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Gamification-Based Cyber-Enabled Learning Environment of Software Testing

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Gamification based Cyber Enabled Learning Environment of Software Testing

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Abstract

Gamification is a new emerging pedagogical technique in higher education to engage students into a non-game context during the last five years. A cyber enabled learning environment can provide a collaborative and sustainable platform for learners to continue studying outside the classroom and lecturing time. In this paper, we describe the design mechanisms of gamification used in a software testing cyber enabled learning environment, named WReSTT-CyLE (Web-Based Repository of Software Testing Tutorials – a Cyberlearning Environment) and the experimental results of class studies at Alabama A&M University. As a highly integrated online learning tool, other than gamification technology, WReSTT-CyLE synthesizes several key concepts including social interaction, collaborative learning, and learning objects to support student learning of software testing concepts effectively and efficiently. This work focuses on the design architecture of gamification, assessment, and analysis of the effectiveness of WReSTT-CyLE based on our study results.

Introduction

Gamification is a new emerging pedagogical technique in higher education to engage students into to non-game context within five years. A cyber enabled learning environment can provide a collaborative and sustainable platform for learners to continue studying outside the classroom and lecturing time. In this paper, we focus on the design of a cyber enabled learning environment (WReSTT-CyLE) for software testing concepts and strategies, as well as describe a study involving students in programming courses ranging from CS1 to CS3. WReSTT-CyLE (*Web-based Repository of Software Testing Tutorials – a Cyberlearning Environment*[1]), is a cyberlearning environment that uses several learning and engagement strategies to help students to learn how to test programs

Currently, software testing education in academic institutions is not well developed in current computer science curricula. As a result many institutions do not offer the software testing course or even concepts of quality assurance in any course. WReSTT-CyLE is an online software testing repository that provides educators and learners with online materials and socio-psychological supporting components. This project provides several learning and engagement strategies (LESs) such as gamification, collaborative learning,

[1] http://wrestt.cis.fiu.edu/

social interaction and networking to improve students' knowledge of software testing in programming courses ranging from CS1/CS2 to more advanced courses with a programming component. In this experimental study at Alabama A&M University (AAMU), through a two-year collaborative effort with Florida International University (FIU) [1], we present the data, results and analysis of using gamification in programming related courses, as well as the way to improve student learning outcomes using WReSTT-CyLE and gamification.

Access to resources (funding and otherwise) is often cited as the primary barrier to technology adoption and the integration of software testing and programming skills. The role of negative disposition towards educational technology and digital games, has not been fully considered as a contributing factor in the relatively slow pace of technology adoption in higher education. The example of such slow adoption of technology in higher education can be exhibited in many programming courses. Moreover, these negative dispositions towards technology may hold also reflect more than several decades of dominant values informed by the naturalist and romantic beliefs about programming, student learning, and software engineering concepts to higher education. For instance, a recent study endorses this by showing that 69% of European workers are 'not engaged' or 'actively disengaged' in their job duties [2].

Overall, gamification is still fairly new in higher education, but it builds on the success of the gaming industry, social media and decades of research on human psychology [3]. Many On-the-Job Training (OJT) programs are already encouraging the use of gaming strategies to make work and study more engaging, rewarding and applicable [4]. This article looks at the adoption of gaming strategies in e-Learning for job training and the effectiveness of using these strategies to help stimulate learning. More specifically, we focus on how to encourage learners to integrate software testing and other quality assurance concepts into their programming skills.

This paper is organized into four sections. WReST-CyLE will be introduced in Section 2. Afterwards, gamification design architecture used in WReSTT tool will be presented in Section 3. Following that section, class study and assessment results will be presented in Section 4. Conclusions and future works will be discussed in Section 5.

WReSTT-CyLE – A Cyber Enabled Software Testing Learning Environment

WReSTT, the initial repository, was an online software testing repository which is contained with learning materials about software testing tools only. This project was a collaborative effort between Florida International University (FIU) and Florida A&M University (FAMU) [5]. The NSF Course, Curriculum, and Laboratory Improvement (CCLI) Phase I project had the following objectives: (a) create learning materials on testing tools, (b) increase the number of students who have access to testing tool tutorials, and (c) train instructors on how to use testing tools and WReSTT in the classroom.

WReSTT-CyLE is a NSF Transforming Undergraduate Education in Science (TUES) II project that aims to provide a cyberlearning environment that facilitates the improvement of students' conceptual understanding and practical skills in software testing. The ***main goals*** of this project are to *create new learning materials* and *develop faculty expertise* to

significantly increase the number of undergraduate students that are exposed to testing methodologies and tools in undergraduate courses with a programming component. The WReSTT-CyLE project is developed using the Drupal 7 content management system using PhP 5 or higher version. The key features of WReSTT-CyLE tool include the following:

Social Features: allows each student to setup a profile; access the activity stream of students in their class; pose questions to the members of his/her virtual team, other students in their class, or to the WReSTT community; and view the virtual points leaders of students in their class. In the near future students will be able to link other social networking accounts to newly created WReSTT-CyLE user groups and feeds from other testing user groups.

Learning Objects (LOs): are important enhancements to the contents of WReSTT-CyLE for software testing education and community. The LOs were made in response to feedback from users in the academic community. These enhancements include: (1) presenting the material in the learning objects using varied formats (e.g., video, audio and text); (2) new learning objects on testing techniques for black-box and white-box testing; and (3) new tutorials for testing tools based on cross-platform IDE (e.g., Eclipse and NetBeans). The transition to learning objects from tutorials allows for the sequencing of different levels of content on a specific testing topic and the ability to link objects on testing techniques to tutorials on testing tools.

The gamification design and mechanism is integrated in the social features and is developed with several elements that are connected to the project objectives. We will discuss these elements, mechanism, psychological characters and system implementation in the next section.

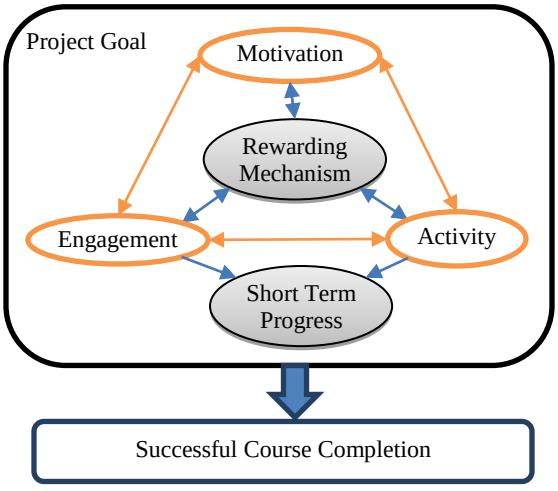

Figure 1: Overview of Gamification Design

Gamification in WReSTT-CyLE

The gamification in WReSTT-CyLE is designed and implemented with a intent of favoring the student engagement and motivation through playful and context-centric activities. The engagement of student activities is at the root of motivating students by a

rewarding mechanism that is associated to the design objectives and content. An abstract design architecture of gamification in WReSTT-CyLE is summarized in Figure 1.

There are two hierarchical levels of working cycles identified through the design architecture – first, the rewarding mechanism get the short term progress for student learning software testing concepts, based on the feedback from learning objects, quizzes, and tests scores; second, rooted on the learning results, the continuous progress on the learning materials can take students/learners to the successful completion of the course and concepts, which is indicated by the outside level.

Design Objectives

Several high level design objectives are adopted by WReSTT-CyLE. A short description is given as follows:

1. Emphasis is placed on self-motivation and diversity in the software engineering and software testing learning ecosystem.
2. Fosters an organic learning orientation by creating formative and innovative practice based on an experimentation format.
3. Creates an outline for the seamless connection with the online learning environment through a well-designed architecture.
4. Encourages peer-mentoring through the designed component (forum and posts).
5. Recognizes and highlights the role models and paths of students through the factors of academic and psychosocial elements.

Gamification Mechanism

Gamification is one of the core design themes embedded in WReSTT-CyLE [6]. To reach the objectives of design, several gamification mechanisms were applied and implemented in WReSTT-CyLE. We simply illustrate some of the key mechanisms here.

There are three key elements of gamification mechanism – *rewards points*, *badge*, and *leader board*.

Reward point system – WReSTT-CyLE provides a rewards system to motivate and engage students in the cyber enabled learning environment. The virtual point system covers both academic aspects including the course/LO's contents and psychosocial contents. The LOs in WReSTT-CyLE covers content from introduction level to the more advanced level of software testing techniques. The materials and effectiveness of learning results are reflected in the WReSTT-CyLE system as virtual points for the LOs, see Figure 2.

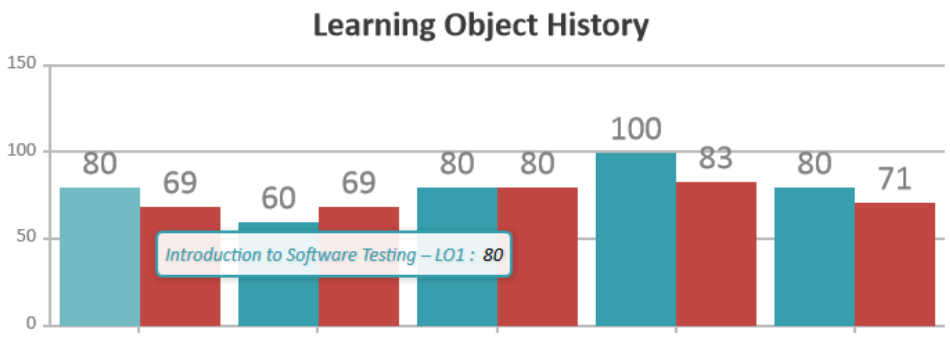

Figure 2: Virtual points for LOs in WReSTT-CyLE.

The detailed report is also shown on the same page as the scores for the LOs, see Figure 3. The detailed report for the student shows the virtual points, the number of times the course was access, and the number of post made by the students. The student is also able to view a detailed text report in a tabular form by clicking on the button below the bar chart, e.g., "View Full Point Record".

Badge – The reward system is separated from the class assessment results. It is able to be displayed within the student report (ref Figure 3.).

Leader board – In WReSTT-CyLE the leader board offers the information to the instructor and students with whoever earned the most experience points (XP) to date or whoever reached the highest level of play based on the cumulated virtual points and course assessment.

In addition to the gamification elements, some researchers have proposed five levels of abstractions for the design including (1) play testing, (2) engagement and feedback loops, (3) principles and heuristics, (4) time constraints & resources, and (5) interface elements that reflects all the above levels. The current version of WReSTT-CyLE does not provide all five levels of gamification, we can still see some key concepts with complex design that provide an in-depth engagement and strong self-motivation for students' learning.

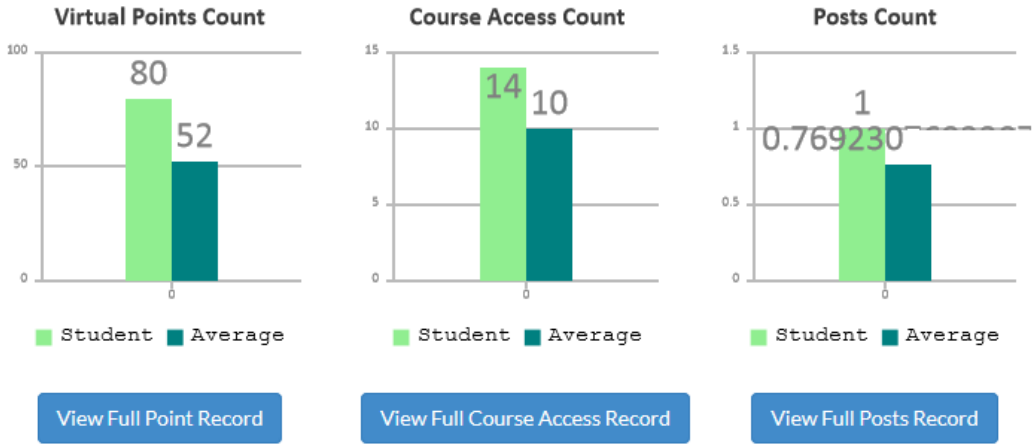

Figure 3: Virtual Points, Course Assess Count, and Posts Count in WReSTT-CyLE.

Psychosocial Characters

Several psychological and social aspects are considered in the study of WReSTT-CyLE at Alabama A&M University.

First, entertainment vs. challenge. Is the design UI fun to drive students to continue and work on the topics? Time and constraint, access frequency built in WReSTT-CyLE, were retrieved and used to analyze this issue.

Second, learning or playing (L vs P). This is a key psychological issue that we have observed during class study so far by using WReSTT-CyLE. From an educator's point of view, the L would be more important, while from a learner's point of view, it may not be true. We have added some catalyst strategies during class study, the observation is very interesting.

Third, collaboration and ethics. WReSTT-CyLE is an environment that emphasizes the collaborative learning strategy through a team based approach. At the same time, as an online learning environment, out of class study would be suitable for students and is one of the main purposes of this project. Does the organic collaboration bring efficient results and learning outcomes? Does gamification emphasize independent and team wide learning? Is each team learning on an independent based XP? If some of the answers to the above questions are no, how do we adjust the bias in the results?

After the study, we retrieved the data and detailed report for each student, we found that WReSTT-CyLE was able to provide an efficient learning environment if students followed the collaborative study and instructions.

System Implementation

The system was designed and implemented in two layers – data collection and user interface. A summary version of the system implementation is shown in Figure 4.

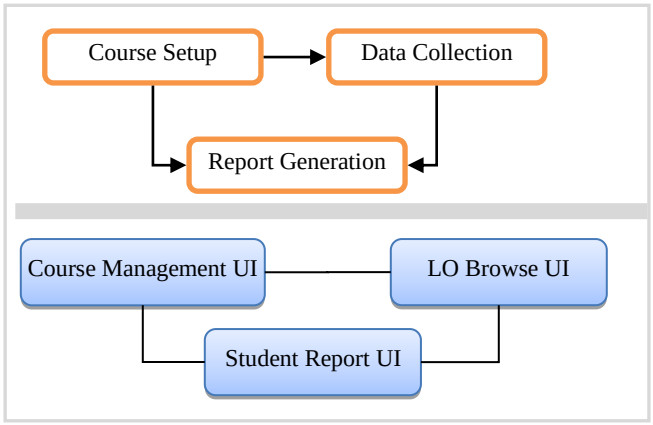

Figure 4: System design and implementation layers.

Data Collection

The data collection layer extracts data from other components, such as the LO component, forum component, collaborative learning component, and the Drupal analytics component, and generate reports that can be accessed by both professors and students. The data collect in WReSTT-CyLE may be accessed using both a text format and an html format. The professor also has the ability to download student reports using a csv file. This file contains the following for each student: first name, last name, total number of course accesses, total points, total posts, LOs completed, and LO quiz score. One example of student access report is collected from WReSTT-CyLE in the html format and shown in Figure 5. Note that the student's name is removed for privacy reasons.

User Interface

There are several user interfaces (UI) that allow the professor and student to enter data into WReSTT-CyLE. Figure 6 shows the UI that professor uses to initialize the virtual points system for a course. One of the main UIs for student to interact with WReSTT-CyLE is the course interface shown in Figure 7. The menu on the top of the page allows student to navigate to other parts of WReSTT-CyLE. The UI provides the student with the ability to browse the software testing tool tutorials and LOs using the button located on the top left side of the page. The center of the page shows the LOs that have been assigned to the student and the progress they and their team members have made on each LO. At the bottom of each LO the student has the ability to open the LO and continue working on it.

Points Record -

Course: CEN 4072 Fundamentals of Software Testing

Student:

Activity	Points	Date
recieved 15 points for completing the Learning Object: Introduction to Software Testing – LO3	15	2015-10-26 21:21:04
recieved 15 points for completing the Learning Object: Black Box Testing - LO1	15	2015-10-26 21:24:58
recieved 15 points for completing the Learning Object: Black Box Testing - LO2	15	2015-10-26 21:28:20
recieved 15 team bonus points.The team finished Learning Object: Introduction to Software Testing – LO3 in first place.	15	2015-10-26 21:33:24
recieved 10 team bonus points.The team finished Learning Object: Black Box Testing - LO1 in second place.	10	2015-10-26 21:34:52
recieved 10 team bonus points.The team finished Learning Object: Black Box Testing - LO2 in second place.	10	2015-10-26 21:35:58
Total Points:	**80**	

Figure 5: The data collection from the student report UI (student name removed).

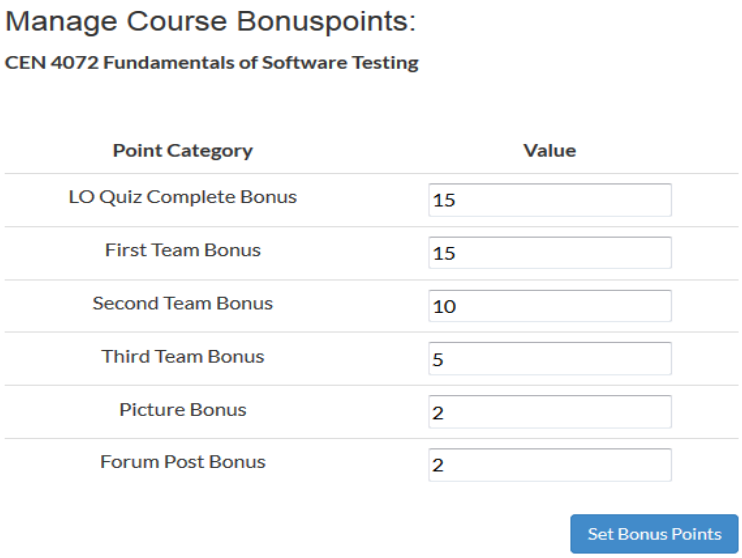

Figure 6: The setup page of virtual points.

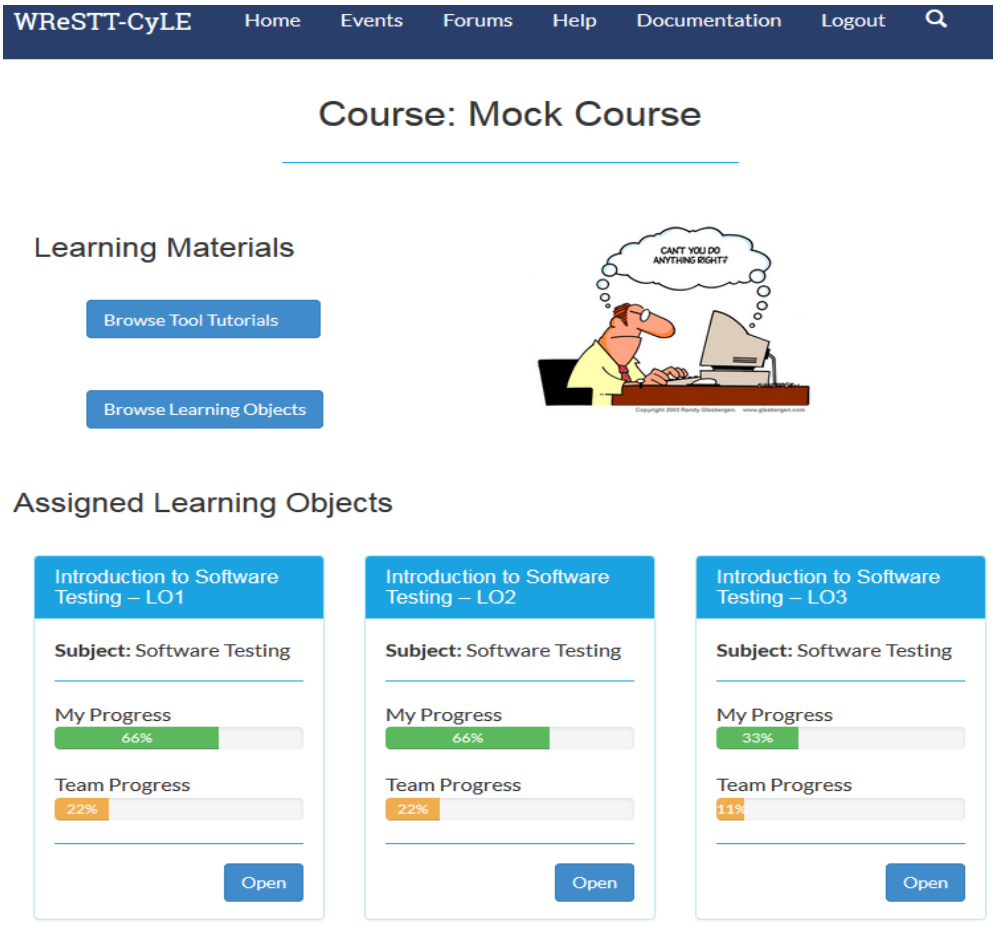

Figure 7: The interface for the student's course page.

As a part of gamification design for the online learning environment, the design features of user interface needs to reflect functions easily, simply and integrated. The screens shown in Figures 6 and 7 are similar to those used by students from the class study for the sophomore of Java at Alabama A&M University.

Class Study and Assessment

Four computer science courses at Alabama A&M University that were taught by two instructors were involved in the class study. Results were collected in WReSTT-CyLE during the semester and then used in the study. This paper focuses on three courses including: CS 206 (Java I), CS 328 (Object oriented Design), and CS 561 (Software Engineering). Table I. shows the demographic data of all participants of three courses during the Spring 2014 semester. In this study three questions were investigated:

1. Is there a relationship between the virtual points earned in WReSTT-CyLE and the student's final grade?
2. Is there a relationship between the number of posts and virtual points earned?
3. Is there a relationship between virtual points earned and the course access frequency?

Table 1: Classes at AAMU CS and participants

Classes	Num (#)	African-Americans (#)	Sessions
CS 206	33	30	**1**
CS 328	15	14	**1**
CS 561	13	8	**1**
Total 3	**61**	**52**	**3**

Experimental Environments

The experimental environments of the class studies require academic knowledge and system setting.

First, LOs were developed, reviewed and available in WReSTT-CyLE by March 2014. All study elements of each LO were available at the same time.

Secondly, it is observed that, students with a background of software testing or preliminary knowledge in software engineering are easily be persuaded during the learning process An introductory lecture was given to two of the courses, CS 328 and CS 561, which mainly explained the research project, the features and learning materials available in WReSTT-CyLE, the features included the help facility available to both professors and students. One course was not given the introductory lecture (CS 206) mainly due to the time limitation.

Thirdly, since these class studies were used to evaluate WReSTT-CyLE, which is not the main context of the courses, an assessment policy to encourage students to use WReSTT-

CyLE was necessary. To this end students were informed that 5 to 10 percentage points would be added to the final grade upon completion of the courses.

Class Studies and Current Results

Data for the three classes mentioned in the previous section was collected and later extracted from WReSTT-CyLE. From the instructor's point of view, this tool is very convenient for the teacher to extract the class data for the purposes of class assessment and evaluation.

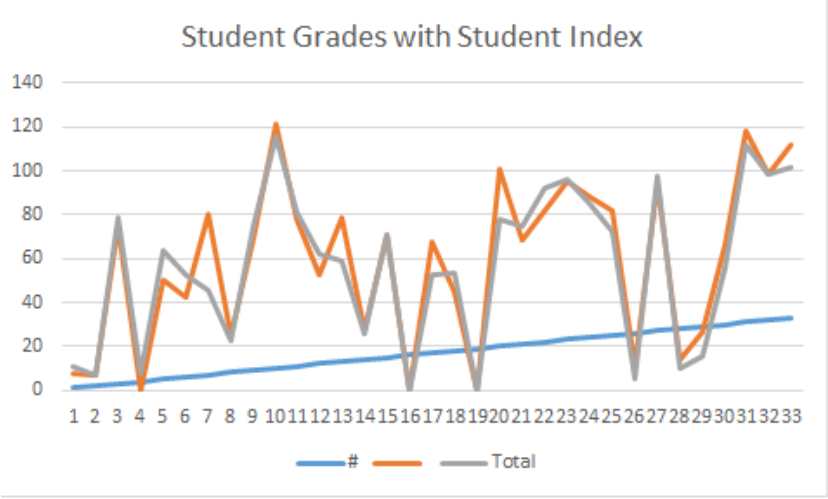

Figure 8: Student class grade with student virtual points.
Note: orange line in this graph represents the grade made from virtual points.

Three categories of data were collected and analyzed to answer and evaluate the above issues and concerns.

1. *Relation between student virtual points they earned and their final grade*. This relation is to demonstrate if virtual points match the student grade. If there is a match between these two values, it may be easier for us to claim that the gamification mechanism drives students' motivation to learn. Figure 8 shows a graph representing the relation between virtual points and course grades.
2. *Relation between number of post and virtual points*. Figure 9 shows the relation between virtual points and posts.
3. *Relation between virtual points and course accesses*. This function provides an alternative view of assessment for the student engagement to the class topics (LOs). The results can be used to adjust the first relation of virtual points with regard to student learning outcomes. The chart in Figure 10 indicates students' access to the WReSTT-CyLE has the similar shape as the virtual points in Figure 8.

For three classes, we have generated nine charts based on the data collected from WReSTT-CyLE and course grades. Due to the space limitation, we only demonstrate our results by using data from the CS 206 (Java I) class.

Discussions

The score of virtual points has a match with the student final grade slope for the majority of students, see Figure 8. There are two biases that must be eliminated (1) some students are constantly missing class lectures and assignments, which resulted very poor grade; and (2) some students focused more on getting the virtual points of the LOs without paying much attention to the content of the subject which impacted their grades.

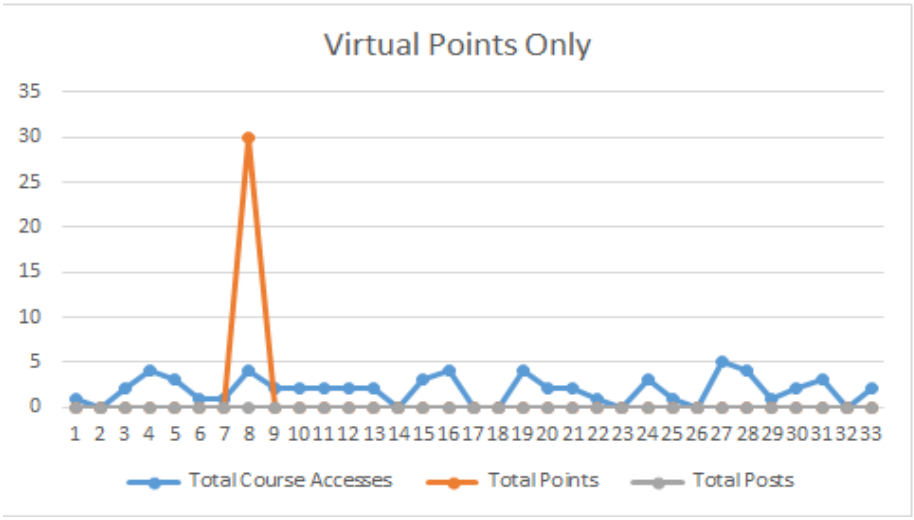

Figure 9: Student scores and virtual points.

Based on the graphs in Figure 10 we can conclude that there is little or no correlation between virtual points collected and the total number of posts. The result does not demonstrate the there is a relation between the social interaction among students using WReSTT-CyLE, and the psychological view of the learning component.

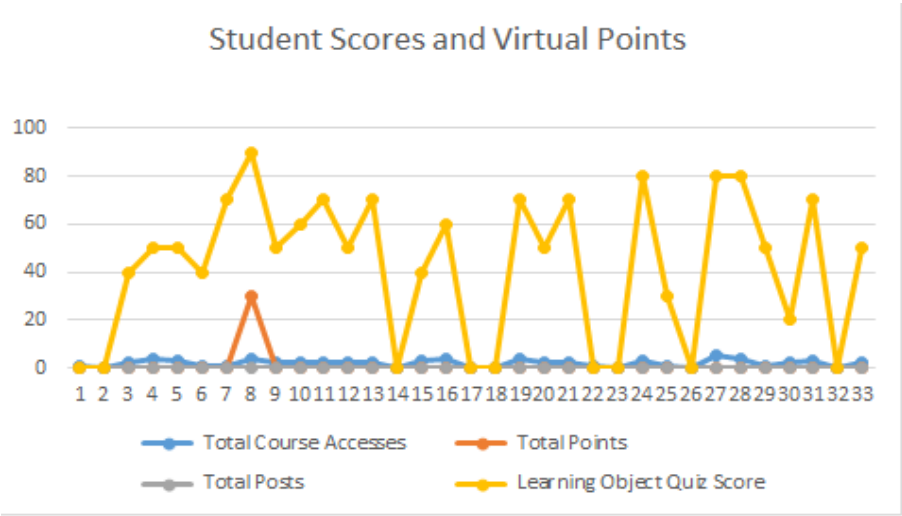

Figure 10: Student virtual points vs. post points.

Finally, from the pre- and post-tests, we can see 50% learners can answer these testing questions with 67% correctness. The results demonstrate two points. First, WReSTT-CyLE is an efficient learning environment for students to use outside classroom any time

anywhere. Secondly, some students ignored the post-tests. Two biases exist here (1) some students checked the Internet to answer the pre-test questions, which can be an ethical issue, especially for the cyber enabled learning environment; and (2) the correctness of the results does not fully reflect the student learning if he or she has prepared it for times.

Conclusion and Future Work

All the class studies have been conducted in Spring 2014. The results have demonstrated a meaningful relationship between the engagement and motivation of students using gamification and an online learning environment, specifically in the area of software testing. The context of software testing was developed by collaboration team [1] and realized in the new technology named Learning Objects using SCORM [7].

The relations of collaboration, psychological characters and ethics issues with gamification were analyzed and discussed based on the data collected. We will summarize this work using two additional aspects – gamification in online learning environment, and gamification with student learning outcome and social studies. After that, some limitations of this class studies are explained, and future works will be presented.

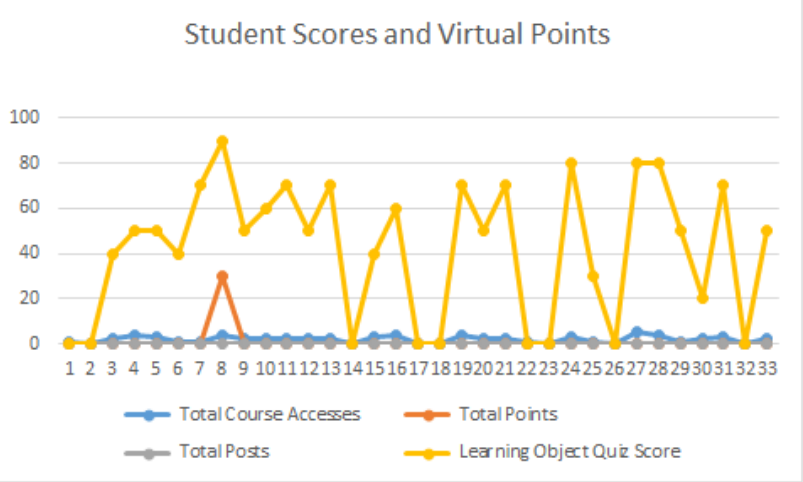

Figure 11. Relations between virtual points and course access frequencies.

Gamification in Online Learning

The engagement of gamification to the online learning environment was studied by many researchers. Literally, engagement levels in e-learning activities are often lower, while those with high intrinsic motivation are typically as engaged as they would be with face-to-face learning [8]. There are some observations from our study to support this claim. Instructors observed that highly motivated students were more efficient in the completion of LOs and getting more virtual points. There is no case shown that lower motivated students can still get high virtual points even if they are given more time to complete the tasks. One exception is that some students may get high virtual points one time with a

very poor grade in the LO, while the overall class grade for the student is still particularly low.

As proposed by some educators and researchers, more gaming features could encourage learners to be more engaged in their own learning process and interactions. We claim that there is a threshold value for the assessment of how entertaining and joyful the gaming features are, and how many features to add to the e-learning environment to increase and motivate students. There is no doubt that more gaming features will increase more students to engage, however, the question is, will more gaming features improve overall student learning outcomes? Previous studies at AAMU from the instructor has observed more gaming features consumed student learning time while they were playing with the features – some learners were playing, not learning.

Therefore, we need to find a theoretical statistical model for the use of gamification in e-learning environment. This model could provide guidance on how the use of computers and gamification can be effectively harnessed to encourage productive work, at least the same level of physical learning spaces (classroom).

Gamification and Student Learning Outcome and Social Studies

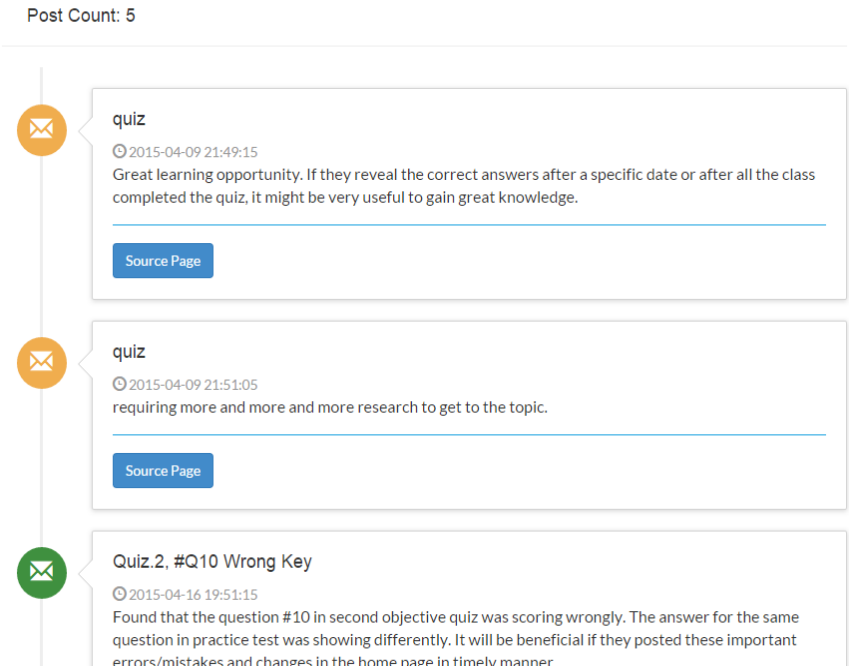

Figure 12. Detailed Record of Posts

The features provided by WReSTT-CyLE, from the social science point of view, are the forum posts and virtual points, part of the reward systems. We have collected the post points manually, due to the limitation of current interface in WReSTT-CyLE, to evaluate the relationship between how the virtual points for posts drive student centered learning. Figure 12 shows some of the posts from the class study of CS 206. Due to the large volume of data and processing needed, and based on a quick review of the data we cannot conclude that posts is another catalyst to motivate students learning. Reasons are two-fold – one is that most posts are short and mainly related to issues of use. There are no

meaningful posts from these three class studies at AAMU that reveal the thoughts and opinions while using the WReSTT-CyLE tool. On the other side of the coin, we find that the majority of the posts are directly related to student grades. The snapshot in Figure 12 was taken from a report of a student with final grade of 'A'.

Limitations

There are some limitations of the presented works of class studies. We discuss as follows:

First, the short time of exposing LOs to students. The LOs were presented to student by April and three weeks period.

Second, not enough data was collected to fully study how students use the WReSTT-CyLE tool. To provide more conclusive results data for the same courses should be collected in more than one semester and preferably with different instructors.

Third, with respect to the learning environment side, WReSTT-CyLE will need to be equipped with more components of gamification. From previous class studies, we can observe some limitations while using the virtual points, especially, there is no collaborative data evaluation regarding to both reward points and test grades.

Finally, the psychological factors were not included in the current study. The definition and retrieval of psychological data may provide more meaningful results regarding student engagement using WReSTT-CyLE.

Future Work

We have conducted studies and analyzed the correlation between gamification and an online learning environment. In comparison with previous works using the tool [6] [9], we have new results focusing on the use of gamification in the classes with mainly minority students. Future work regarding student engagement using gamification fall into two main categories:

First, the need to use WReSTT-CyLE in more programming courses to evaluate how gamification in a virtual learning environment can be used to improve students' conceptual understanding of software testing techniques.

Second, the need to have an in-depth analysis by developing a statistical model to analyze the relationship between the following: gamification, an online learning environment, psychological characteristics, student learning outcomes and social media.

In summary, we have conducted a class study and observed meaningful results of gamification in the WReSTT-CyLE cyber enabled learning environment developed to introduce software testing in advanced programming class. The participants of the study were 85% African-American majoring in computer science at Alabama A&M University. Based on the results of the class study, we can conclude that gamification can be used in a cyber enabled learning environment, WReSTT-CyLE, can have some positive impact on student learning. We have also identified two main future improvements for

WReSTT-CyLE with respect to how gamification may be used to introduce software testing into programming courses.

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