The Modernization of the Framework of Learning

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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STS Thesis

The Modernization of the Framework of Learning

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Peer Reviews and Comments

Throughout the whole process, I have received so many good comments and feedback from my peers and my professor. I would like to take the time to thank everyone who has given me feedback. I will address everyone's feedback and how it has impacted my direction on this project.

Makonnen Makonnen really helped me finalize and make my idea concrete. We spent many hours discussing what problems we have with the courses we have experienced and what incentives students generally respond to. He brought up the different social and ethical factors that students can face in a semester and I have tailored my ideas factoring those in.

Yonathan Fisseha helped me out by fixing some grammars and helped me elaborate my ideas through different vocabulary and sentence structure. Also, he helped me with narrowing down my application of my idea to courses that are more project-based and have more advanced topics beyond that course.

Youssef Errami helped me by undergoing a small version of my implementation of a modern course related to the computer graphics. He provided feedback on what he liked about the system specifically the freedom to choose more advanced topics and that I should include a way

to also tailor to students that learn in a different style or take different feedback cues.

Professor Gorman reviewed a draft of the paper and offered ways for me to expand upon my ideas and give examples of applications of my idea to different types of courses. He also helped with incorporating more of the STS framework towards my project. I have taken all of these recommendations into this version of the paper.

One point that I would like to make is the differentiation of the term gamification and my implementation. While my idea for a modern course takes ideas from gamification, I don't follow all of the strict rules of gamification and I wanted to create my own implementation with what I liked about aspects of gamification.

My STS framework of choice was tacit knowledge and trading zones and I have drawn ideas upon many research papers on the results of gamification.

I would like to thank everyone who has helped me get this far on this assignment and their feedback. Without other people's help I would not have been able to come up with such a concrete idea and tweak it with revisions and feedback.

Abstract

Throughout my whole college career, I have always pondered about the education system and its effectiveness on the retention of knowledge and value that it provides. Being in an industry that moves at such at a high pace, I began to notice that the material, teaching styles, and methods of learning being utilized in the classroom setting is in this stagnant state especially after taking some and examining the market of online courses and coding bootcamps. Utilizing the framework of tacit knowledge and trading zones, I am going to exemplify a few points: why the methodology of learning within the college is outdated, what gamification is and how it is being applied in industry and could be applied to courses, and examples of utilizing gamification to change the learning methodology of courses. The goal is through repeated application and analyzing, to come up with a concrete answer for “what is the best way to learn something new”. Hopefully, this answer can be repeatedly applied to fit within an STS context and change the courses, student happiness, and learning for the better.

An Outdated Framework

With the increasing amount of online courses and coding bootcamps, one has to wonder why a college degree is still worth going for. There is an advent of coding bootcamps where one doesn't have to pay the tuition amount for the courses until they land the full-time job, and they get 1-1 practice with senior developers within industry of their choosing. The timeline, value, and reward for doing one of these coding bootcamps seems so much greater than that of a college course since these companies also give you insider help into getting hired full-time for your dream company. It's amazing and it makes sense with all of these incentives why someone would decide to go with the approach of completing one of these coding bootcamps. The most beneficial aspects of these coding bootcamps was the Tacit Knowledge that they provided. "Tacit knowledge, on the other hand, is knowledge that has not been (and perhaps cannot be) formulated explicitly and, therefore, cannot effectively be stored or transferred entirely by impersonal means."[1] Furthermore, the 1-1 service that the coding bootcamps provided to their customers provided a vast amount of tacit knowledge. Within any industry and workforce, there

[1] MacKenzie. Donald, & Spindarni. Graham (1995), *Tacit Knowledge, Weapons Design, and the Uninvention of Nuclear Weapons*

are these aspects of “trading zones”. A trading zone “typically begins with a few common terms, or jargon, quickly develops phrases that can be learned quickly and understood across the zone, then eventually can lead to a new language, or creole, that is taught to future generations.”[2] When viewing specific industries in society today, a lot of what Gorman says in this chapter is very relevant. Within a workplace, community, or industry, there usually develops quick terms and idioms that have a significance towards the project or have some kind of meaning that can only be learned if one is in that same situation. For example, there are many types of acronyms and vocabulary terms that get created by workers within an industry. AI and machine learning are clearly distinct terms as the former deals with algorithms that apply a certain decision to machine learning while machine learning is just the concept of algorithms fixing and teaching itself new parameters to better predict and classify things. However, people in industry usually blend the two terms and only a fixed number of people (the ones who work on it) truly differentiate the meaning between the two. Coding bootcamps seem to have an edge over college courses partly because they have the advantage of providing industry professionals that have relevant, recent experience in those trading zones. Especially within

[2] Gorman. Michael & Werhane. Patricia H, *Using Trading Zones to Prevent Normalized Deviance in Organizations*

the computer science community, students are typically taught within a large setting with professors that highly specialize within one sub-topic in the whole major as opposed to being someone that has numerous amounts of experience within industry. Unlike the coding bootcamp counterparts, the professors likely do not have the same tacit knowledge and access to trading zones that most of the students are looking for within their value of their education. Even though, some professors may be industry leading professionals, a lot of their expertise is too specific most undergraduates in the CS major who are trying to get a job instead of specializing in one topic. This is by no means saying that these coding bootcamps should replace traditional college courses, but I believe that there is something to be learned and applied to the makings of college courses as “The bachelor’s degree may be the classic pass to join the world of work, but increasingly it’s no longer enough. And that prompts a provocative thought: Could credentials replace traditional education? Do we need college?”[3] Thus, I believe that colleges can do much better by revamping their courses into a different format; one that works and provides value in the modern society. To be able to tackle problems, one must first recognize them. From my

3 Pappano. Laura. *Is the college degree outdated?*

research, experience, and conversation with others, I noted that college courses are outdated and not providing the best value because of grade inflation, the lack of a feedback loop and rewards, and lack of organization. These three problems with courses all lead to the same problem of the student not maximizing information retention and happiness. For example, grade inflation slowly becoming an issue to college courses. "Undergraduate GPAs are now so saturated at the high end that they have little use as a motivator of students and as an evaluation tool for graduate and professional schools and employers."[4] This makes logical sense as when there is nothing to accurately evaluate one's progress, there is little incentive to make progress. However, how does one evaluate progress? This brings me to my second point, college courses don't have a reliable feedback loop system in place. This feedback loop is built into our daily lives whenever we learn something new. For example, when first learning how to play a sport, it feels awkward and hard to reach success like scoring a basket, but once you do, you feel good and want to do it again but maybe more efficiently and faster. Finally, I don't think that college courses provide a very clear goal or organizational scheme. There are some courses that leave students wondering why they enrolled in them or leave them wondering what they can get out of it. When a student reaches this thought

process, usually it means that the class has not been organized in a correct manner that makes concepts build on top of each other and “click” in the student’s head. In my experience, a lot of college courses do not organize well and make the end goal of the course unclear. For example, I took a class called Programming Languages where the goal was to learn different programming paradigms and how the languages work under the hood with syntax and semantics. Halfway through the course, I was left wondering what the goal of the course was, because we had steered in a direction that just utilized different languages not learning the semantics and how to think in different programming paradigms. None of the homeworks and what we learned built on top of each other so the concepts didn’t stick. Learning best happens through repeated applications of the concepts, but this course jumped all over the place and we only got a shallow look at each topic, leading to a very ineffective way to retain information. At the bottom line, “Value is low when, as the research shows, too many of our college graduates are not prepared to think critically and creatively, speak and write clearly, solve problems, comprehend complex issues, accept responsibility and accountability, take the perspective of others, or meet the expectations of employers.”[4] College courses fail to challenge the students

4 Pierce, S. R. (2014). *Governance reconsidered : How boards, presidents, administrators, and faculty can help their colleges thrive*

enough so that they are able to attain mastery and be able to accept responsibility for their own mistakes and failures. Through my research, I am applying the concept of gamification towards college courses in an attempt to modernize college courses for maximizing student retention of learning and the value of the course.

Gamification:

Gamification is a design system with a different type of experience. "Gamification applies elements related to game theory and mechanics, such as the use of prizes and rewards, to increase the user engagement and motivation, in not traditionally ludic contexts"[5] Traditionally, gamification is the idea of utilizing a feedback system with active participation of the users to boost motivation, learning, and engagement. In other examples, companies have utilized gamification as a way of increasing customer engagement, increasing the training success rates of their employees, and even using it as a source of teaching customers on how to utilize their products. For example, Twilio, a company that automates SMS and other services for companies, has a game called Twilioquest where the user plays as a character, finishing quests, and

5 Dolores López Carrillo , Amelia Calonge García , Teresa Rodríguez Laguna , Germán Ros Magán and José Alberto Lebrón Moreno. (2019) *Using Gamification in a Teaching Innovation Project at the University of Alcalá: A New Approach to Experimental Science Practices*

receiving awards I believe that applying gamification towards college courses will be an effective way to modernize them and provide the same or greater amounts of value than the coding bootcamp and certificate programs. I will use gamification to tackle the aforementioned 3 problems that are in the outdated college course system. Theoretically, if everything goes well in this new course utilizing gamification, it will be able to deal with the problems of grade inflation, the lack of a feedback loop and rewards, and organization. Gamification when applied correctly, “means applying techniques based on games and video games to motivate students and encourage their positive progress.”[6] There are many aspects that fall under the category of gamification, but I am going to focus on the aspects of Achievements and Goals, Rewards, and Quests. In traditional college courses, there are grades which are supposed to signify feedback for student progress. In this gamification model, rather than using grades, this notion of achievements and goals should be utilized. There are sometimes that the grade received has a disconnect from the goal of the course. Gamification will fix that by keeping the overall goal in mind and in focus throughout the whole semester. Similar to how RPG style games have the main goal clearly outlined which provides reasons for why the character

6 Goethe, Ole (2019), *Gamification Mindset*

has to go on this side quest, grind, etc. everything that is taught by the course will clearly have this outline of what the end goal is and all the material should explicitly tie back to that end goal. Rewards are also important in the gamification system. The whole system is based on this feedback loop; a student tries something new and gets feedback on whether they did a good job or not, similar to that of rewards in quests in video games. The great thing about the reward system is that it can be many different kinds of rewards. They could be extrinsic such as extra credit, or intrinsic such as the student feeling confident with a concept covered in class. Finally, game structures usually need to be very organized in their storytelling. Utilizing the same style of organization that video games use, I will apply that idea to tackle the notion of disorganization in the traditional college curriculum. I will tailor the college curriculum to have the same progress tracking as a video game system and make each assignment like a main quest that provides feedback to the student on why they are completing it. The goal is to organize the class such that all of the assignments directly build on top of each other and utilize concepts before it to teach more advanced topics within the course. A class made with this new system will be project focused with assignments that build on top of each other. Ideally, a course following this

structure will allow for dynamic learning and give enough knowledge to students to implement the course goal from scratch later on. The project will apply theoretical concepts learned in class and make every student implement a basic version of what the course is about. For example, for Computer Game Design, each student would implement a basic game engine. The way the dynamic learning aspect comes in is that each student gets to choose how they want to satisfy an assignment in the course such as implementing a solution or writing a detailed diagram of the solution. Furthermore, students will be able to choose if they want to tackle more advanced assignments to replace of the basic assignments of their choosing. For example, in an Algorithms class, a student may choose to implement a more complicated Dynamic Programming algorithm instead of completing the generic homework for Dynamic Programming. This will allow students to tackle assignments in a way that helps them understand the material the best and is the most interesting to them as well as giving them freedom for exploring more advanced topics. This is different from that of the current course curriculum as each student is put through this general template of requirements that can only be satisfied through assignments and tests. This may work to gain a baseline of understanding, but it doesn’t challenge students enough or spark passion. This new

method of learning will be able to greatly transfer any tacit knowledge than that of its older counterpart. Within learning, a lot of the tacit knowledge relates to the process and methodologies rather than the information itself. In my experience, to be a professional, one not only needs the relevant information but also mastery of the process to create something out of nothing. Most classes today relay the information through mini-assignments and exams, but not much on the process. For example, I learned what makes up an operating system, but I still don't know how to set one up and implement one from scratch. In contrast, applying this new version of the class allows the students to follow the instructor's footsteps, struggles, and process on diving the problem up. This would not only transfer the hard information but also the tacit knowledge from instructor to student that is often the missing piece in most modern education courses.

Application:

To apply gamification to the course and analyze the results, I am currently undergoing a research project with Professor Floryan to develop a course that utilizes gamification. In accordance with my ideals and points that I made in the previous sections, the course, Computer Game Design, is going to utilize the gamification aspects to modernize the course and

provide better value. In this course, the goal is to learn the principles of good game design and work in teams to create a video game engine and utilizing the engine to develop a professional level video game to release on Steam. To provide the most value to the students, we are aiming to make the whole course result in a professional level product similar to that of the coding bootcamps. We will have a direct correlation of the grade received with the number of “Quests” passed. If a student shows mastery over all of the “quests” then the student receives an A. In addition, every quest will be split up into sub modules with specific tasks defined that contribute to the overall class goal. This is utilized to tackle the grade inflation that was in courses before. This way a student’s grade is completely dependent on the amount of work they decide to put into the course and it is easy to see the feedback of putting in the effort as the grade reflects that. The feedback system is made such that at the end of each week, each team has a team meeting. Everyone shows up with their own implementation of the task that was given and the person with the best overall implementation gets to have their solution added to the final product. This gives a nice edge of competition and incentive as getting the solution chosen gives that student more weight in the direction the game development goes and what features get added. However, because the

students are in teams it is not like they are disconnected. The assignments can be worked in groups but every implementation has to be turned in individually. The goal of this is so that students don't feel alone when working on the assignment but have to understand the material enough to create an implementation. For the organization of the course, students will be able to dynamically choose their own path. There are multiple subteams within the overall course and each subteam works on a certain part of the overall goal. For example, we will have teams like Art, Engine, Special Effects, Character Programming, Game Design, etc. In the beginning of the semester students will be able to choose certain "classes" based on what they wanted to learn. There could be a student that enjoys coding the most and might be on the "engine" class where the student on every quest can choose to join the teams within that class. This engine student could join the engine one quest and then the special effects in another quest. This way, every quest, the student can specialize in what they want to get out and learn from the course while still staying on track with the overall goal of the course. Within each subteam, the team will focus on building parts that are crucial to the overall game that will result in this skill-tree like structure. Similar to that of RPG style video games that have skill trees to show progress and mastery, there will be an overall diagram that shows parts of

the engine that build on top of each other and progressively get more advanced as the semester continues. For example, the engine will need a collision detection system, but later quests will have the engine team revamp the collision detection system to become more optimal and run faster, or have multiple hitboxes. This is similar to that of progression in video games. The player starts out with easier quests and once the player gets more skilled, tackles harder quests that might build on top of the previous easier quests. Furthermore, at any quest a student has the option to do a “side-quest”. Side-quests are things that might be necessary and more advanced that won’t be explicitly covered in class, but the student has the choice to explore it. For example, even though multi-player functionality is not explicitly covered within the semester, a student has the opportunity to complete this side-quest and use it to replace a quest. This provides incentives in multiple ways. First, the student will be able to work on what he or she desires and tailor their own learning. Also, they will be able to see the fruits of their own creative labor in tangible form at will be utilized in the final product of the game and in the programming of the levels. By allowing students to specialize in what they want as well as choose their own path that still ties to the overall goal, this allows for more flexibility and motivation for the students as the course feels more under their control. This can be

applied to most other CS courses as well. For example, this concept can be applied to an Algorithms course. Most Algorithms courses all cover the basic algorithm and problem solving techniques where the assignments require the student to utilize those techniques to solve different algorithms problems. Due to the nature of problems, different algorithm problems have varying amounts of difficulty and assignments can be made to follow this pattern of difficulty. Assignments can be split between a basic understanding assignment and an exploration assignment where the student can either choose to explore different applications of the algorithm or implement a more complex algorithm that relates to that topic. This kind of structure allows for students that relish discovery and problem solving to both flourish as it gives them a choice. Also, each student can choose to stay on a topic that they find interesting and use that to replace an assignment. For example, if a student really enjoys the dynamic programming topic, they have the choice of going further exploring known dynamic programming problems and implementing solutions and a small project use case of that algorithm. This is one example of the application of this new methodology of learning, but right now I believe that the application is limited to more concrete project based classes. I have tried thinking about applying this to something like a Linear Algebra course, but I

am not sure how to apply it since I cannot figure out more advanced topics within a Linear Algebra course. This application works for courses that cover topics that have optimized and more advanced techniques. The way that this new class is set up also allows access to trading zones within the class and the transfer of tacit knowledge. Just the nature of the course requires high amounts of communication between the different teams and to the stakeholders. In my experience, when people are involved in a huge group project over time, trading zones appear and the communication flows smoothly similarly to that of an actual game development company. Contrast this to a regular classroom setting where information is just thrown at the student. Keywords and ideas may come up that exist in the trading zone of game development, but the students aren't actively interacting or utilizing them. I believe that students will also be able to come out of the course with important tacit knowledge. Anybody can look up concrete information on how to implement a game engine or specific features, however the tacit knowledge that exists is the interaction between separate teams and contributing key features that be cross compatible with the current iteration. There are hardly any guides or ways to transfer knowledge on how to tackle a problem and work together well in a big team. This new style of a class requires students to have to deal with those

minute intricacies. While most teachers and professors would say that these small details don't contribute to the goal of a course, I would argue that its these small details that truly glue the information of a course together and is likely the information that will carry past the lifetime of a course.

Data Analysis:

For effective understanding of how successful my implementation is and a way to quantify retention of knowledge and happiness is necessary. This is necessary because it opens up the ability to run significance tests on parameters that pertain to learning. For example, with overall satisfaction as the statistic, one could run pair-wise significance tests with a traditional college course as one side and this implementation version as the other. In order to quantify the data, there has to be some discrete statistical values that allow for comparison. The discrete values might include: overall satisfaction, passion levels for the material, how well the class was organized on a scale of 1-10, or the frequency of keywords that come up in a free response section to an evaluation. Speaking on that last statistic, one way to quantify feedback on learning models is to take a bunch of free response sections and categorize the number of times a certain keyword has come up that might have meaning towards the goal. For example, if a

significant amount of people responded with “dynamic” it may speak as a characteristic of the course implementation. All of these statistics can be gathered and combined into some kind of graph for visualization such as box-and-whisker plot. Furthermore, one can apply significance testing such as A/B testing or paired t-tests that can prove significance based on a hypothesis. For example, by running A/B tests, we can prove whether there is a significant difference on overall student learning utilizing this new implementation of a course as A and the traditional version of the course as B. In this test, we would gather the proportion of people who took a version of the course that responded positively and compare the results to see if the new implementation of the course had a significant difference. These types of data analytics are essential as it helps quantify success which not only plays into the dynamic aspect of learning as it helps determines student interests so course materials can be matched easier, but also provides information for improvements that can be made on the course for the future.

Future Research:

With regards to this implementation and the STS frameworks mentioned, I noticed that there are many avenues to explore and perspectives to consider. One notable argument could be that what if the students do not

complete the course as intended such as through cheating, and their knowledge is worse off than that of a different iteration of the course. To address this, throughout the next semester, I am going to continuously obtain feedback from the students on the organization of the course, the interests and personalities of each student, and the confidence of each student with regards to the goal. I plan to dynamically alter the course materials such as including extra assignments based on the feedback I receive. At the end, I will compare the success of this new course implementation with that of its older counterpart. Using this information, I want to be able to identify what is tacit knowledge that students are missing and how teaching students this tacit knowledge affects their confidence and passion for computer science.

Conclusion:

There is no guarantee that the changes made to the course will maximize student learning and happiness. However, the application of principles in gamification will aim to tackle the core problems with the outdated college system today: grade inflation, poor feedback, and confusing organization and application of topics. Overall, the new Computer Game Design aims to bring out the best of each student by really honing into each student's specialties and interests and dynamically craft a learning experience just

for them. After further analyzation of the course feedback, I aim to make revisions as necessary and start applying this model to other courses within the computer science department to maximize the value each course provides.

Bibliography:

1. MacKenzie. Donald, & Spindarni. Graham (1995), *Tacit Knowledge, Weapons Design, and the Uninvention of Nuclear Weapons*. Retrieved Oct 31, 2019. Retrieved from: https://www.jstor.org/stable/2782506?seq=1#page_scan_tab_contents
2. Gorman. Michael & Werhane. Patricia H, *Using Trading Zones to Prevent Normalized Deviance in Organizations*. Retrieved Oct 31, 2019. Retrieved from: https://mitpress.mit.edu/books/trading-zones-and-interactional-expertise
3. Pappano. Laura (April 17, 2017). *Is the college degree outdated?* Retrieved Nov 1 2019. Retrieved from: https://hechingerreport.org/college-degree-outdated/

4. Pierce, S. R. (2014). *Governance reconsidered : How boards, presidents, administrators, and faculty can help their colleges thrive*. Retrieved Nov 1. 2019. Retrieved from http://ebookcentral.proquest.com
5. Dolores López Carrillo; Amelia Calonge García; Teresa Rodríguez Laguna; Germán Ros Magán; José Alberto Lebrón Moreno. (Jun 2019). *Using Gamification in a Teaching Innovation Project at the University of Alcalá: A New Approach to Experimental Science Practices*. Retrieved Nov 1, 2019. Retrieved from: https://content.ebscohost.com/ContentServer.asp?EbscoContent=dGJyMMTo50Sepq84zOX0OLCmr1Gep7ZSs6a4S66WxWXS&ContentCustomer=dGJyMPGpsUm0qq5NuePfgeyx847f1d%2Bl5wAA&T=P&P=AN&S=R&D=ehh&K=137616126
6. Goethe, Ole. (2019). *Gamification Mindset*. Retrieved Nov 1, 2019. Retrieved from: https://link-springer-com.proxy01.its.virginia.edu/content/pdf/10.1007%2F978-3-030-11078-9.pdf