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An evaluation of an automated, interactive learning method for a database query language

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AN EVALUATION OF AN AUTOMATED, INTERACTIVE LEARNING METHOD FOR A DATABASE QUERY LANGUAGE

by

Summer L. Campbell

A thesis submitted in partial fulfillment
of the requirements for the Master of Science
degree in Industrial Engineering in the
Graduate College of
The University of Iowa

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Graduate College
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CERTIFICATE OF APPROVAL

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MASTER'S THESIS

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This is to certify that the Master's thesis of

Summer L. Campbell

has been approved by the Examining Committee for
the thesis requirement for the Master of Science degree
in Industrial Engineering at the August 2018 graduation.

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ABSTRACT

Effective learning models adopt a highly structured approach for introductory topics, then provide students more freedom as topics increase in depth and complexity. The structure guides beginning students with rapid, appropriate feedback and provides a framework that can be expanded later with extra flexibility that encourages students to flesh out the basic framework with trial and error. This trial and error phase would also be more effective with informative feedback but providing copious feedback on open-ended problems is only feasible with a small student-to-teacher ratio or with the help of e-learning. Training engineers involves introducing many complex topics and the educational costs are high, making the use of e-learning an important training opportunity.

This project introduced a novel e-learning system to engineering students in an introductory course. An experiment compared a highly structured electronic game with a more traditional, flipped classroom teaching approach. The novel learning method is intended to engage students with a consistent cognitive load as they progress through increasingly difficult learning experiences within the MySQL database querying language. Performance was measured with a post-task exercise. Task load was measured using an unweighted NASA Task Load Index (NASA-TLX). The two cohorts experienced both learning methods in two training sessions in opposite order.

In the first session, participants in the current learning method group outperformed the participants in the game group (a score of 95.78 versus 93.94), but the second session was a reverse of these results (92.79 and 95.76). The task load indices also follow this pattern, with participants in the current group recording a lower task load than the game group in session

one and a higher load in session two. However, as the training progressed in each session the task load increased less for the game group than for the current group, indicating that the game group experienced a more consistent task load, as expected. The game tended to extend the time that students stayed at a comfortable but challenging cognitive load, while the students in current training group experienced more periods of very low or very high cognitive load. This consistent task load may be responsible for the game producing better results on the more difficult content of the second week. We expect that as the game techniques improve, this will lead to more consistently efficient learning acquisition. We expect that the general technique may be adapted to other training areas, yielding broader educational efficiency.

PUBLIC ABSTRACT

Much like the use of training wheels, the best learning methods allow individuals the ability to practice in a 'safe' environment, free from harm or mistakes that may deter motivation. Once the learner has a good sense of the skill or material to be grasped, the training wheels can be removed, affording the freedom to tackle more challenging tasks. However, a learning environment should be structured as a gradual increase of difficulty and independence rather than, a singular monumental event.

Following this notion, we have developed a virtual learning environment that incentivizes learners with elements of gaming to teach undergraduate industrial engineering students the MySQL programming language. We divided students into two cohorts, with one receiving the current class lecture and the other participating in the novel virtual learning environment. We then measured task load of each student experiencing each learning method. We also measured student performance on an assignment completed after each learning session. We compared both values across two separate class sessions. We found that a game environment with copious feedback and an easy to follow path created a consistent task load for students in both class sessions and improved performance on difficult material.

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CHAPTER 1: INTRODUCTION

The retention rate of students pursuing an engineering degree is only 57% (Ohland et al., 2008). Students become disinterested or disappointed in their performance leading to drops in self efficacy and eventually dropping out (Seymour & Hewitt, 1997). Additionally, students that do graduate often do not feel they have learned the skills necessary to succeed. Tinto (1998) believes that there are two factors that determine an individual's success in an engineering degree: student commitment and institutional commitment. Students must be motivated to learn or 'commit' and institutions must create a successful atmosphere.

One way to help students understand the importance of what they are learning is to engage them in active learning activities featuring open-ended problems. Engineering courses should be designed for innovation, creativity and individual thinking (Richards, 1998). Open-ended problems are hands-on and require the student to wrestle with divergent ideas. Courses that adopt these ideals provide students with the opportunities to try and fail while working towards a goal. Often these sorts of problems demand many resources. E-learning provides an inexpensive alternative to traditional course projects. Perhaps surprisingly, engineering has one of the lowest uses of e-learning (Allen & Seaman, 2008). This means the majority of feedback from instructors is only taking place in the classroom or post-assessment and not in real time.

One learning method that has proven to be successful in introductory courses, and one used regularly at the University of Iowa, is a flipped classroom (Tucker, 2012). Students are expected to complete the learning material before class, typically via reading or listening to lectures. Class time with the instructor is devoted solely to practicing and applying the learning material. Ideally, students should be able to get immediate help, but there are usually more questions than instructors available to answer them. It is possible to mitigate this by allowing students to work in groups and help each other. However, since group setting provide less accountability, students sometimes find short-cuts around the difficult effort of learning the material.

Many engineering undergraduates feel bored or discouraged during their training. A learning environment that encourages creative thinking and enforces a problem-solving mindset could help to mitigate this problem. The high costs of providing immediate, informative feedback to students working on diverse, self-paced, open-ended problems can be reduced by developing appropriate software. This work considers one such e-learning system that emphasizes providing immediate feedback for students learning a database query language and tests the success of the new system.

CHAPTER 2: BACKGROUND

2.1 Teaching Through Problem Solving

"human beings do not learn primarily from generalizations and abstractions. They learn from experiences…" (Gee, 2013, p.17)

Norman Webb defines four basic levels within the learning process: recall and reproduction, skills and concepts, short-term strategic thinking and extended thinking (Webb, 2002). Each level is important for ensuring that new material becomes part of long term memory. Several other learning models follow a similar, four-level approach, such as the aviation learning model and the component display theory (Federal Aviation Administration, 2008) (Merrill, 1983) (Merrill, 1994). Bloom's Taxonomy is somewhat different; learning is mapped out in six distinct categories (Forehand, 2010) (Adams, 2015). However, the four levels of Webb's model contain all elements listed in Bloom's (Crofut). Figure 1 shows the overlap of the two ideas. Note the last two levels of Bloom's, evaluating and creating, are grouped together.

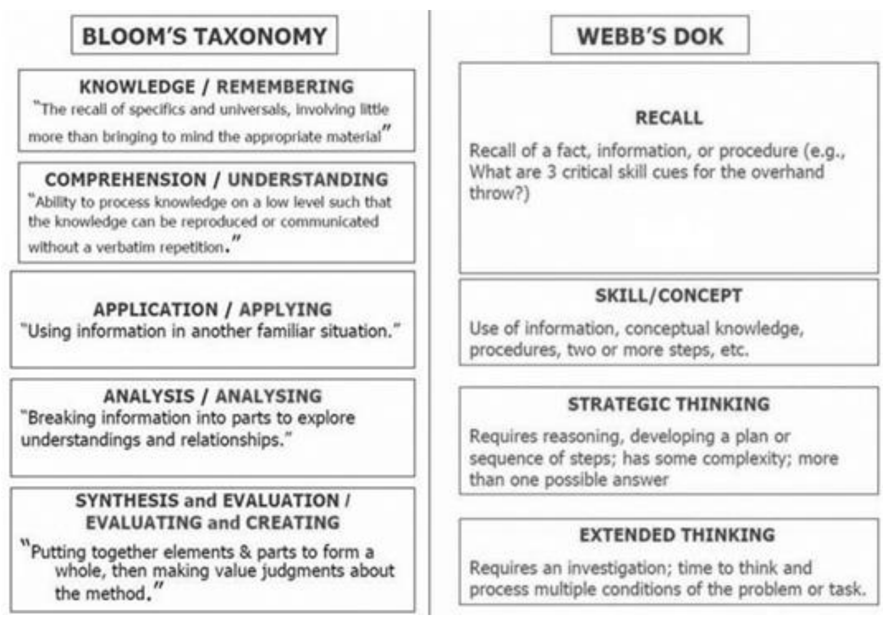

Figure 1: Norman Webb's four-level learning process compared to the six levels (levels 5 and 6 are combined) defined in Bloom's Taxonomy (Crofut).

Student's in Webb's recall and reproduction level need to simply replicate learned material. Preliminary information should be easily accessible, emphasizing recognition rather than recall. Students should feel they have all the resources necessary and presented in an ideal way. This is echoed by the Cognitive Load Theory (CLT), which stresses the need for a fully embedded task environment for novice learners, as struggling students are the least likely to consult a manual (Van Merriënboer, Kirschner, Kester, 2003). Without a proper base, beginners often find themselves lost from the start with little hope of catching up (Laurillard, 2002).

One popular teaching style is to test a student's short-term recall ability in short term, a style that may actually be responsible for students failing to retain information in the long term. Schank (1997) even goes as far as to question the usefulness of current education, stating: "School isn't really about learning; it's about short-term memorization of meaningless information that never comes up later in life." (p.7) While this is a harsh over generalization, there are educators who focus on recall, rather than understanding (Ramsden, 2003). Instead of only teaching and testing for recall, Webb's first level of learning emphasizes using a 'fading rationale' or removing structured examples to include more complex questions that involve problem solving techniques (Renkl, Atikinson, & Maier 2000). Recall and reproduction must be part of the learning process, but they shouldn't have an overpowering prominence.

Students in Webb's second level, skills and concepts, focus on mental processing. When students make mistakes at this level, they will not have the ability to quickly check their answers, since they typically require instructor feedback. Students should have the opportunity to try and fail, since this is one of the best ways to learn (Schank, 1997). Unfortunately, with a large class setup, students do not receive corrections quickly, and are typically penalized for these mistakes. This creates a high stress environment, where students are afraid to make any mistake, which is unproductive to growth.

Webb's third level is short-term strategic thinking, consisting of planning, reasoning, and analysis. This step allows students to integrate previously learned topics, pushing them to think like problem solvers. Skills learned by a student in the previous level become their tools for problem solving in the third level (Gee, 2013). If concepts are only taught superficially, or have been learned incorrectly, students will struggle to connect them to practical applications.

Lastly, level four of Webb's DOK focuses on extended thinking, applying the same strategies learned in level three to complex tasks, possibly using all the tools they learned in one setting. This turns students into producers, a switch from other learning methods, such as reading or listening to a lecture, in which students are passive (consumers) (Gee, 2005).

One of the challenges of education is to move students past rote memorization to a deeper understanding of the material. The method of teaching through problem solving helps students gain conceptual understanding of the target subject matter (Fi, 2012). The method contextualizes target skills and offers opportunity for repetition, a benefit to both instructor and student. Problem solving motivates students to reflect on the structure of the problem, facilitating their construction of a knowledge framework. The Cognitive Load Theory and Norman Webb's learning strategy both support a problem-solving approach to learning (Van Merriënboer et al., 2003) (Aungst, 2014).

During all four learning levels, instructors should be sensitive to student's cognitive load. Cognitive load is a measure of the mental activity in the working memory. When a task becomes too difficult, the resulting stress can affect the learner's performance. Figure 2 illustrates the tradeoff between stress and performance. It is important to have some stressor present, for example a deadline, to motivate the student. This is known as eustress (beneficial stress). If enough eustress is present in a task and the activity does not cause distress, your audience will perform best. The goal for instructors is to provide enough eustress without creating distress throughout the learning process.

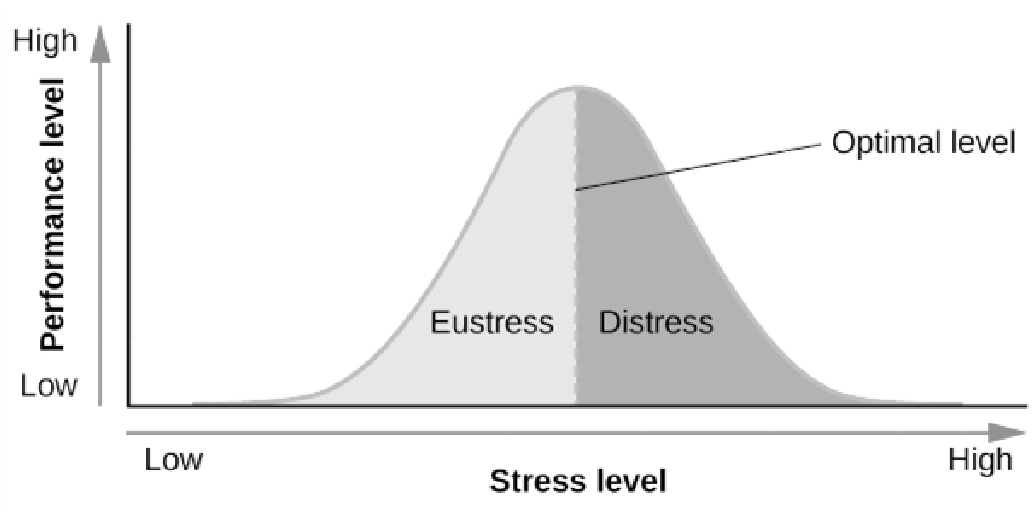

Figure 2: Performance level based on stress of a task (Weiser, 2014).

Creating a task for all students to maintain at peak performance is often difficult. Every student has different background knowledge and interest, finding a tradeoff between challenging coursework and an engaging task is key. A NASA-TLX can be used to measure the task load, which includes the cognitive load, felt by each student. The NASA-TLX consists of six parameters rated on a twenty-point scale, thought to be the major contributors to task load. The parameters are: mental demand, physical demand, temporal demand, effort, performance and frustration (Hart & Staveland, 1988). An unweighted or raw NASA-TLX can be used, since it is shown to have highly correlated results to the weighed option (Cao, Chintamani, Pandya & Ellis, 2009). The unweighted NASA-TLX requires individuals to rate their level of task load on all six parameters, but does not require them to rank each parameter on importance.

2.2 Online Learning

"The main idea is to reach an abstract common goal: to provide users with what they want or need without expecting them to ask for it explicitly." (Kurilovas, Kubilinskiene & Dagiene, 2014, p.655)

In 2002, under half of higher education institutions believed online education, or e-learning was critical for growth. In 2011, close to 70 percent of these institutions included online learning as part of their long-term education strategies (Allen & Seaman, 2013). Students rate the four highest benefits of technology in the classroom as: organizing and managing the logistics of studying, flexibility of place and location, time-saving and the ability to review, and replay and revise (Henderson, Selwyn, & Aston, 2017). Yet, online education still fails to retain student enrollment, with most students dropping because of the time commitment (Nawrot & Doucet, 2014). Students don't perceive the benefit of these courses to be worth the time required to complete them.

One of the greatest benefits of online education is the immediate feedback available to students. Unfortunately, when universities switch to an online system, they begin by mimicking the set-up of a face-to-face course, with similar assignments and exams still graded by an instructor (Allen & Seaman, 2013). This design causes more work for the faculty than current courses and fails to improve the learning experience (Henderson et al., 2017). Instead, an online environment should be designed for quick feedback for the students, so mistakes can be identified and remedied before they become habit. Students feedback should be built into the e-learning environment, reducing the instructor's load. In addition, there should be high structure at the start of a course, encouraging beginner level students and reinforcing the recall and recognition concepts before continuing to more advanced skills or tasks.

Online training techniques use this idea of continuous feedback. This allows individuals to learn by doing, instead of sitting through a demonstration (Schank, 1997). Knowledge retention is higher, and better trained workers contribute to a safer environment.

A very unique aspect of online learning is the ability to monitor students' advancement, intervening when necessary. The e-learning system has a model for each student and tracks their decisions and interactions for each learning objective, updating the model as the student progresses (Kurilovas et al., 2014). This allows students to work towards their main goal, increasing the difficulty when needed and providing extra support for topics they struggle through. Each student has a unique experience or path through the e-learning system.

This benefit of e-learning is vital when students are learning skills and concepts, the second level of Webb's learning model. This is the base line of the Cognitive Control Theory, which deals with skill, rule and knowledge based behavior (Rasmussen, 1983). At this stage in learning, it is common for students to make a mistake and have it become a habit if they are not corrected quickly. By monitoring a students' progression, an online learning system could remind a student of the correct method when the student seems to go off track. Again, students should be allowed to make errors, and test their knowledge without fearing of the consequence. Knowing the system will provide feedback while allowing for continued progress helps alleviate such fears.

The benefit of e-learning will only be fully utilized if we understand how students learn so that educators can use this knowledge for future designs (Laurillard, 2002). This could lead to the design of a system that both understands student learning and presents challenges that facilitate learning without exhausting a student. This system would involve offering students continuous feedback while maintaining an ideal cognitive load so users do not become bored or overwhelmed. Such a system has the potential of sustaining students at their peak performance level for the entire learning process.

2.3 Game-based Learning

"By allowing the learning process to become informed rather than supplemented by processes identified with successful gameplay, instructors can maintain consistency and coherence without relying on extrinsic motivational interventions." (Begg, Dewhurst, & Macleoad, 2005, p.1)

Gamification is the term used when game elements are added to a non-game system in order to improve enjoyment of the experience (Deterding, Sicart, Nacke, O'Hara, Dixon, 2011). The application of gamification is an emerging phenomenon, one that warrants further research, especially in academic settings (Deterding, Dixon, Khaled & Nacke, 2011).

Games are helpful learning aids because they lower the cost of failure, give copious feedback, focus on well-ordered problems and allow students to see how they can accomplish their goals (Sandford & Williamson, 2005). They let students "learn by playing" without the need to consult a manual (Johnson, 2005). Games help break up complex concepts into simple manageable tasks. They are able to focus on building critical thinking skills while forcing the gamer to retain previously learned information (Gee, 2013). Gaming has no age limit, engaging students at every level (Byrd, 2016).

Games, when used in an online environment, can significantly improve how beginners learn by offering individualized, continuous feedback without the fear of failure that learners sometime encounter in a current learning environment. Games allow novice students to step outside the classroom, and learn by trial and error (Gee, 2005). In the game environment, you have a different identity, and mistakes made will not affect your actual identity or grade (Garris, Ahlers, Driskell, 2002). One example of this that proved successful at the university level was developed from the popular recreational game, Minecraft. Polycraftworld created a virtual chemistry lab, allowing students to combine polymers and witness the results, something that is not always feasible in an actual lab due to safety hazards (ScienceDaily, 2017). Just like with e-learning, online games have built-in feedback to reassure players or correct them when a mistake is made. Positive feedback, either with a reward system or through encouraging, positive feedback, is shown to promote creative thinking (Thornburg, 2010). Beginners are free to experiment and learn by playing in this environment.

Foreign language courses will often use games to improve student performance. Aside from the clear benefit of easy motivation for students to continually practice, these games help focus on well-ordered tasks (Murphy, 2012). For instance, a language learning game could focus on sentence structure, encouraging students to solely learn this concept. Students have a set objective and can accomplish this without being over whelmed.

In the last level of learning, students are expected to extend their thinking to complex tasks (Aungst, 2014). In a game environment, students can easily learn the rules, or strategy for success. People dislike chaos; therefore, they are always trying to find a pattern and make sense of everything (Koster, 2013). This can be used to reinforce complex thinking. This pushes the student to connect the elements of the game on their own, and in the end, to master the topic.

2.4 Teaching Engineers

An efficient approach to teach problem solving to students is to follow the levels of learning to complex thinking. This means teaching concepts as tools for problem solving, instead of surface-level facts. This can be accomplished at each level of the learning process. Add an incentive for students to continue practicing their basic knowledge. Allow mistakes and immediately correct them in positive ways to improve retention. Push students to make connections and apply their knowledge to in depth problems. Finally, provide the framework for complex thinking and let students think creatively.

Engineering students should learn in an active environment where cognitive load is sustained at a level that encourages peak performance, motivation is high and learning activities are sensitive to the specific needs of individual students. Repetition should be encouraged, especially when topics become increasingly difficult. Students have been programmed to avoid failure, and therefore struggle or fail to develop important skills. The concept of computer anxiety, a condition in which students experience a drop in self-esteem when confronting a computer, was commonly seen in the early introduction of e-learning (Connolly, Murphy, & Moore, 2009). Students are no longer nervous dealing with technology, but now feel this same self doubt when confronted with coding courses. The new term, programming anxiety, portrays the feelings many students experience when first presented with any new coding language. This is certainly the case for many students attempting to learn MySQL, a database query language.

Statistical concepts can also perplex students. An experiment tested the efficacy of a novel technique to teach the concepts of the Taguchi method to industrial engineering students. The technique removed the fear of statistics by focusing on the performance of different paper helicopters with varying wing width and length (Antony & Jiju Antony, 2001). Students learned the statistical approach to quality improvement by performing the experiment, and the analysis that normally frustrated them was more easily connected back to the knowledge gained. Students could learn by focusing on a simple task, eventually learning a difficult concept by relating it to something practical.

Gamification encourages a switch from the passive environment of the classroom to a hands-on, immersive learning style. Good learning games possess timely feedback, a reward system that drives students, a new identity for users, and engaging features, yet they remain underutilized in academia (Kazimoglu, Kiernan, Bacon & Mackinnon, 2012) (Gee, 2005). We have seen the successful use of games in language learning, training practices, and coding, but infrequently in education and rarely at the university level.

Games remove some stress from the learning atmosphere by encouraging practice and testing on completion rather than a single grade or score. They foster student learning and allow for mistakes to be made, all while challenging individuals and keeping them invested. If used in the academic realm, games could give students a chance to escape from the pressures of grades and deadlines, instead focusing on their own learning process.

2.5 Specific Aims

We seek to test the benefit of an interactive, self-paced e-learning environment among university students in an introductory Industrial Engineering course. This environment will be expanded to mimic a game, with a built-in reward system and exciting challenges. The goal is to build a stand-alone system in which each student will learn and demonstrate their knowledge of MySQL. Students will receive feedback after each completed task and future questions will emphasize areas of weakness, providing an individualized structure. The structure itself will improve with feedback. In addition, the self-paced system will allow students to move more quickly through material that they readily understand and get extra practice on new material.

Specific Aim #1: Determine whether the task load is more consistent for the game compared to current methods. The hypothesis is students using the game method will have a more consistent perceived task load, measured using a NASA-TLX scale, than students in the in-class lecture.

Specific Aim #2: Measure whether training with the game leads to faster understanding and greater skill acquisition than training with the current method. The hypothesis is students who participated in the game will perform better on the given assignment, including faster completion, versus students who were in the in-class lecture.

Following the current knowledge about the most effective ways students learn, we will analyze the cognitive load, through the NASA-TLX, and performance of students completing both learning methods—the game prototype and current classroom lecture. Students will complete an identical assignment following their learning method. Scores and time to completion will be recorded for every participant and compared across groups. We expect students completing the game method will have a more consistent perceived cognitive load on the task and will out-perform students in the current learning method. In a future, planned development stage, open-ended problem solving will be added in order to increase students' practical knowledge and overall student retention rates.

CHAPTER 3: METHODS

3.1 Participants

Fifty-four students enrolled in a sophomore-level Industrial Engineering course at the University of Iowa were given the option to participate in the experiment as part of their coursework. The course material covers basic coding and website design, and most of the students enrolled are at a Sophomore standing. Activities involved in the experiment, aside from a graded assignment completed by all students, were not graded. Students did not gain any advantage or disadvantage for their grade or coursework by deciding to participate. Forty-one participants students elected to participate in the experiment.

3.2 Design

The course meets once each week. The experiment was conducted over two consecutive class sessions, referred to as training sessions. Students were assigned randomly to two experimental cohorts. One cohort participated in the game in the first training session while the other participated in the current lecture. Cohorts then switched roles for the second training session. Students who did not wish to try the game were invited to participate in the normal class lecture and did not have to complete the surveys.

All participants completed a training session (consisting of one learning method, explained below) of the material for each week's assignment. The material for both weeks covered the MySQL database query language. Session one was an introduction to queries and session two expanded the material to cover complex queries, including multi-table join queries. After each training session, students were expected to complete an assignment utilizing the knowledge they had acquired. Students could work together and get help from the instructors as needed. Experiment activities were completed during the set classroom time.

3.3 Learning Methods

Participants in the experiment were exposed to two separate learning methods within their training sessions. In both learning methods, students were taught the learning objectives listed in Table 1. The "Training Session" column represents the session in which the learning objective was covered during the experiment, since each session focused on different learning objectives for the MySQL language.

Table 1: Learning objectives covered in both learning methods

Learning Objective	Description	Training Session	Game Level
1	Students will use the SELECT … FROM statement to display different columns from a table.	1	1
2	Students will use the grave accent to identify tables and columns in a database.	1	1
3	Students will use comparison operators, like >=, <> as part of the SELECT … WHERE statement to select rows within a table.	1	1
4	Students will use logical operators with SELECT … WHERE statements to select rows satisfying multiple constraints.	1	1
5	Students will use the LIKE comparison operator with WHERE to select pattern-matching data.	1	1
6	Students will differentiate grave accents and apostrophes.	1	2
7	Students will use the ORDER BY command to sort results.	1	2
8	Students will recognize appropriate applications of LIKE and equals.	1	2
9	Students will use the SHOW DATABASE command to view databases on a server.	1	4
10	Students will apply the USE command to select a database.	1	4
11	Student will use the SHOW TABLES command to view tables within a database.	1	4
12	Students will use the INSERT command to add information to a table.	1	3
13	Students will use the DELETE command to remove information from a table.	1	3
14	Students will use the JOIN command to combine information from two tables.	2	5
15	Students will use the DESC operator to order elements in a table.	2	5
16	Students will use the JOIN command to combine information from three tables.	2	6
17	Students will use aggregate functions to create distinct columns in a table.	2	6
18	Students will be able to construct a SELECT … JOIN … WHERE statement to extract information from a multi-table database described in a word problem.	2	7

3.3.1 Current

The Information Systems Design course utilizes a semi-flipped classroom educational approach, where students are expected to read the course material prior to lectures. However, there is no assessment on this material until the following week, and many students either read the material late or not at all. Class time is devoted to a short lecture with examples students can follow along with or simply watch. Once instruction is finished, the remainder of class time is devoted to a graded assignment, which students have the option to receive help to complete. Typically, a student will work through the assignment alone or with close peers. Should students have a question, two instructors—the professor and one teaching assistant—are available to resolve the problem.

While this learning method is not ideal for feedback, students do receive quick remarks from their peers, or delayed remarks from the instructors. However, the feedback received is not controlled and a student could receive incorrect explanations from their peers who are also trying to learn the material. Both learning methods provide feedback, but the current method is typically slower, and unstructured.

3.3.1 Game

The primary focus of the experiment was the analysis of participants' reactions to a novel learning environment; therefore, a prototype interactive learning environment was used. It will still be referred to as a game environment, but the actual environment consisted of quiz-like questions available to students through the university's learning management system, Canvas. Participants' performance determined their path through the activity.

When completing the game training, participants were given a set of online quizzes with questions that began with self-evident answers, then moved towards questions requiring conceptual recognition, recall, and ultimately application. This design follows Webb's four level approach to learning.

Participants are not required to know any MySQL prior to beginning the game. As previously mentioned, students have access to the course content, meaning that if they read the material on MySQL before attending the training session, they would likely finish the game quicker than those who did not. This would not necessarily be advantageous, however, as the game is structured to teach the same content to every student at the pace of each individual. The learning objectives are grouped into seven separate levels, as specified in Table 1. Within each level, students are presented with questions to teach and test those specific learning objectives. During the first training session, students completed levels 1-4, and during the second session they completed levels 5-7. The content in these levels corresponds to the current lecture material for that week.

Game levels consisted of a baseline quiz, mostly used to teach the learning objectives relevant to that level. If students received a perfect score on this, he or she had the opportunity to skip to the next level. However, if the student missed a question, the feedback would guide that student through to their next level. For instance, students who missed a question on the use of the grave accent were instructed to their next quiz, which consisted of extra practice on the use of grave accents in MySQL queries. There was a quiz on each level for students who missed more than three learning objectives, affording them the opportunity to practice all learning objectives within that level without excessive repetition. If they still struggled with a concept, feedback would instruct them to take the quiz on that specific concept.

3.4 Dependent Variables

3.4.1 NASA-TLX

Participants were asked to complete a NASA-TLX scale in order to rate their current task load. The six NASA-TLX parameters are: mental demand, physical demand, temporal demand, effort, performance and frustration. Students were provided with a short description of each. An example of a NASA-TLX the students completed can be found in Appendix A. In this experiment, we used the unweighted or raw NASA-TLX.

3.4.2 Graded Assignments

At the end of each training session, participants completed a graded assignment as part of their customary coursework and were asked to record their start and end time for the assignment. The game group completed a shorter assignment than the current group; in other words, in session one, students in the game group only completed questions 4-6 of the assignment found in the Appendix C, while students in the current group completed all 6 questions. This was because the first three questions were preliminary questions, which the game group had already practiced. In session two, the game group completed only one of the three graded assignment questions, the most difficult question of the set. In part, this was due to the fact that the current group only lasted around 30-40 minutes whereas the game took many students between 50-60 minutes.

The current group was asked to record their time on the identical assignment as the game group. In week one, the game group only completed questions 4-6, which was why we asked the in-class group to record their start time beginning with question 4. Week two was similar in that the in-class group recorded their start and end times for question 2 only.

3.4.3 Graded Assignment Results

All students in the course received a grade on each in-class assignments. Participants in the game group completed their training through the online system, meaning all of their in-class assignment grades could be recorded and averaged. The in-class group had students who opted not to participate, therefore, all remaining in-class assignments were used as the average for students' in-class scores. Any student who received a zero, likely due to absence, was removed from the average. The scores between groups were later compared to ensure that students participating in the game learning method were not performing significantly worse than their classmates. The expectation was for scores to be relatively similar between groups.

3.4.4 Game Flow

Participants' completion of the online quizzes, as part of the game training session, were recorded to track their path through the game. After completing a quiz, students were asked to mark their progress on the flow chart given in the packet, Appendix B. The online system also recorded which participants completed each quiz and when.

3.5 Procedure

For each experimental run, participants in the game group moved to a separate identical room. Every participant was seated in front of a computer for the entire duration of the experiment, learning method and graded assignment. Both groups were given a booklet with multiple NASA-TLX sheets, and on the second week, students were given a short survey about their experience. Participants in the game group also had an instructional page. The procedure for each group remained constant across both experimental runs.

In the game group, students were given a few minutes to login and get settled in the new room. The proctor then explained all experimental procedures mentioned in the booklet but allowed participants extra time to read through the steps. Once everyone in the group was prepared, each participant completed a NASA-TLX before beginning the learning method. Participants were stopped every 15 minutes to complete a NASA-TLX, and when they switched to the in-class assignment, they were reminded to record their start time. After they completed the assignment, participants recorded their end time, and on week two, students had the opportunity to complete a short survey on their experience.

The in-class group followed similar procedures, completing the NASA-TLX every 15 minutes and recording their start and end time for the assignment. However, they did not record their first NASA-TLX until after the lecture was complete. This allowed students to listen to the lecture as they would normally, and before starting the in-class assignment, document their task load.

CHAPTER 4: RESULTS

Students completed the NASA-TLX measures every 15 minutes during both training sessions. Students in the current group recorded their first measures post-lecture, while the game group completed an assessment before beginning the game. Since the first game group assessment occurred before they completed any activities, this value was used as a baseline, and the values from the second recording of task load were compared to the current group's first recording. Students completed about six task load assessments in the game group and five for the in-class group, however, the last assessment had only four to six participants per group as many students had already completed the assignment and left the experiment. With such a small sample, we chose not to use these values, instead comparing task load indexes across four trials.

Figure 3 illustrates total task load, the sum of the six rating scales, from each students' NASA-TLX assessment for all four trials each session. The scores are a combination of both game and current group. Session two's average task load was significantly higher than week one's, the 95% confidence intervals are (52.4, 58.8) and (43.1, 49.3) respectively.

Summed Task Load Scores Compared by Week

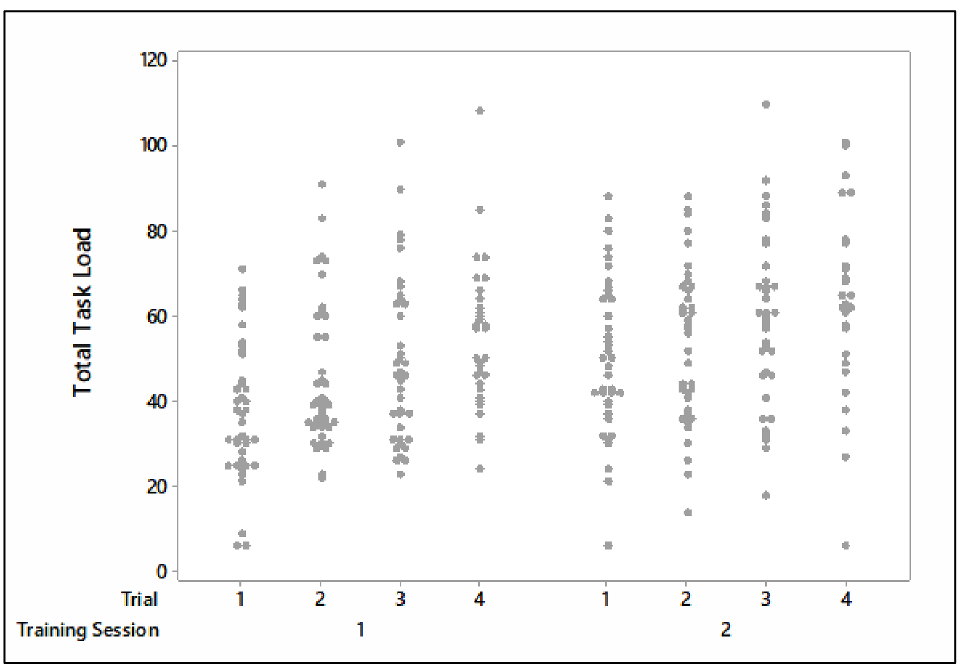

Figure 3: The Total Task Load (summed six NASA-TLX measures) of each participant is plotted by trial and split by training session.

In Figure 4 the total task load scores are split by group, with regression lines that represent the interaction term of training session and learning method. Table 2 shows the ANOVA output of the general linear model for the data. Participants are treated as a random variable and trial is a covariate for the data.

Summed Task Load Scores Compared by Session and Learning Method

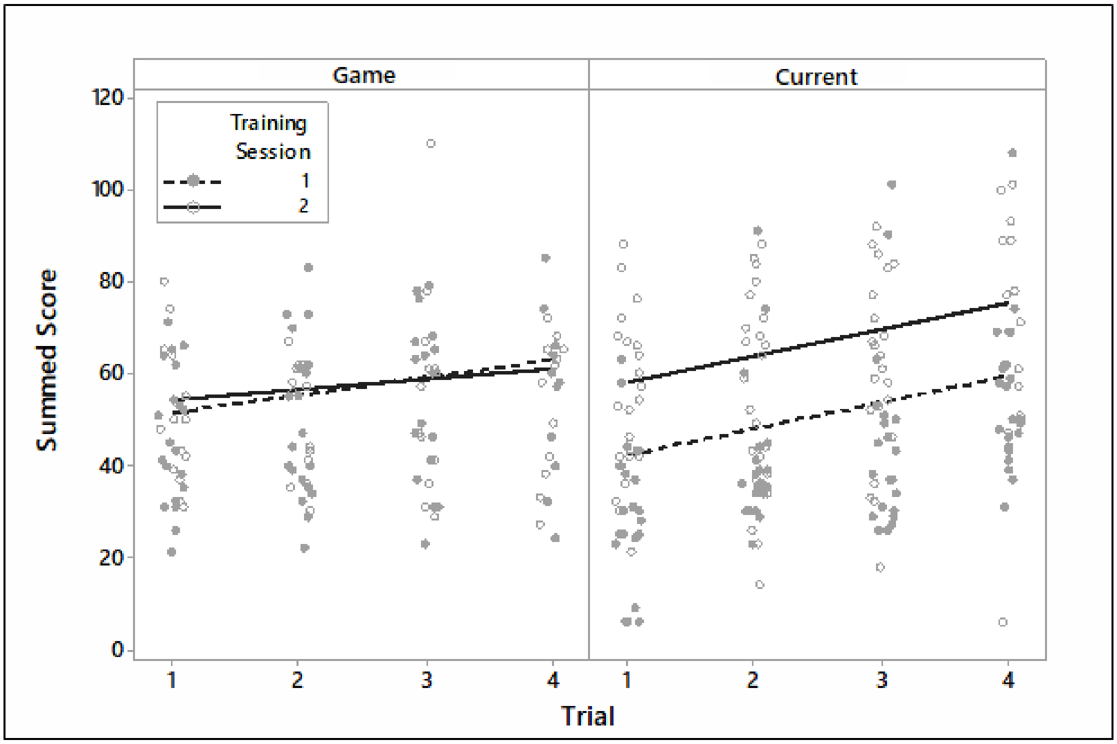

Figure 4: Effects of week and game interaction terms (regression lines) on the Total Task Load of participants.

Table 2: ANOVA table output obtained from the general linear model of the total task load, plotted in Figure 2.

Source	DF	Adjusted Sum Squares	Adjusted Mean Squares	F-Value	P-value
Trail	1	5234.3	5234.27	41.68	0.000
Training Session	1	1003.3	1003.30	2.08	0.315
Learning Method	1	0.0	0.02	0.00	0.994
Participant	40	32690.3	817.26	6.51	0.000
Trial*Training Session	1	117.7	117.66	0.94	0.334
Trial*Learning Method	1	920.9	920.85	7.33	0.007
Training Session* Learning Method	1	1867.4	1867.37	14.87	0.000
Error	246	30893.6	125.58		
Total	292	78208.4			

All parameters of the NASA-TLX were treated independently and compared by mean. Figure 5 shows the relationship of each means 95% confidence interval for all trials, sessions and both learning methods. The means and groupings of each parameter are shown in Table 3. Physical Demand is significantly lower than all other measures, and Performance has the highest mean. Mental and temporal demand, performance and frustration all overlap confidence intervals with at least one other measure.

Confidence Intervals of the Mean for Each Parameter of the NASA-TLX

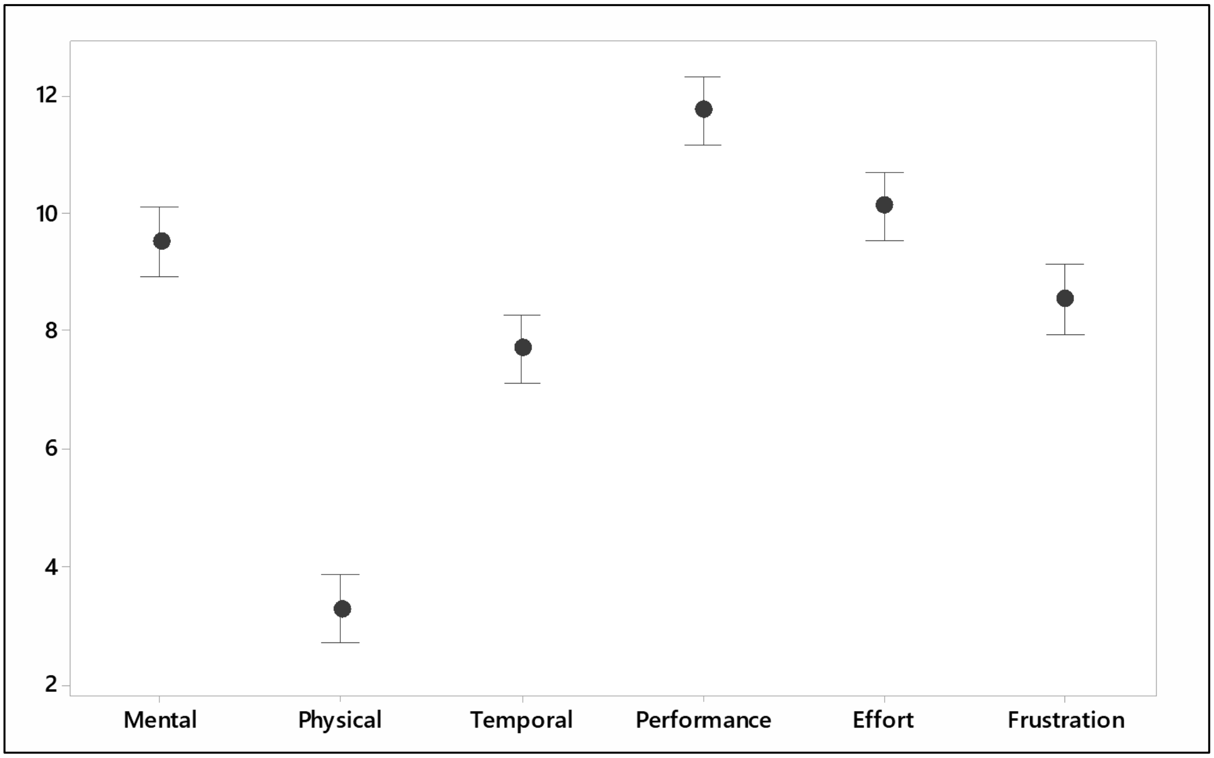

Figure 5: Interval plot of all individual task load criteria measured (mental demand, physical demand, temporal demand, performance, effort, frustration) with a 95 percent confidence interval of the true mean for each parameter.

Table 3: Tukey pairwise comparisons for each parameter of the NASA-TLX, shown in Figure 4.

Factor	N	Mean	Grouping
Performance	293	11.751	A
Effort	293	10.119	B
Mental Demand	293	9.515	B C
Frustration	293	8.539	C D
Temporal Demand	293	7.696	D
Physical Demand	293	3.263	E

Although a standard part of the NASA-TLX, physical demand seemed irrelevant to this experiment, and from the comparisons of all six task load measures an outlier measure (Table 3). For the remainder of our analysis, we will remove the physical demand score from the sum, resulting in a new max task load 100. Figure 6 has the same constraints added as Figure 4, but summed scores do not include physical demand.

Total Task Load, without Physical Demand

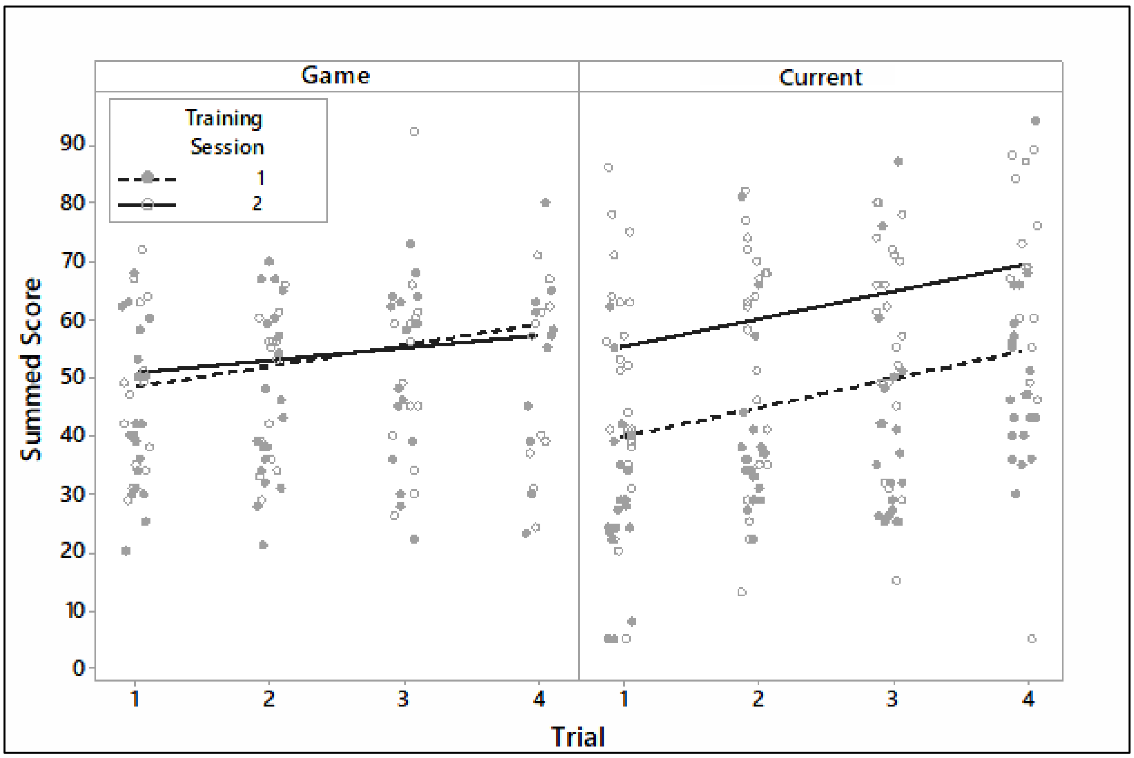

Figure 6: Effects of training session and learning method (regression lines) on the Total Task Load of participants, with physical demand removed. Data is split into two groups: the current and game group.

Performance has an adverse effect on Total Task Load compared to the other five parameters. For instance, performance has a non-significant p-value (.656) for the trial variable, while all other parameters returned a significant p-value (0.000). Performances scores across trials also returned a negative slope for two cases of interaction between training session and learning method, session one current and game.

Four Main Task Load Factors

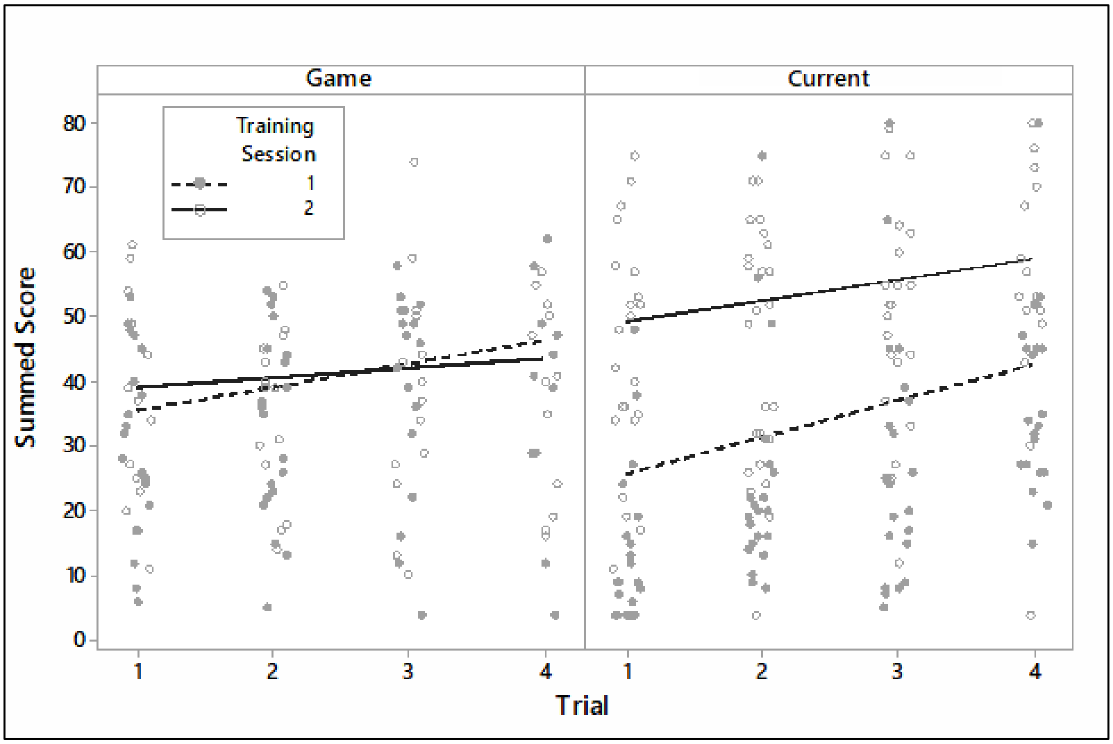

Figure 7: Effect of week and game interaction terms (regression lines) on the four relevant task load criteria.

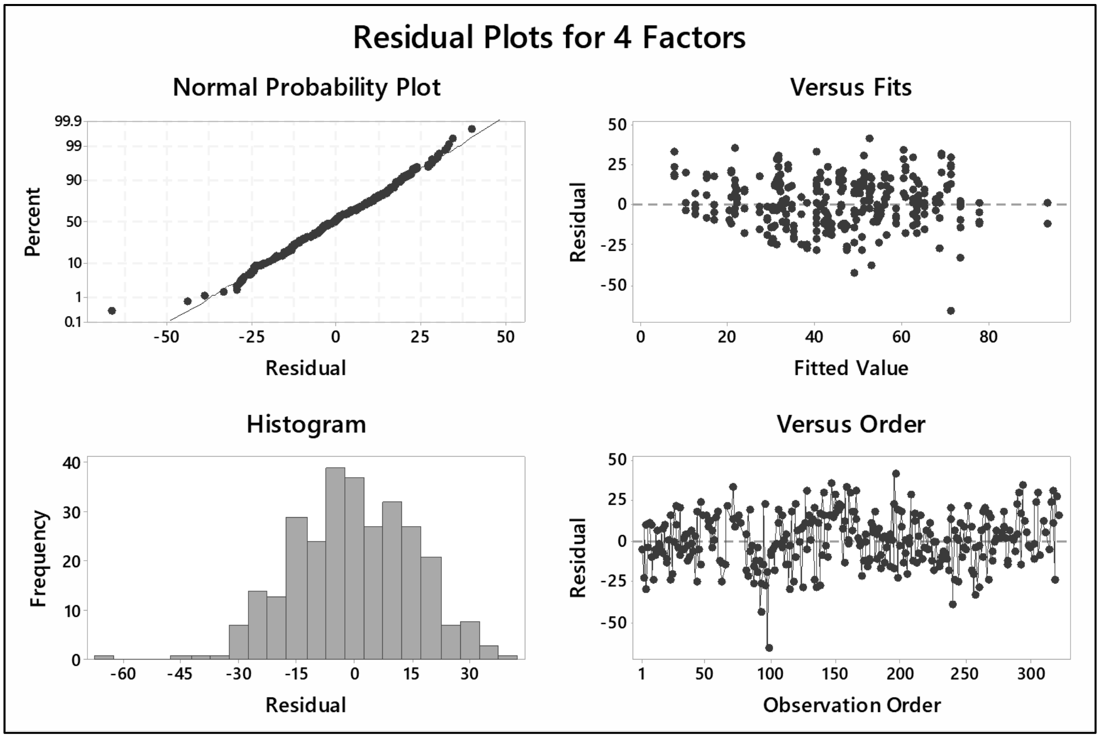

Figure 8: Residual plots of the general linear model of the four task load factors plotted in Figure 7.

Table 4: ANOVA table for the regression model of the four task load factors plotted in Figure 5.

Source	DF	Adjusted Sum Squares	Adjusted Mean Squares	F-Value	P-value
Trail	1	8716	8715.64	36.32	0.000
Training Session	1	5315	5314.57	2.98	0.295
Learning Method	1	84	84.21	0.09	0.798
Participant	40	60983	1524.57	6.35	0.000
Trial*Training Session	1	1135	1134.68	4.73	0.031
Trial*Learning Method	1	1789	1788.65	7.45	0.007
Training Session* Learning Method	1	7781	7780.72	32.42	0.000
Error	246	59040	240.00		
Total	292	162461			

Students recordings of their perceived performance are inversely related to other NASA-TLX measures. This is seen in the negative slope and the decreased variance of Total Task Load, standard deviation is 18.870 without performance and 17.796 with performance added (this is not a significant difference, p-value = .231). Based on these observations, performance was removed and analyzed separately, shown in Figure 9.

Perceived Performance Plotted Across Trials

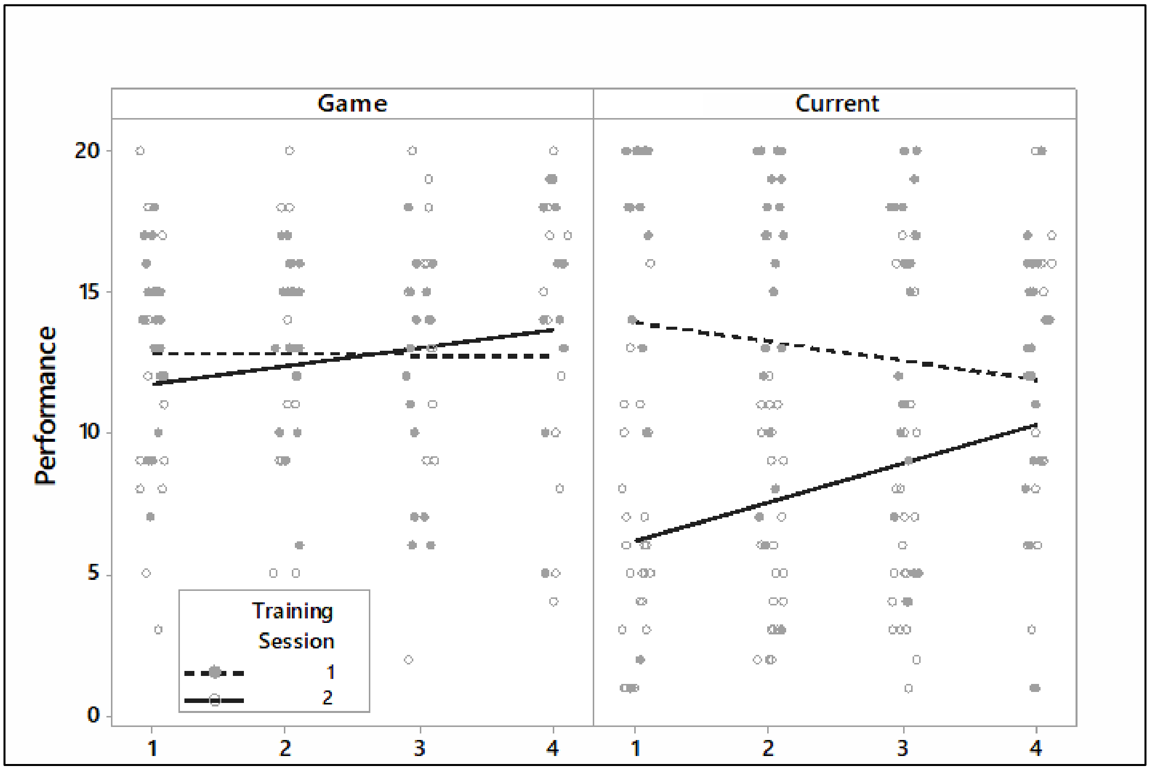

Figure 9: Effect of game and week interactions (regression lines) on the participants' perceived performance.

Table 5: ANOVA table for the regression model of the four task load factors plotted in Figure 9.

Source	DF	Adjusted Sum Squares	Adjusted Mean Squares	F-Value	P-value
Trail	1	3.46	3.455	0.20	0.656
Training Session	1	538.86	538.858	4.83	0.223
Learning Method	1	3.05	3.048	0.05	0.845
Participant	40	2052.54	51.314	2.96	0.000
Trial*Training Session	1	175.17	175.168	10.11	0.002
Trial*Learning Method	1	3.34	3.339	0.19	0.661
Training Session* Learning Method	1	477.19	477.195	27.55	0.000
Error	246	4261.44	17.323		
Total	292	8516.81			

Participant Score Distributions by Training Session and Learning Method

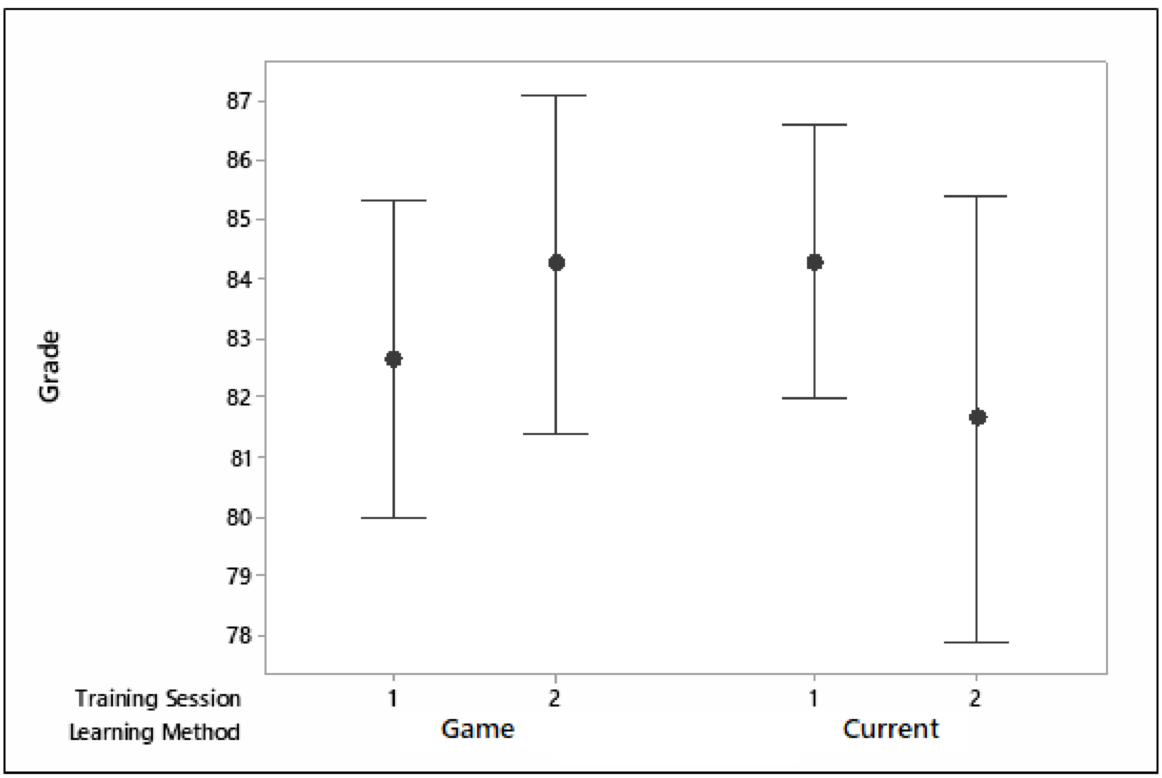

Figure 10: The 95% confidence interval of the mean score on the graded assignment, by week and group assignment (game or current).

Table 6: ANOVA table output for the comparison of means within an experimental group across training session.

Source	DF	Adjusted Sum Squares	Adjusted Mean Squares	F-Value	P-value
Factor	3	7.766	2.589	0.78	0.510
Error	89	296.492	3.331		
Total	92	304.258			

Table 7: Tukey pairwise comparison output for the mean scores within an experimental group across training session.

Factor	N	Mean	Grouping
Scores: Week 1, In-class	28	21.071	A
Scores: Week 2, In-class	15	21.067	A
Scores: Week 1, Game	21	20.667	A
Scores: Week 2, Game	29	20.414	A

*Means that do not share a letter are significantly different.

Part of the experiment was to have each student record their time on a set assignment. In week one, the in-class group completed six questions on basic MySQL concepts, while the game group only completed the last three questions. Each group recorded the time it took to complete questions 4-6 for that week's assignment. In week two, the in-class group completed three advanced MySQL questions, while the game group only completed the second question of that set. Again, each group recorded their time from start to finish for question 2 only. Results are illustrated in Figure 10 below and show that the game group took longer to finish week one's assignment, but finished significantly faster in week 2.

Graded Assignment Completion Time

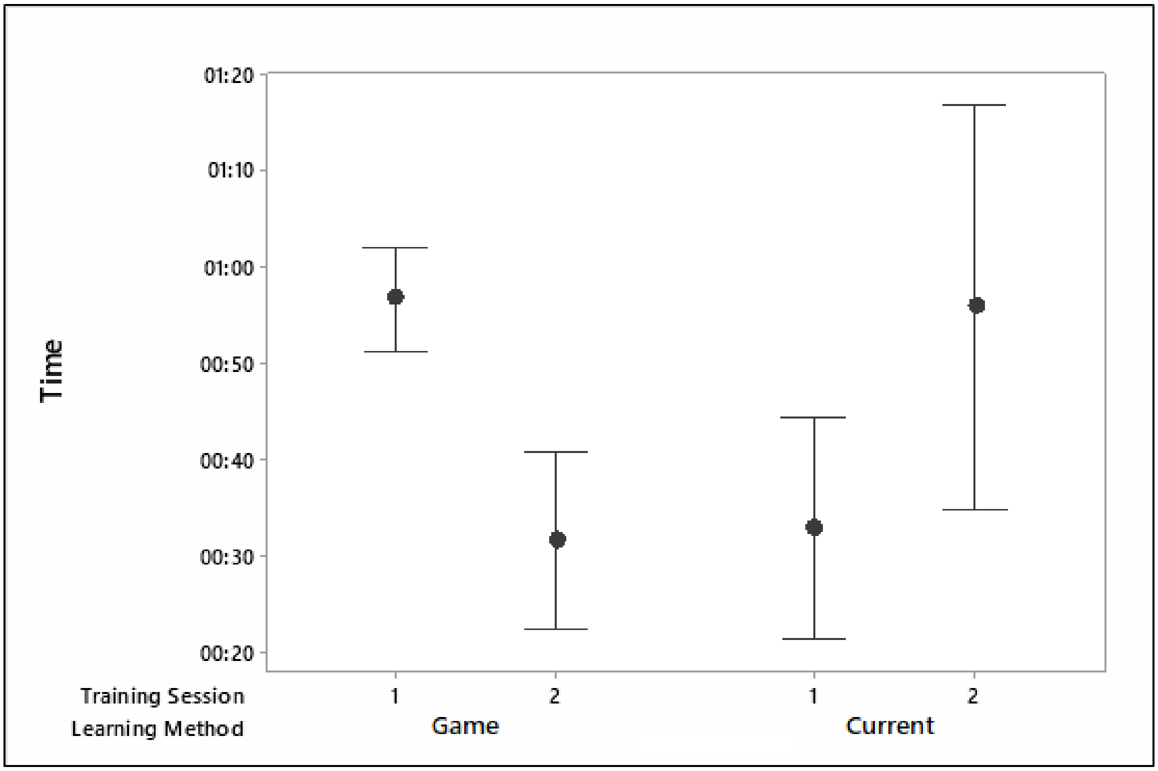

Figure 11: Plot of each participant's time on the graded assignment, split by week and group assignment.

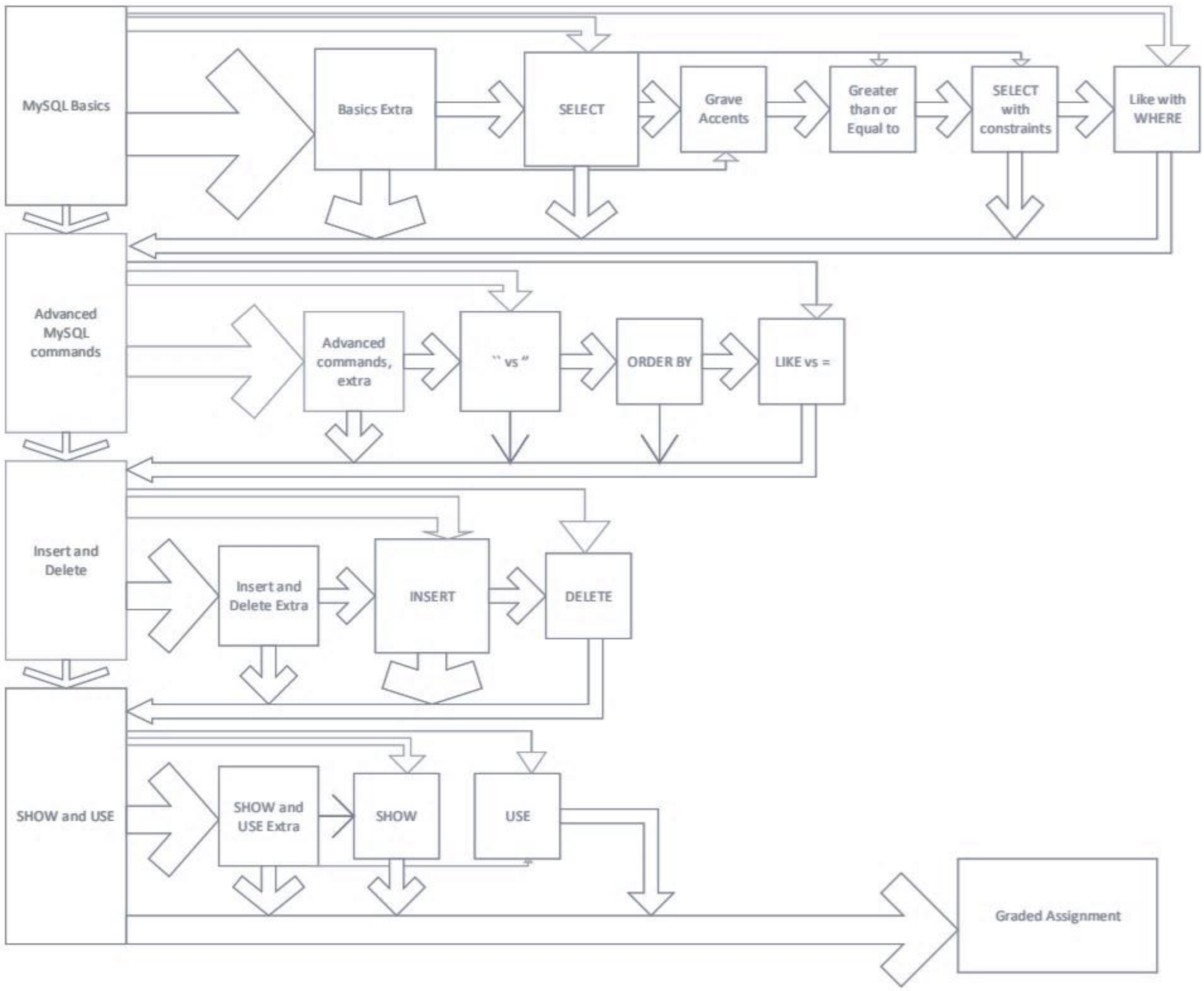

Figure 12: Student flow within the game activity on week one.

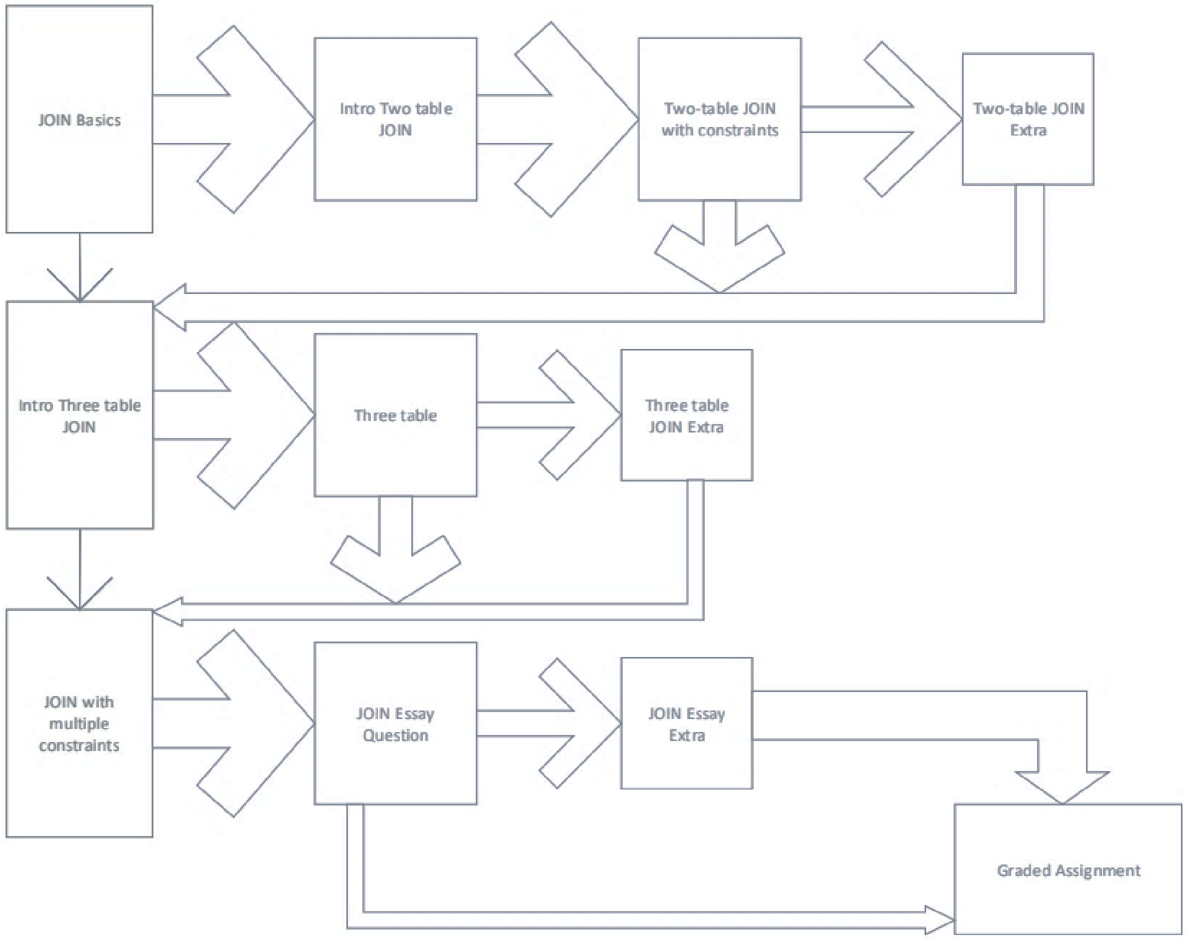

Figure 13: Student flow within the game activity on week two.

Out of the 41 participants, twenty-one completed the post-experiment survey after session two. Fourteen participants checked current for their preference in learning method, six checked game and one participant checked both options. The results to the seven Likert style questions are below, with mean and standard deviations. The category referenced was found by subtracting and adding the standard deviation to the mean and rounding to the nearest Likert category. Participant comments are available in Appendix E.

Table 8: Participant post-experiment survey results

Question	Mean (Standard Deviation)	Category	Game First: Mean	Game Second: Mean
I was prepared for the assignment after listening to the in-class lecture.	4 (1.18)	Slightly Disagree - Agree	3.67	4.25
I was prepared for the assignment after taking the online quizzes.	3.62 (1.02)	Slightly Disagree – Agree	3.33	3.83
I had to ask for help several times to complete my Intro to MySQL assignment (Unit 3a).	4.3 (1.7)	Slightly Disagree – Strongly Agree	5.4	3.36
I had to ask for help several times to complete my Complex MySQL queries assignment (Unit 3b).	3.95 (1.94)	Disagree – Strongly Agree	5.11	3.08
I wish there was more instruction prior to completing the assignment.	3.95 (1.28)	Slightly Disagree – Agree	4.67	3.42
I have adequately learned MySQL and have confidence in my ability to use it on my own.	3.5 (1.1)	Disagree – Agree	3.42	3.6
The different learning methods did not affect my performance.	3.1 (1.1)	Disagree – Slightly Agree	3.3	2.83

Participants' final exams were collected and compared by group assignment, completing the game method first or second. Only questions involving MySQL topics were used. These scores were also compared to the final exam of students completing the course the year before the experiment took place (2017). Across all MySQL questions, the 2018 group, who completed the experiment, performed better with a significant p-value of .015. Some of the MySQL questions changed between years, in the second comparison, using only identical questions, the averages were not significantly different, p-value of .074, but students in 2017 did have higher scores.

Figure 14 shows the percent of participants who answered each MySQL question correctly on their final exam. Exam questions can be found in APPENDIX F. Participants are split into groups based on when they participated in the game, either session one (1st) or two (2nd). Questions were removed if the percent correct was identical between groups.

Comparison of Participants Final Exam Performance by Question

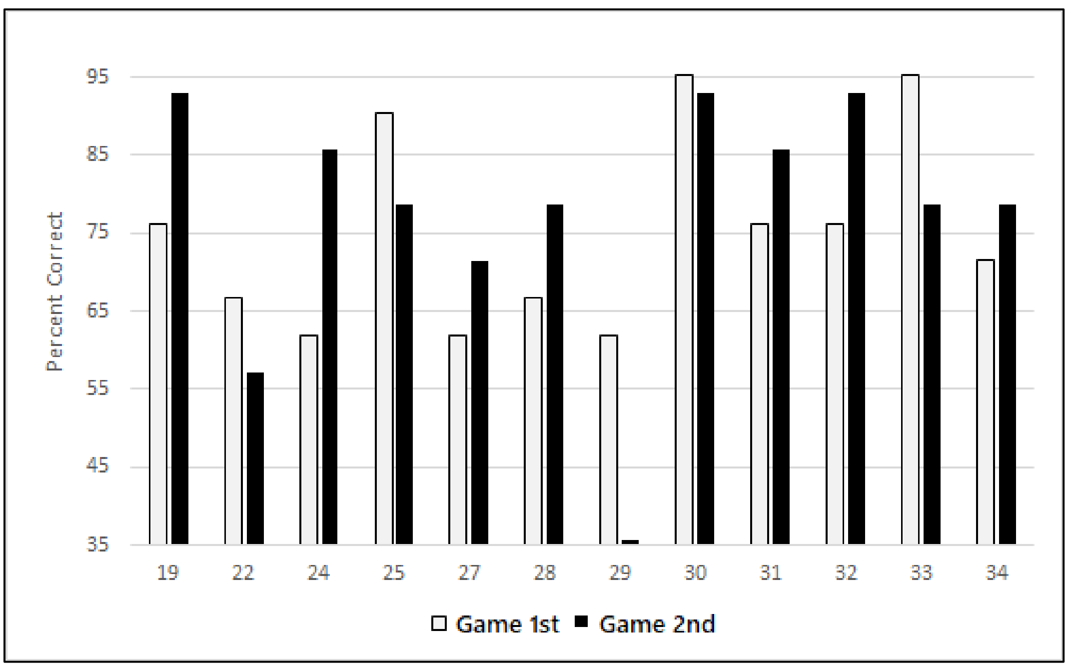

Figure 14: Participant performance on individual final exam questions that covered MySQL topics, grouped by completion on the game learning method.

CHAPTER 5: DISCUSSION

The total task load of all participants across the four trials is shown in Figure 3, split into two groups, training session one and two. In both training sessions, the overall task demand rose on average as the students worked. There are clear clusters of student scores around 20-30 (out of a possible 120) in the first three trials of session one, suggesting very low task demand at the very beginning with the most basic material. Session two is more varied, with student scores ranging from 6 to 70 on the first trial alone, suggesting that many students were already experiencing high task load at the beginning of the exercise. The increase in overall task load from training session one to two is clearly shown in this graph. Session two's 95% confidence interval for the true mean doesn't overlap with session one's confidence interval, suggesting that the overall task demand was higher in the second week than in the first.

Figure 4, which splits the data by learning method, also supports a higher total task load in session two. The regression lines for the interaction variables (training session and learning method) are clearly different, suggesting that the rate at which the task demand increases over the duration of the experiment depends on the learning method and training session. The current group, which participated in a lecture, shows an almost twenty-unit increase in task load from session one to two. The game group, completing the learning game, shows no increase from week one to two; the interaction lines actually intersect.

In Table 2, which shows the ANOVA table output of total task load, all factors with p-values less than .05 are significant. Although the learning method main effect is not significant, the interaction of training session by learning method is significant. The interaction of training session by trial was also significant. Figure 4 illustrates the pattern behind both of these significant interaction terms. The interaction of training session by learning method is evident in the average task load on the left and right half of the graphs. The participants in the current condition experienced much higher task load in the second week than they did in the first. Apparently, participants in the current condition were more stressed with the difficult material than the easy material, but the task load was relatively constant for the participants in the game condition. The slope of the lines is related to the interaction of trial by learning method. The task load index increased faster over the course of the training for the current condition than in the game condition. This indicates that the participants in the game condition had a more uniform stress level, while the stress of participants in the current condition grew more quickly as time progressed.

The physical demand measure of the NASA-TLX was included to maintain the integrity of the assessment. We did not expect to see any significant differences as students moved through the activity, or from sessions one to two. However, there was an increase in physical demand recorded by the students across trials, and there was a significant difference from session one to two of the current group. The description for physical demand is 'How physically demanding was the task?'. It was not specified that this meant the strenuousness of physical activity required. Therefore, students could have given the physical demand a score from simple actions and assumed it increased as they went through the assignment, since other task levels increased.

Figure 5 shows the confidence interval of the mean recorded scores from all parameters of the NASA-TLX. These values and their groupings are given in Table 3. Physical demand and performance are significantly different from all other parameters. The tasks were not meant to be physical demanding, and the participant scores reflected this, as seen in the significantly lower average score. Because it was such an outlier and presumably not part of the task load for this experiment, physical demand was removed from the total task load.

Figure 6 illustrates the total task load of students after physical demand is removed from the analysis. The patterns are very similar to the earlier analysis, with the game group having more consistent task load across both weeks and trials.

The performance component was also an outlier within the task load index. As Table 3 indicates, it is significantly larger than all the other measures. Also, where all the other task load index components tended to vary with trail, the performance component had a non-significant interaction with trial, and the small effect that it did have was actually in the opposite direction, decreasing with trial where every other task load component increased with trial. Figure 7 illustrates the task load without the performance component. Again, the patterns are similar to the earlier analysis, but some subtle features become more prominent. The variance increases when performance is removed (e.g., comparing Figures 6 and 7).

Presumably, when a participant is doing well on the assignment, they respond with a lower demand rating and a higher performance rating. The reverse was also true: a struggling participate will respond with a higher frustration rating and lower performance rating. Consequently, the performance rating tends to mitigate the other effects, so to understand the other effective, it will be helpful to remove the performance rating.

Thus, Figure 7 illustrates the remaining four factors: mental demand, temporal demand, effort, and frustration. The goal of our educational approach was to keep frustration and temporal demand low and have a consistent mental demand and effort. The students should be challenged but not cognitively overloaded to the point of resentment toward the task. The current group experienced a significantly higher average frustration and temporal demand than the game group in session two. They also experienced a greater increase in mental demand in session two and greater increase of effort in both sessions. After analyzing these four factors individually, all follow similar patterns, and can be grouped together for the remainder of the analysis.

The regression lines shown in Figure 7 show a larger increase across trials for the current group. Session one showed a 5.65-unit increase each trial and week two 3.27-unit increase. The game group experienced a 3.63 and 1.45-unit increase respectively. The starting task load in the current group from session two was over 8 units higher than the game group.

Returning to the performance component, Figure 9 shows the plot of all individual participants performance measures, with regression lines of the interaction between game and week variables. For the current group, perceived performance started high in session one and decreased as the activity progressed. Likely, students underestimated the difficult of the assignment and began to record a lower performance when the experienced the challenges. In session two, participants experiencing the current training had the inverse effect: their perception of performance was initially low, then increased, which is consistent with students initially thinking that they were not going to succeed in this activity, then gaining understanding as the exercise progressed. The game group's scores were within 1-2 units of each other through all trials. The game participants also increased their self-assessment of performance across session two's trials.

Student scores on the graded assignment were recorded for each group. In session one, the current group outperformed the game group 95.78 to 93.94 (scores were out of 100). During the second session, score results flipped, with the game group averaging 95.76 and the current group at 92.79. The difference in scores between training session and learning method interactions was not significant, even while their self-assessment of performance was significant.

The two flow diagrams (Figures 11 and 12) represent the movement of the students through the game activity. Assignments are labeled with their respective learning objectives. This diagram shows the bulk of student flow and illustrates which learning objectives students struggled with the most. For instance, on the first level, Basics, SELECT and LIKE with WHERE were the hardest concepts. With this knowledge, we can refine this level to add extra help to guide students through those concepts.

As mentioned, students who participated in the game activity did not experience a significant change in their NASA-TLX ratings across sessions. The game group had an average task load from the four main factors of 34.44 (out of 80) in session one and 36.83 in session two. The current group recorded a mean of 25.64 in session one and jumped to a 46.26 the second session. This increase for the current group shows the learning method is not maintaining a consistent task load, resulting a high task load or stress from students when topics increase in difficulty.

The regression lines show an increase in task load as the activity progresses, this is expected since students are shifting from the game/lecture environment to their graded assignment where they are expected to know the topics. During both sessions students in the current group experienced a higher increase in task load between recordings. It may be that students in the current group were less engaged with the first few, easier questions, but then felt much more stress when the problems became hard. In the game group, students were used to performing the tasks through the environment, and did not experience such an increase when expected to complete their graded assignment. This pattern supports specific aim one, that the game environment will provide a more consistent task load for students.

By having students record the time it took to complete the assignment, we were able to gain more evidence on the benefit of a game environment. Session one students took longer in the game group, likely due to the unfamiliarity with a specific software skill needed to complete the assessment assignments, the MySQL server software, that was not introduced in the game assignment but was introduced in the lecture, which was an error in the experimental design. Another factor may have been that the current group in session one had three extra questions prior to their start time in which to set up the MySQL workbench. During session two, we noticed a reverse in the results, as the game group finished well before the current group. The second sessions assignment covered more advanced topics, and usually took students the entire time to complete. The game method, which led students to interact with the material rather than passively listening, showed evidence of improved performance on the advanced topics, supporting the second specific aim. Improvements can be made to the game to allow an easier transition into the MySQL environment.

Survey responses showed a preference for the current method over the game. The results to the Likert style questions are shown in Table 7. These questions, when split by group (either game first or game second) student who completed the game first showed a higher agreement with the need to ask for help in both sessions. Participants who completed the game second, showed a lower agreement of needing help in session two. This group also had a higher confidence in their understanding of MySQL.

Figure 14 shows the percent of participants who completed each MySQL question correctly on their final exam. Questions in which performance was identical between groups were removed. Questions 24 and 29 had the biggest difference in scores based on when participants completed the game learning method. Question 24, deals with the MySQL operator, DISTINCT. While DISTINCT is not one of the specified learning objectives, it is taught with the DESC operation, a topic in session two. Students who completed the game second, performed better on this question than students who completed the game first. Question 29 requires student to think conceptually of the MySQL language structure. This question tends to be difficult for students, however students who completed the game first, had more success with this question then those that completed the game second. Having more practice on beginner content, with the game method, likely helped the students think about the structure of the language as they were learning it.

5.1 Review of Specific Aims

5.1.1 Specific Aim 1

The hypothesis for specific aim one was students participating in the game group would have a more consistent perceived task load than students in the current group. Analyzing only four parameters of the NASA-TLX (mental demand, temporal demand, effort and frustration) shows a significant difference between the learning methods. The game group had no significant difference in average task load between sessions, while the current group had a significantly lower load session one and significantly higher session two. In addition, the increase in the task load between trials in both sessions was greater in the current group than the game group.

Mental demand, frustration and temporal demand were all lower in the current group in session one, however only effort was significantly lower. This suggests the students did not feel they had to put forth much effort in session one, which resulted in a spike in session two when the tasks required more effort. This jump was not seen in the game group, therefore students felt they had a consistent effort, temporal demand, mental demand and frustration level. The hypothesis for specific aim one can be confirmed from this evidence.

5.1.2 Specific Aim 2

The hypothesis for specific aim two, was students completing the game method would score higher on the graded assignment and complete the assignment faster than the current group. In session two, the game group finished the assignment on average twenty-four minutes faster than the current group. The score distributions had no significant difference, but the performance was slightly higher in the game group session two. Participants also rated their performance higher in the game group in session 2. The participant survey results showed participants who completed the game in session two slightly disagreed with the statement, “I had to ask for help several times to complete the complex MySQL queries assignment (session two)”, while the participants in the current group agreed. Also, participants who completed the game in the second session rated a higher understanding of MySQL. There is evidence to believe students perform better with the game method for higher level problems, in the case of the experiment, complex MySQL queries.

5.2 Limitations:

The game group performed faster and with lower stress levels in the second week of the experiment, which might be a result of having a superior training experience the first week, when that cohort listened to the in-class lecture instead of the playing the game. However, not all participants opted to participate in the game activity, meaning there was a mix of both current and game participants from session one in session two's current group. As a whole, this group took longer to complete the graded assessment and rated their demand on the NASA-TLX scale higher.

With the game environment, students are learning MySQL concepts away from the MySQL server and are not interacting with the MySQL workbench software, which is required in the assessment. In a typical lecture setting for the class we are analyzing; the instructor performs MySQL commands in the workbench as students watch. During session one, the instructor performed a demo for all students before they were split into two groups. Unfortunately, the game group was switched into the game environment and when asked to complete their assignment in MySQL, many forgot about the demo and needed extra help. The current group had the advantage of opening MySQL during the demo and working along with the instructor to get comfortable with the workbench. There are opportunities to improve the game environment so that students are able to interact with MySQL, while still maintaining the advantage of allowing students to move at their own pace and receive individualized feedback.

CHAPTER 6: CONCLUSION

This experiment compared the task load and performance of participants in two different educational frameworks, in order to determine whether an educational approach featuring a quiz-like game yielded more consistent task load and better performance acquisition than a more current teaching approach. Within our forty-one industrial engineering students learning the language of MySQL, task load recorded with the NASA-TLX was more consistent in a gaming environment. We expect that the balanced task load reflects students having a longer period within the average cognitive load, neither bored nor overwhelmed by the educational material, which should be associated with more effective learning. The evidence suggests that the hypothesis for specific aim one was confirmed, that students using the game method will have a more consistent perceived task load. Performance on higher level tasks improved, this was evident in the quicker completion times and higher scores of students in the game group in session two. The hypothesis for Specific Aim Two, that the game would lead to faster understanding and greater skill acquisition, was only partially confirmed. The performance of participants in the game group was better on the complex queries of the second week, but weaker the first week. The poor performance in the first week may be the results of a flaw in the experimental design. On the balance, we are led to believe that students learning complex concepts, such as coding, can benefit from a gaming, e-learning experience. Particularly for complex tasks, the novel approach seems to improve their speed of learning and reduce the task load, leading to an improved learning experience.

The game environment was designed to provide a tight structure when students begin the learning process, and slowly add in elements that allow more freedom in student responses. This experiment focused primarily on the highly structured stage and assessed performance with a less structured state. Previous research suggests that learning may be most effective when the learning environment facilitates trial-and-error processes with immediate, informative feedback to encourage growth. Students experienced a small increase in task load as they worked towards more complex tasks, the increase in task load was significantly smaller than the increased task load perceived by the control group that listened to a lecture before completing the assignment. This learning environment allowed students to comfortably begin the tasks, with high levels of success and continue through complex topics without overwhelming them.

This learning structure can be expanded to other courses by emphasizing initial, highly structured introductions that emphasize information recognition and recall, then working towards more open-ended exercise. When topics are first introduced, the answers should be easy to find and interpret, but as learning objectives increase in difficult it is up to the learner to recall pertinent information. As learners continue to expand their base, questions will involve deep understanding and multiple concepts. This gives the learner the power to expand their knowledge, since they have the tools available to them. The electronic learning system should be designed to provide immediate, informative feedback, particularly in the early stages of learning.

University courses can be designed for more efficient learning. They can be designed to invoke less distress in students and promote an environment for consistent educational growth. This increase in efficiency is likely to make more students, and students who begin their studies with different backgrounds and experiences, gain the education they seek faster and with higher levels of success, ultimately reducing costs, reducing the drop-out rate, and generally increasing access to higher education.

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Appendix A: NASA-TLX

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Very Low — Very High

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed were you?

Very Low — Very High

APPENDIX B: INTRODUCTION PACKET FOR PARTICIPANTS IN THE GAME GROUP

Welcome to the MySQL Game!

Information Systems Design IE:3500

Unit 3

Thank you for your participation in this experiment, this is entirely voluntary and if you feel uncomfortable with this learning style you have the option to leave at any time and complete the current course work. Over the next two classes we are going to try a novel learning method, meant to engage and test your abilities. You will be presented with a series of questions that will cover the course material, and challenge you to learn the MySQL language. It is important you give your best effort on each question, since the concepts will build, helping you fine tune your skills.

While the game is structured to teach you the concepts of MySQL, you may not get every question correct. By following the game structure, you will have opportunities to practice all necessary material and fix any mistakes that may occur. This is a learning tool, don't be frustrated if certain levels take longer than others or if your path is different from your neighbors. Every question and the comments that follow are designed to help you, think of them as clues that will help you break the code of MySQL.

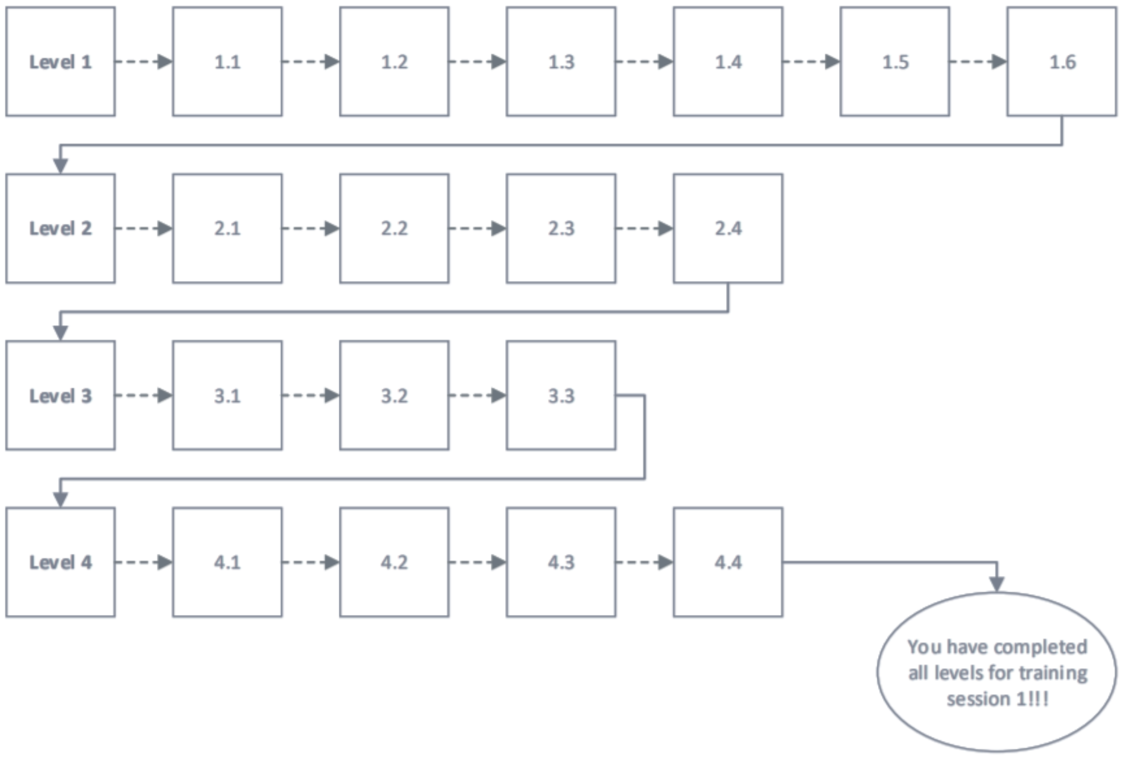
There are seven levels you will complete. Each level has a set amount of learning objects that you will demonstrate your mastery of, and move on to the next level! This assessment is identical to the current course work, so you are not expected to do more than the rest of the class.

Week 2:

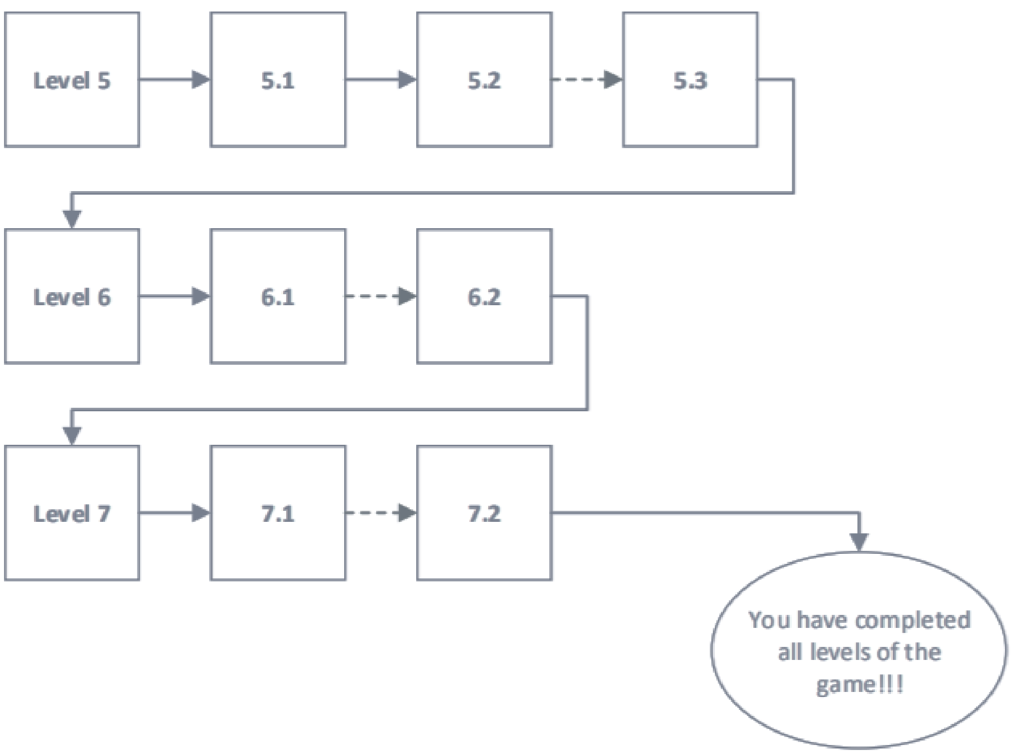
1. Begin with Level 5, you are only expected to know the concepts from the MySQL intro, everything else will be presented within the questions.
2. Complete all bolded quizzes
3. Only take quizzes 5.3, 6.2 or 7.2 if your feedback informs you to.
4. Please denote every quiz you take on the flow chart!
5. The questions do not always have prompts, often there is an outputted MySQL table and you are expected to complete the MySQL statement. This is to help you understand the pattern on the workbench, and save reading time!

If there are any questions, please inform the instructor, otherwise you may begin!

Game Flow Chart: Session 1



Game Flow Chart: Session 2



APPENDIX C: GRADED ASSIGNMENTS

Session 1: Introduction to MySQL

Objective: Learn how to make queries in MySQL

Methods: Use the SQL Editor in the MySQL Workspace to practice MySQL.

Write a multiline script that performs the following actions:

1. Select the world database.
2. Read all the rows and columns of the countrylanguage table (the workspace will limit this to 1000 by default).
3. Read just three columns of the country table. Choose the columns yourself. Be creative – don't just choose the first three.
4. Read all the columns of the country table, but apply a WHERE constraint that is a logical combination (e.g., using AND or OR) of both a numeric value and a string value. Again, be creative – everyone's constraints should be different.
5. Add a row to the city table.
6. Delete the row that you just added to the city table. Be careful not to delete any rows that you did not intend to delete.

Session 2: Complex MySQL Queries

Objective: Practice making more complex MySQL queries

Methods: Write queries for the World database that accomplish the following tasks. Comment your queries explaining your logic. Save these in a single SQL file and submit them to the drop box.

1. Return a table of the average life expectancy for each region in the world. Your list should include the region and the average life expectancy. The first few rows should be:

	Region	Average LifeExpectancy
	Australia and New Zealand	78.80000
	Nordic Countries	78.33333
	Western Europe	78.25556
	British Islands	77.25000

2. Create a list of a city's population as a percentage of the total population. List only those countries that have a LifeExpectancy greater than 73.0 and cities that have a population greater than 200,000 people. Order your list with the highest percentage first. The first few rows should be:

	Name	City	Percentage
	Singapore	Singapore	112.6362
	Macao	Macao	92.4947
	Uruguay	Montevideo	37.0393
	Chile	Santiago de Chile	30.9247
	Libyan Arab Jamahiriya	Tripoli	30.0089
	Hong Kong	Kowloon and New Kowloon	29.3128
	United Arab Emirates	Dubai	27.4142
	Macedonia	Skopje	21.9515
	South Korea	Seoul	21.3082
	Cuba	La Habana	20.1411

Note: Oddly enough, Singapore City's population exceeds 100% of the population of the country... This is because the database information has a higher city population than the country population. Don't worry about this.

3. Create a list of all the cities in which English, French or Swedish is spoken by at least 50% of the residents of the country in which the city is located. Include city name, country name, language the country speaks, and the percentage. The result may start with rows like:

	City	country	LanguageSpeaks	Percentage
	Sydney	Australia	English	81.2
	Melbourne	Australia	English	81.2
	Brisbane	Australia	English	81.2
	Perth	Australia	English	81.2
	Adelaide	Australia	English	81.2
	Canberra	Australia	English	81.2
	Gold Coast	Australia	English	81.2
	Newcastle	Australia	English	81.2

APPENDIX D: PARTICIPANT POST-EXPERIMENT SURVEY

Please note the time when you begin working on your in-class assignment, question 2, and when you complete the question!

Start time: ___________________ End time: __________________

After completing each learning method (current and game) which would you prefer in the future?

____ Current (In-class lecture)

____ Game (Online quizzes)

Please check the box that accurately represents how you agree/disagree with the statements provided.

Question	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
I was prepared for the in-class assignment after listening to the in-class lecture.						
I was prepared for the in-class assignment after taking the online quizzes.						
I had to ask for help several times to complete my Intro to MySQL assignment (Unit 3a).						
I had to ask for help several times to complete my MySQL queries assignment (Unit 3b).						
I wish there was more instruction prior to completing the assignment.						
I have adequately learned MySQL and have confidence in my ability to use it on my own.						
The different learning methods did not affect my performance.						

If you have any comments on the assignments, please use the space below to add them. Any feedback is welcome.

____

____

____

____

____

APPENDIX E: OPEN-ENDED SURVEY RESPONSES

If you have any comments on the assignments, please use the space below to add them. Any feedback is welcome.

Comments:

1. The quizzes really help create template on how to navigate MySQL.
2. You need to leave original directory up the whole time.
3. Game method has potential but could use more work. More like quizzes than a game.
4. A combination of both would seem the best to me. A general overview lecture 10-15 min and then 4-5 quizzes would seem best tome.
5. I like how you learn through quizzes and it relates to the assignment.

APPENDIX F: FINAL EXAM QUESTIONS INVOLVING MYSQL TOPICS

SPRING 2018

18) Which of the following commands selects a **database** on the server?

A. SHOW
B. USE
C. SELECT
D. OPEN

19) What is the SQL command that provides a list of all the tables that are in the currently selected database?

A. USE world;
B. SHOW tables;
C. SELECT * FROM `city`;
D. LIST tables FROM database;

22) Choose the list that only contains data definition SQL commands:

A. SELECT, CREATE, ALTER
B. DROP, INSERT, UPDATE
C. ALTER, CREATE, SHOW
D. DELETE, UPDATE, SHOW

24) Which SQL statement is used to return only different values?

A. SELECT DIVERSE
B. SELECT UNIQUE
C. SELECT DIFFERENT
D. SELECT DISTINCT

25) Which SQL keyword is used to sort the result-set?

A. SORT
B. SORT BY
C. ORDER
D. ORDER BY

The form below is part of the City table in the MySQL World database. Questions (26) through (28) are based on this table.

ID	Name	CountryCode	District	Population
1024	Mumbai (Bombay)	IND	Maharashtra	10500000
2331	Seoul	KOR	Seoul	9981619
206	São Paulo	BRA	São Paulo	9968485
1890	Shanghai	CHN	Shanghai	9696300
939	Jakarta	IDN	Jakarta Raya	9604900

26) Which of the following SQL commands returns cities with population greater than 3000 and within the District of Seoul?

A. SELECT * FROM `City` WHERE `Population` > 3000 && `District` LIKE "Seoul";
B. SELECT * FROM `City` WHERE `Population` > 3000 OR `District` LIKE "Seoul";
C. SELECT * FROM `City` WHERE `Population` > 3000 || `District` AS "Seoul";
D. SELECT * FROM `City` WHERE `Population` > 3000 AND `District` AS "Seoul";

27) Which of the following SQL commands returns the name and population of the city for all the cities in the table that **end** with ‘a’?

A. SELECT `Name`, `Population` FROM `City` WHERE `Name` LIKE 'a%a';
B. SELECT `Name`, `Population` FROM `City` WHERE `Name` LIKE 'a%';
C. SELECT `Name`, `Population` FROM `City` WHERE `Name` LIKE '%a';
D. SELECT `Name`, `Population` FROM `City` WHERE `Name` LIKE '%a%';

28) Which is the correct SQL command to insert a new record into the City table?

A. INSERT ('My Town', ‘USA’) INTO `City` (`Name`, `CountryCode`);
B. INSERT INTO `City` (`Name` = 'My Town', `CountryCode` = 'USA');
C. INSERT INTO `City` (`Name`, `CountryCode`) VALUES ('My Town', 'USA');
D. INSERT VALUES ('My Town', 'USA') INTO `City` (`Name`, `CountryCode`);

29) A query has five major parts. Which of the following is the correct order in which to express such query.

A. Definition of table to select from, definition of the columns to return, WHERE clause, ORDER BY, GROUP BY.
B. Definition of the columns to return, WHERE clause, definition of table to select from, GROUP BY, ORDER BY.
C. Definition of the columns to return, definition of table to select from, GROUP BY, ORDER BY, WHERE clause.
D. Definition of the columns to return, definition of table to select from, WHERE clause, GROUP BY, ORDER BY.

Questions (30) and (31) are based on the tables below.

city

ID	Name	CountryCode	District	Population
1	Kabul	AFG	Kabol	1780000
2	Qandahar	AFG	Qandahar	237500
3	Herat	AFG	Herat	186800
4	Mazar-e-Sharif	AFG	Balkh	127800
5	Amsterdam	NLD	Noord-Holland	731200

countrylanguage

CountryCode	Language	IsOfficial	Percentage
ABW	Dutch	T	5.3
ABW	English	F	9.5
ABW	Papiamento	F	76.7
AFG	Spanish	F	7.4
AFG	Balochi	F	0.9

30) Which of the following is a correct way to combine the above tables?

A. SELECT city.Name, city.CountryCode, countrylanguage.Language, countrylanguage.IsOfficial ON `city` JOIN countrylanguage FROM city.CountryCode = countrylanguage.CountryCode;
B. SELECT city.Name, city.CountryCode, countrylanguage.Language, countrylanguage.IsOfficial FROM `city` JOIN countrylanguage ON city.CountryCode = countrylanguage.CountryCode;
C. SELECT city.Name, city.CountryCode, countrylanguage.Language, countrylanguage.IsOfficial FROM `city` JOIN ON city.CountryCode = countrylanguage.CountryCode;
D. SELECT Name, CountryCode, Language, Is Official FROM `city` JOIN countrylanguage ON CountryCode = CountryCode;

31) What is the correct way to constrain the Joined table (from Question 30), so only official languages are shown?

A. WHERE `IsOfficial` = 'T';
B. WHERE DISTINCT `IsOfficial`;
C. ORDER BY `IsOfficial`;
D. GROUP BY `IsOfficial`;

33) There's a town in Wales with the name "Llanfairpwllgwyngyllgogerychwyrndrobwllllantysiliogogogoch", which has 58 letters. This is the longest town name in the world. If you are making a database containing all the town names in Great Britain, what would be the most appropriate choice of data type in which to store the names? (1 point)

A. TEXT

B. VARCHAR(58)
C. CHAR(58)
D. VARCHAR(57)

34) What is the command to delete a table named product?

A. ELIMINATE product
B. REMOVE TABLE product
C. DELETE product
D. DROP TABLE product