in their own learning and growth (Sandler, 2010). Another technology that has been used to engage students in a meaningful way in distance education is the Online Discussion Forum. The social interaction and the collaborative active learning nature of the online discussion forum environment have been found to increase achievement when students utilize online forums to learn (Alzahrani, 2017; Wu & Hiltz, 2004).

How to increase communications and make them most effective between students and teachers is a major concern in academe. Some students find it difficult to participate in traditional classroom lectures because of their inability to socialize or lack of confidence; sometimes faculty do not have enough time to engage each student through questions or elaborate on the topics they have to teach in the traditional classroom, which can both decrease students' understanding of a given topic and motivation to participate fully. Students rate online discussion forums highly since they are engaging, vibrant and active (Revill & Terrell, 2005). In the online forum, each student answers the questions posed by the professor and has equal time to be heard; students can build on what they learn from other students as well as the professor's feedback. In addition, Cox and Cox (2008) found that collaboration and reflective higher-order learning are effectively taking place in online discussions.

In illustration of how the *Engagement Theory* works, Miliszewska and Horwood (2006) assigned a real-life software development project to their students online who resided in two different countries. The following learning objectives were emphasized: 1) "to appreciate the needs of the business client for whom they are expected to build the software system; 2) to apply software engineering and database design methodologies to the implementation of a complete system; and 3) to confront issues developers face, such as liaison with clients, working in a team, and documenting the project" (p. 1). Through online hands-on projects, students are fully engaged (despite residing in different locations) and developed problem-solving skills that enhanced their learning environment (Campidoglio, Frattolillo & Landolfi, 2009; Fogarty, 1997; Kingsland, 1996).

Problem-Based Learning Theory

Problem-Based Learning is a teaching method in which complex real-world problems are used as the way to promote student learning of concepts and theories as opposed to direct presentation of facts and abstract ideas. In addition to course content, PBL can promote the development of critical thinking skills, problem-solving abilities, and communication skills. Also, it can provide opportunities for team work, finding and evaluating research materials, and life-long learning (Duch, Groh & Allen, 2001).

Lomo-David & Shannon (2009) support the idea that projects, increasing student's practice and problem solving skills in informational systems, increase student employability; they found a significant impact of the use of computer simulation design methods on students' problem-solving skills for circuit construction in an undergraduate Electronic Computer Engineering Technology course. The learning that occurs in working with a problem enables students to acquire new knowledge, and deepen their existing skills and knowledge (Schiller, Ostwald & Chen, 1994). Students have a greater responsibility for their own learning (higher self-efficacy) and receive less guidance from the teacher in the online environment (Dolmans, 1992). Project-based activity is seen as "essential to transforming computing students into competent graduates" (Miliszewska et al., 2006, 3).

Safar and Alkhezzi (2013) used a blended approach in creating a more Problem-Based Learning environment, which included: (1) face-to-face or traditional instruction/training; (2) online instruction/training over the Web (i.e., online teaching/ learning environment) using a learning management system and an online training system; (3) **computer**-based instruction/training using educational software; (4) internet/**computer-**based testing; (5) internet/**computer**-based standardized certification testing; (6) traditional testing in the classroom; and (7) traditional curriculum/ materials such as textbooks, training manuals, and lectures' notes. The students enrolled in the experimental group (blended class) vs control group (traditional face-to-face class) using Information and Communication Technology submitted projects with better quality; earned higher final grades; attended more online training **courses**; took more computer skills certification tests; and the majority attended all classes (i.e., had zero absence rate).

According to Veenman, Elshout, and Busato (1994), problem-oriented simulations helped develop higher-order thinking strategies and improved students' cognitive abilities of recall, problem-solving, and creativity. Kazemi and Ghoraishi (2012) conducted a comparison of Problem-Based Learning approaches and traditional teaching on attitude, misconceptions and performance of university students in an applied math class; Hillman (2003) emphasized Problem-Based Learning approaches to teacher education as a way to engage the students more effectively in their own learning. Problem-Based Learning (PBL) tools enhance "students' performance and attitude" (Kazemi et al., 2012, 3852).

Frequent Feedback

Pennebaker, Gosling, and Ferrell (2013) examined the effect that frequent quizzing, which provided immediate and personalized feedback to over 900 students in introductory psychology classes, had on student performance. Exam performance was approximately half a letter grade above previous semesters, based on comparisons of identical questions asked from earlier years. Students in the experimental classes performed better in other classes, both in the semester they took the course and in subsequent semester classes, meaning the learning behaviors became ingrained (attending class, engaging in class). The authors also found a 50% reduction in the achievement gap among students of different social classes. These findings suggest that 'frequent quizzing' can improve course performance and impact student behaviors in courses, as well as other concurrent and subsequent courses. Nakos and Whiting (2018) also investigated the impact of frequent short exams on performance with 128 students in a hybrid global business course. The expectation of a short exam forced students to watch the online lectures and study the course material before class, gave the professor more class time to discuss in-depth international business issues and resulted in significantly higher student performance in the course.

Gholami and Moghaddam (2013) investigated the effect of weekly quizzes on students' performance on final achievement tests, finding positive impacts on learning and a decrease of anxiety while taking achievement tests. Proponents claim that frequent quizzes stimulate practice and review, give the students more opportunities for feedback, have a positive influence on students' study time and supply motivation for students to attend classes or become more engaged in online courses (Basol & Johnson, 2009; Zarei, 2008; Wilder, Flood & Stromsnes, 2001). Frequent quizzes help students to retain the material for longer periods of time and prepares them for high-stakes exams (Johnson & Kiviniemi, 2009; Roediger & Butler, 2011; Roediger and Karpicke, 2006). In addition, many studies have shown that frequent testing increases student's classroom attendance (Clump, Bauer, & Alex, 2003; Wilder et al., 2001). The opponents, on the other hand, believe that too frequent of testing might inhibit larger units of instructional material and frustrate anxious students hindering their learning (Jang, Pashler & Huber, 2014; Mulligan & Peterson, 2013).

Effectiveness of Information and Communication Technology Tools

The findings of 125 respondents (Ololube, Eke, Uzorka, Ekpenyong & Nte, 2009) revealed that Information and Communication Technology tools --when used with instructor-led teaching and learning strategies--enhance effective knowledge delivery; improve access to knowledge; encourage effective critical thinking; enhance student academic achievement; produce richer learning outcomes; and in general, enhance both the quantity and quality of teaching and learning. The study also discovered a statistically positive correlation between prior experiences with Information and Communication Technology and students' attitudes and anxiety toward such tool use (Ololube et al, 2009). This paper focuses on the effectiveness of three Information and Communication Technology tools – computer simulation, the online discussion forum, and frequent online quizzes.

Computer Simulation

Computer Simulation, as an Information and Communication Technology tool, has been very effective in a wide array of science, computer science, education, communications, engineering and social sciences courses. In fact, Rutten, van Joolingen, and van der Veen's (2012) comprehensive review of 24 experimental studies, provides robust evidence that a computer simulation can enhance or effectively replace traditional instruction, especially as far as laboratory activities are concerned. Several gaps in the research were identified: 1) the impact of teacher support, 2) the lesson scenario, and 3) the computer simulation's place within the curriculum (Rutten et al., 2012, 135).

In addition, a systematic review of 9 quantitative healthcare science studies by Ravert (2003) found that 75% of the research showed positive effects of computer simulations on skill acquisition. Reporting on the outcomes of 61 empirical studies on computer simulations in science instruction, Smetana and Bell (2012) also found simulations to be as effective, and in many ways more effective, than traditional (i.e. lecture-based, textbook-based and/or physical hands-on) instructional practices in promoting content knowledge, developing process skills, and facilitating conceptual change in applied science courses. Similarly, assessment results of 29 computer networking students by Wolf (2010) showed learning can be observed and that the amount of learning in the virtual lab is approximately equal to learning in the lecture. *Computer Simulations* are most "effective when they (a) are used as supplements; (b) incorporate high-quality support structures; (c) encourage student reflection; and (d) promote 'cognitive dissonance', involving students in 'inquiry-based' and 'authentic explorations'" (Smetana & Bell, 2012, 1337).

Simulations also help to develop and enhance higher-order cognitive skills (Alnoukari, Shafaamry & Aytouni, 2013; Issariyakul & Hossain, 2008; Veenman, Elsout & Busato, 1998). Computer-based simulation software enables the students to experiment interactively with the fundamental theories and applications of electronic devices (Dobrilovic & Odadžic, 2006). It provides instant and reliable feedback and, thus, gives students an opportunity to try out different scenarios and evaluate their ideas for accuracy almost instantly (Potemans et al., 2002). As an experiential and active "hands-on" learning style, computer simulations generate more student interest than the traditional classroom (Baumgartner, Braun, Kurt, & Weyland, 2003; Al-Rizzo, Al-Habsi & Addada, 2004). Virtual labs enable learning activities that might be impossible, dangerous, or too expensive to carry out in reality (Dengel, 2019).

Taher and Khan (2014) cite several advantages of *Computer Simulations* compared to laboratory activities: 1) pedagogical advantages of computer simulations over classroom labs (such as more time to conduct the experiment and individual feedback is possible); 2) the costs of purchasing, maintaining, and updating lab equipment is often more expensive than computer hardware and software; and 4) no concern for students' physical safety in the simulation learning environment. Computer virtual lab simulations have the potential to improve student understanding of fundamental networking concepts and increase enthusiasm for experimentation with complex technology in all of the MINT subjects of mathematics, information technology, natural sciences and technology (Dengel, 2019). Further-more, these benefits can be delivered with less effort from the instructor than using traditional approaches (Wong, Wolf, Gorinsky & Turner, 2007).

Online Discussion Forum

Another important Information and Communication Technology tool for effective communications has been the Online Discussion Forum (Biriyai & Thomas, 2014; Tolmie & Boyle, 2000; Balaji & Charkrabarti, 2010). It also has been described as an "effective way of engaging students outside the classroom" (Balaji & Charkrabarti, 2010, 1; Edwards, 2005). It is an e-learning platform where students can post messages to the discussion threads, interact and receive feedback from other students and the instructor, and hence creates a deeper understanding of the subject matter being discussed. In computer education and business, online discussion forums have been deployed to complement traditional learning techniques such as lectures and tutorials (Dube, Bourhis & Jacob, 2006; McDonnell, 2000). Online discussions also "harmonize with the educational philosophy that makes communication a necessary tool and fundamental mechanism for effective learning" (Harman & Koohang, 2005, 69).

Online discussions enhance learning, by increasing motivation, engagement, and deeper understanding of a subject matter (Thomas, 2002). Jalongo, Twiest, and Gerlach (1999) observed that the following critical thinking skills increased in online forums: 1) Application, where students use knowledge and understanding to complete a practical task; 2) Analysis, where students break a task down into its component parts; 3) Synthesis, where students integrate various sources of information; and 4) Evaluation, where students assess the value, or worth of something when completing a task. Online discussion forums also successfully increased students' critical thinking skills (Li-Jen & Bennett, 2012). In addition, Pena-Shaff, Altman & Stephenson (2005) found several significant correlations between pre-course attitudes, expectations about online discussions, and expected learning. They also discovered greater levels of participation in the forums were tied to greater satisfaction.

The "interaction of the learners with both human and inanimate objects, and their participation in technology mediated education, were essential for the quality of their learning experience", because they enrich the knowledge exchange processes among students/faculty and positively affect students' performance (Zhang, Zhou, Briggs, & Nunamaker, 2006, 27). Other researchers note that online discussion forums can be successful in enhancing collaborative learning by attracting students to participate and interact (Dube et al., 2006; Swan, Fredericksen, Pickett, Pelz, & Maher, 2002). Three key factors of "consistency in course design, contact with course instructors, and active discussion" were crucial to the success of online courses and the creation of an online learning community (Swan et al., 2002, 359). Online forums have been described as "facilitating discourse, reflective thinking, assessment and connectedness" (Balagi et al., 2010, 17).

Past research delineates the following benefits of *Online Discussion Forums*: 1) higher participation by students; 2) more in -depth discussion of topics; 3) ability to easily form small group discussions; and 4) feedback for students and faculty about what students understand and where they need clarification (Balaji et al. 2010; Brodie, Karat & Feng, 2005; Fagin et al., 2006; Mazzolini et al. 2007; Menchaca & Bekele, 2008). McDuffie and Slavit (2003) go on to suggest that the dialogical nature of an online discussion provides a forum for students to share their reflections with other participants in their introductory math classes. Using a variety of instructional media in the online forum leads to enhanced learning as well as shapes students' attitudes, expectations and perceptions of the e-learning experience (Balagi et al., 2010; Pena-Shaff et al., 2005).

Online forums provide an avenue where class material can be reviewed, discussed and reinforced. The "underlying presumption is that knowledge can be constructed by an online asynchronous dialogue of class material" (McDonnel, 2000, 374). The conversational model of learning by Thomas (2000) stipulates that it will enhance learning, including increased motivation, engagement, and deeper levels of understanding. Communications technologies – such as online forums – enable students to discuss class material in an asynchronous manner, which supports discussion outside the classroom and more flexibility for working students.

Alzahrani (2017) investigated the effect of using *Online Discussion Forums* on students' learning, particularly on their achievement, including a higher grade. Statistical analyses revealed significantly positive relationships between student participation in online discussions and their final course mark, but no significant relationships between their participation in online forums and grade point average. In a similar context, AlJeraisy et al. (2015) found significant relationships between the number of times students participated in the online discussion forum and their achievement. Collaborative findings in other contexts were reported by

Alghamdi (2013), Carceller et al. (2013), Hartnett (2012), Koole (2009), and Palmer and Holt (2010). In contrast, no significant relationships were found in Song and McNary's (2011) study, which analyzed graduate level courses only. Ellis et al. (2007) also found that sense of connectedness or community among the students increased the interactions in the online environment creating bonds among the students and promoting academic participation.

Frequent Feedback Using Online Quizzes

Frequent Feedback is in the top 10 influencers of achievement, according to a comprehensive review of 12 meta-analyses, which included specific information on feedback in classrooms (196 studies and 6972 effect-sizes), finding an average effect-size of .79, which is twice the average effect of all other learning effects (Sutton, Hornsey, & Douglas, 2011). Shute (2008) provides five recommendations to make feedback more effective for learning: 1) focus feedback on the task not the learner; 2) present detailed feedback in manageable units (e.g., avoid cognitive overload), 3) reduce uncertainty between performance and goals (i.e., help the student to see where they are now relative to success on a task), 4) give frequent, unbiased, objective feedback, written or via computer (more trustworthy sources are more likely to be received), and 5) provide feedback after learners have attempted a solution (leading to more self-regulation).

"Assessment for learning is characterized by information being used to inform learning and teaching, its focus on learning conceived broadly, and actively engage progressively more autonomous students" explains Sue Swaffield (2011, 433). Frequent online quizzing (monthly or weekly or daily) is an automatic and objective way for students to gain self-knowledge in small doses. Allowing students to retake quizzes (or allowing multiple attempts) or giving them the opportunity or incentive to create self-quizzes also provides them a chance to adjust their thinking, helping them to focus more on learning and not as much on the grade. In her research on frequent quizzing's impact on student performance, Norris (2016) investigated online "pre-quizzes" designed to prepare students for follow-up classroom discussions and short "post-quizzes" given during class time after discussing questions about the material covered by "pre-quizzes". This longitudinal study (fifteen semesters) of 348 students indicated that students performed better on the final exam (8-point difference in final exam for Computer Systems I course and 10-point gap for Computer Systems II course) with this quizzing strategy compared to a more traditional homework-based approach.

RESEARCH QUESTIONS

In this exploratory research, we are interested in how online tools and practices, like an online computer simulation, (which assesses the higher-order skills of application, analysis and evaluation in networking experiments), persistence in the lab, engaging online discussion forums, and feedback through frequent online quizzes, impact student achievement and performance. The simulation used (LabSim) was part of TestOut Network Pro, which is a professional training software program that prepares computer science students for two professional certifications - the TestOut Network Pro certification exam and CompTIA's N10-007 certification exam. In the simulation, students gain the knowledge and higher-order skills they need to install, configure, and maintain a network for a small business.

The TestOut Network Pro training program includes the simulation lab, instructional videos, text lessons, quizzes, and certification exam preparation materials (students may take practice exams as many times as they like) with real-time scoring and Learning Management System (LMS) integration. Achievement of higher-order skills of analysis, application and evaluation in the computer simulation was calculated using the overall lab score. For the computer simulation (LabSim), persistence was calculated as the total hours spent in the lab. Engagement was measured by the Online Discussion Forum grade; high engagement was considered when students earned an 85% or higher score in the discussion forum. Weekly quizzes were given and the average quiz grade was the 'frequent feedback' measure. Performance was measured by midterm exam, final exam and the final grade.

The research questions posed were:

1. Can student persistence (number of hours spent in the lab) impact achievement in the computer lab simulation (lab score of attaining higher-order skills)?
2. Will simulation skill achievement relate to higher student performance?
3. Will successful engagement in the Online Discussion Forum influence a student's performance?
4. Does frequent feedback in the form of quizzes help to increase student performance?
5. What combination of learning activities (higher-order skill attainment in the simulation, persistence in the lab, frequent feedback, engagement, exams) will effectively impact overall student performance (course grade)?

METHODOLOGY

Data from 133 students in fully online computer networking classes for computer science majors at Troy University's global campus from 2017 to 2019 (taught by the same instructor) were analyzed in this study. The confidential data was aggregated from the Learning Management System called CANVAS. Data from the simulation called LabSim and Test Out Network Pro training was also available in CANVAS. T tests, Pearson Correlations and Regression Analysis were performed to answer the various research questions. This is an exploratory research study and all student data was aggregated and kept confidential.

RESULTS

To answer the first Research Question – "Does student persistence impact computer lab simulation achievement?",the t test results showed that the hours spent in the simulation lab did make a difference. Performance was negatively impacted by a student not reaching a minimum number of hours in the lab. Students who spent less than 10 hours during the semester (9 weeks) doing the computer lab simulation (LabSim) had a significantly lower lab grade (nearly a full-grade lower, 85% vs 94%) than those students who persisted and worked 10 or more hours in the lab (the average time spent was 25 hours total). A significant connection between persistence (time spent in the lab) and student achievement of higher-order skills (measured by overall lab scores) was confirmed; the first research question was fully supported in the t-test analysis (See Table 1).

TABLE 1
Comparison of Mean Differences in Persistence (Total Hours of Lab Use) and Higher Order Skill Achievement (Mean Lab Grade)

Persistence/ Achievement	**Total Hours in Lab Use**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Mean Lab Grades	10 or more hours	119	94.0247	12.40238	1.13692
	Less than 10 hours	14	84.6508	18.55436	4.95886
t-test results: t(131) =2.524 (.013)					

Research Question #2 – "Will simulation skill achievement relate to higher student performance?" was studied using Pearson Correlation. The results showed relationships between the simulation and two performance factors - the final exam and final grade. Simulation achievement was only weakly connected (coefficient = 0.17, $p < .05$) to the final exam whereas the relationship between the final grade and attainment of skills in the simulation was very strong (coefficient = 0.55, $p < .001$). Therefore, the results partially confirm Research Question #2.

TABLE 2
Pearson Correlation Matrix for Simulation and Performance

Simulation and Performance (N = 133)		**Avg Lab Grades**	**Midterm Exam Grade**	**Final Exam Grade**	**Final Grade**
Avg Lab Grades	Pearson Correlation	1	.010	.172*	.545**
	Sig. (2-tailed)		.911	.048	.000
Midterm Exam Gr	Pearson Correlation	.010	1	.148	.377**
	Sig. (2-tailed)	.911		.089	.000
Fin Exam Grade	Pearson Correlation	.172*	.148	1	.604**
	Sig. (2-tailed)	.048	.089		.000
Final Grade	Pearson Correlation	.545**	.377**	.604**	1
	Sig. (2-tailed)	.000	.000	.000	

NOTES: * Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed).

"Can engagement in Online Discussion Forums effect student performance?" was the third research topic of interest. We found that high engagement in the Online Discussion Forum (gaining at least a forum score of 85%) did reveal approximately a 7 percentage-point difference in the final exam (t-test result was significant at the .01 level) and final grade for the course (t-test was highly significant at the .001 level). However, the midterm exam did not show any significant difference between those who were highly engaged in the Online Discussion Forums and those who were not. Therefore, Research Question #3 was partially supported as shown in Table 3.

To answer Research Question #4 about the relationship between frequent feedback (through weekly quizzes) and performance, the results showed positive results on two assessments. A Pearson Correlation was conducted to show interrelationships between the variables. Both the midterm exam (strong coefficient of 62%, highly significant at the .001 level) and final course grade (medium coefficient of 36%, significant at the .01 level) showed strong impact of the frequent feedback (mean quizzes score) on performance. However, the final exam score did not show any significant connection to the frequent feedback measure. Thus, Research Question #4 was partially supported. Please see Table 4 for complete summary. (See table 4)

In the fifth Research Question, "What combination of learning activities (higher-order skill attainment in computer simulation lab, persistence in the lab, frequent feedback through quizzing, engagement in the Online Discussion Forum, midterm

TABLE 3
Comparison of Mean Differences in Performance (Midterm, Final, Final Grade) by Engagement (Total Online Discussion Forum Grade)

Engagement/ Performance	Total ODF Grade	N	Mean	Std. Deviation	Std. Error Mean	T test Statistic (df = 131)
Midterm Exam Grade	>= 85.00	108	92.5942	8.04359	.77399	t = -1.251
	< 85.00	25	94.9000	5.87899	1.17580	
Final Exam Grade	>= 85.00	108	69.7531	18.90555	1.81919	t = 1.975 *
	< 85.00	25	61.8200	13.93677	2.78735	
Final Grade	>= 85.00	108	88.0272	6.08184	.58523	t = 4.577 ***
	< 85.00	25	81.5904	7.36578	1.47316	

NOTES: *** Correlation is significant at the 0.001 level; ** Correlation is significant at the 0.01 level; * Correlation is significant at the 0.05 level.

TABLE 4
Correlation Matrix of Frequent Feedback (Total Quizzes Grade) and Performance (Midterm Exam, Final Exam and Final Grade)

Frequent Feedback and Performance (N = 133)		Total Quizzes Grade	Midterm Exam Grade	Final Exam Grade	Final Grade
Total Quizzes Grade	Pearson Correlation	1	.618**	.152	.358**
	Sig. (2-tailed)		.000	.081	.000
Midterm Exam Grade	Pearson Correlation	.618**	1	.148	.377**
	Sig. (2-tailed)	.000		.089	.000
Final Exam Grade	Pearson Correlation	.152	.148	1	.604**
	Sig. (2-tailed)	.081	.089		.000
Final Grade	Pearson Correlation	.358**	.377**	.604**	1
	Sig. (2-tailed)	.000	.000	.000	

NOTE: ** Correlation is significant at the 0.01 level (2-tailed).

exam, or final exam) effectively impacted course performance?", we used Stepwise Regression Analysis to examine the influence on the final grade. The overall Regression Model was significant at the .000 level and showed five learning activities that effectively explained 75% of the final course grade. The strongest factor, final exam, explained 36% of the variance in the final grade performance at the .000 level. Average lab scores was the next important measure of the effectiveness of the computer simulation, contributing an additional 20% of the final grade performance variance (significant at the .000 level), with the midterm exam adding 9% (p=.000), engagement in the Online Discussion Forum at 9% (p=.000) and frequent feedback through quizzes at 1% (p=.01). The results showed that a combination of five learning activities did significantly impact the course grade. Persistence, as measured by hours spent in the lab, did not qualify as a learning behavior having impact on the overall course grade. Please see Table 5 for Regression Analysis results. (See Table 5)

Discussion and Conclusions

The current research study sought to determine the interrelationships between learning activities/tools such as the higher order thinking skills enhanced in the computer simulation, persistence in the simulation, frequent feedback of weekly quizzes, engagement in the Online Discussion Forum and positive learning outcomes. The research was based on the framework of Taxonomy of Learning by Bloom and others (1956), Persistence in Motivation Theory, the Engagement Theory, Problem-Based Learning (PBL) Theory as well as research on Frequent Feedback. Four research questions were proposed in this initial exploratory approach with several important findings.

First, the relationship between persistence and higher-order skill attainment in the simulation was researched. Persistence

TABLE 5
Model Summary of Regression Analysis for Learning Activities Impacting Final Grade[f]

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.604[a]	.365	.360	5.43891	.365	75.243	1	131	.000
2	.752[b]	.565	.559	4.51649	.201	59.973	1	130	.000
3	.809[c]	.654	.646	4.04607	.089	32.987	1	129	.000
4	.864[d]	.746	.738	3.48139	.092	46.242	1	128	.000
5	.871[e]	.759	.749	3.40522	.013	6.790	1	127	.010
a. Predictors: (Constant), Fin Exam Gr									
b. Predictors: (Constant), Fin Exam Gr, Avg Lab Grades									
c. Predictors: (Constant), Fin Exam Gr, Avg Lab Grades, Midterm Exam Gr									
d. Predictors: (Constant), Fin Exam Gr, Avg Lab Grades, Midterm Exam Gr, T Disc Gr									
e. Predictors: (Constant), Fin Exam Gr, Avg Lab Grades, Midterm Exam Gr, T Disc Gr, T Qz Gr									
f. Dependent Variable: Final Grade									

was measured by hours spent in various aspects of the computer simulation lab (including watching videos, taking quizzes, following lessons, and conducting experiments on simulated equipment for networking). On average students spent 25 hours in the lab. There was not a linear relationship between skill attainment and persistence, but instead there was a minimum threshold of persistent behavior necessary for the student to achieve the learning outcome. Students who spent at least 10 hours in the lab activities overall gained higher-order skills in the computer simulation lab, their lab score increasing by 9% points or nearly a full grade improvement, over those who spent less than the minimum 10 hours.

Secondly, the connection between the simulation and performance was analyzed. Simulation, as measured by a total lab score, reflecting the use of higher order thinking skills, was most tied to the final grade. It also had a weak relationship with the final exam grade, but showed no connection to the midterm exam. The simulation was a semester-long activity with weekly experiments and scores from experiments, quizzes, videos and lessons were incorporated into the final score. It would be expected that the simulation would have more of an impact on performance measures at the end of the semester.

The third focus was on the interrelationship between engagement in the Online Discussion Forum and student performance. Although this research question was not supported in the relationship between the score on higher engagement in discussion forums and the midterm exam, there were two performance measures impacted by higher engagement (discussion score of at least 85%), namely, the final exam and final grade. This finding supports the importance of engaging the student in communications and dialog in online discussions. It provides evidence that facilitating discourse and delving into topics can have a positive effect on student performance measures, such as the final exam and course grade, corroborating previous findings (Dennen, Darabi & Smith, 2007; Fagin et al., 2006, Li-Jen et al., 2012; Menchaca et al., 2008). The final exam, it should be noted, was a timed proctored exam and the mean score was fairly low, 68%. The midterm exam is not proctored with a mean score of 93% and the course grade (mean of 87%) depended on a variety of weighted factors (25% for final, 20% for midterm, 20% for the simulation, 20% for the quizzes and 15% for the Online Discussion Forum). Although the Online Discussion Forum is operated throughout the semester, the first several weeks might show lower engagement as the semester is starting and students are just introducing themselves and learning what is expected of them in the discussion forums. The midterm exam is given in the 5th week of a 9-week course so there is not as much time to see an effect of the dialog and engagement in the online forums on this assessment. The midterm is an open-book exam with no proctor whereas the final exam is a more difficult higher-stakes exam (worth 25% of the final grade, proctored and closed-book).

In the fourth topic of interest, the 'frequent feedback through weekly quizzes' relationship to student success, positive performance effects were seen for the midterm exam and the course grade (a bump of 7 percentage points each) but not in the final exam. By the midterm, students took 6 quizzes (covering 6 chapters in the book). By the final exam, students took an additional 4 quizzes. Quizzes did factor for 20% of the final grade. Perhaps the differences in the timing in the semester, difficulty (open-book vs closed-book), and proctoring of these exams (non-proctored midterm vs. proctored final), can account for the weekly quizzes (also open-book and non-proctored) showing different relationships to the two exams.

Lastly, the researchers were interested in which learning activities successfully effected students' performance in the course (measured by the course grade). Findings were positive for five learning activities in the course. Two factors were the most effective - the final exam and simulation lab scores together predicted 56% of the course grade ($p = .000$). The midterm exam (9%), engagement in Online Discussion Forums (9%) and frequent feedback with weekly quizzes (1%) followed as predictors of a higher course grade. The five factors together explained 75% of the total variance in course grades. The research indicates how the professor can use Information and Communication Technology tools of simulation, online discussions, and online quizzing for higher learning outcomes and, thus impact the overall performance of the students. This study hints at the important role of the faculty member as course content designer, master engager, guider/facilitator and higher-order skill developer, gaining a deeper appreciation of engagement, feedback, and problem-based learning experiences on positive student achievement and performance, as collaborated by past researchers (Alzahrani, 2017; Carceller et al., 2013; Garrisonet al., 2007; Wu & Hiltz, 2004).

Future research would do well to measure the impact of the faculty member's feedback specifically, perhaps through student end of class surveys. Would students spend more time in the lab if they knew it would increase their lab scores and course grade significantly? How many of the students felt confident in their skill development to take the external certification exams in networking at the end of the semester or after the semester? Did the score students receive in their earlier weekly Online Discussion Forum assessments significantly influence the student's interactions and engagement in subsequent weekly discussions? Did the students change their behaviors if they did poorly in quizzes at the beginning of the semester? Again, this was not the purpose of this study, but we did see a stronger effect of the discussion forum grade on the final exam and final course grade compared to the midterm exam, which might indicate iterative and deeper learning from the engagement and dialog in the discussion over the semester. Dabbagh (2005) suggested that evaluation rubrics positively influenced meaningful discourse and enabled course improvement in their research. In addition to a strong need for feedback and presence of the faculty member in the course, students could benefit from additional reflecting on their experiences, particularly after completing the simulation and in the online forums, as recommended by other researchers (Gegenfurtner, et al., 2014; McDuffie & Slavit, 2003; Shute, 2008; Smetana & Bell, 2012), to maximize the effectiveness of these tools.

Honing critical thinking, communication and problem-solving skills are often espoused as vital to student's future success in computer science and applied sciences. This research gives evidence that higher-order skills, engagement and learning can successfully be enhanced using a computer simulation lab, an online discussion forum and online weekly quizzes along with typical performance assessments (midterm, final) for higher overall student performance (course grade) in a computer networking course. Students who persisted in the simulation (over 10 hours in the lab) had a higher lab score, which in turn, indirectly impacted their final course grade.

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