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Empirical Study on the Effect of Digital Badges in a General Physics Homework System

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Abstract: In this paper, we study the effect of digital badges within an online homework system for an undergraduate general physics course at a large university in Taiwan. Students (N=162) self-selected themselves into two course sections; students in one course section (N = 68) were able to earn one badge per assignment for turning their assignments in earlier than the assignment deadline – treatment group, while students in the other section (N = 94) could not – control group. In addition to submission before a special badge deadline, students in the treatment group were also required to obtain maximum scores to get these badges. However, assignments were designed to be easy enough for students to earn the maximum grade (which students generally did). Additionally, students in the treatment group were able to earn higher level badges by combining the assignment badges. Students in the treatment group were fully aware of badge requirements and the badge design was visible. Our results show that students in the treatment group actively attempted to earn badges, and there was a statistically significant increase in the timeliness of their assignment submissions. These findings show that badges can be used to motivate specific behaviors in students whilst requiring minimal changes to the course structure.

Keywords: digital badges, timeliness, graduate attributes, homework system

1. Introduction

A digital badge is an online representation of a skill earned (Mozilla Foundation, 2014). However, it is easiest to understand badges in terms of their affordances. Joseph (2012) undertook a review of the digital badge ecosystem, with the intention of identifying the way different actors approach the concept of digital badges, or the different frames of use. His review identified six frames of use: Badges as Alternative Assessment; Gamifying Education with Badges; Badges as Learning Scaffolding; Badges to Develop Lifelong Learning Skills; Badges as a Digital Media and Learning Driver; and Badges to Democratise Learning.

Of particular interest to this study is the fourth frame identified by Joseph – Badges to Develop Lifelong Skills. These skills are sometimes referred to as (key) competencies, and within higher education, they are referred to as graduate attributes (Hager & Holland, 2006). Timeliness, a major focus of this study, is a translational graduate attribute skill (Barrie, 2004) i.e. a graduate attribute that learners can apply in an unfamiliar environment; as an example, students newly employed in the workplace. The ability of badges to motivate learners to adopt particular attitudes is empirically verifiable. Thus, raising the question: how effective are digital badges at motivating graduate attributes in learners? Having an answer to this question can help educational practitioners know whether creating badging systems is worth the effort expended on it.

This study has one primary research question:

- What is the effect of digital badges on the timeliness of assignment submissions within an undergraduate physics course?

In addition to this question, there was one secondary research question:

- Do students actively attempt to earn digital badges when given the opportunity?

1.1 Context of the Study

The study took place at National Tsing Hua University, a relatively large university in North-East Taiwan. Study participants were enrollees in an undergraduate physics course typically taken by first-year undergraduate students who are non-physics majors. Enrolment in the course was subject to university-wide regulation; hence, enrollees in the course were able to choose one from eight course-sections taught by different professors to enroll in. Thus, this was a quasi-experimental study rather than an experimental one, as the samples were self-selected. Only enrollees in two of the eight sections of the course were participants in the study. One section was randomly picked as the treatment group – students in this section were able to earn badges; while students in the other section were not – the control group. Students were not aware of this difference during the period of course selection.

Students enrolled in the course were required to complete assignments via an online platform. These assignments were accessible to students after students had been taught the related content in class; but were due for submission in three batches. After each batch of assignments, students took an exam; thus, there were three exams.

2. Literature Review

2.1 A Framework for Graduate Attributes

Barrie (2004) employed a phenomenological approach to research academic understandings of graduate attributes, focusing on university teachers who had the task of integrating generic attributes into the undergraduate experience. Barrie (2004) discovered four qualitatively distinct and hierarchical conceptions of graduate attributes. Interestingly, these conceptions of graduate attributes did not pertain to specific groupings of academic disciplines, and there was wide variation within certain disciplines.

In increasing order of complexity, the conceptions of graduate attributes are:

1) Precursor conceptions of attributes: This understanding of graduate attributes views graduate attributes as foundational skills such as basic numeracy and literacy. They can be taught by non-discipline specific educators, are prerequisites for discipline specific study, and are truly generic. Within higher education institutions, these skills are usually imparted via remedial education.
2) Complementary conceptions of attributes: This viewpoint sees graduate attributes as those complementary to discipline knowledge. While precursor attributes are a prerequisite to discipline specific study, complementary attributes are typically learned concurrently with discipline specific study. Nevertheless, they are similar to precursor attributes in the sense that they are truly generic. Teachers may attempt to impart these attributes via extra seminars or workshops.
3) Translation conceptions of attributes: This understanding of graduate attributes views graduate attributes as attributes that help students apply university learning into an unfamiliar environment. These attributes may include personal and intellectual autonomy, and research and inquiry. Furthermore, these attributes can be imparted to students via engagement with the course.
4) Enabling conceptions of attributes: This viewpoint sees graduate attributes as the attitudinal stances and abilities at the heart of all scholarly learning and knowledge, with potential to create new knowledge, and transform the individual. Such attitudinal stances and abilities include global citizenship and scholarship. These attributes may be learned within the broader context of a student’s academic and non-academic experience.

2.2 The Origins of Digital Badges within Education

Based on the writings of Davidson (as cited in Abramovich, Schunn, & Higashi, 2013), badge advocates claim badges as a form of alternative assessment will increase learner motivation whilst maintaining high-quality feedback. Abramovich, Schunn, and Higashi (2013) state the origin for these claims and beliefs in the efficacy of badges can be found by investigating the antecedents to digital badges in education: merit badges and video-game achievements.

The Boy and Girl Scout organizations in the United States offer children the chance to learn different skills. Merit badges are then used to certify that the skills chosen by children have been learned. The underlying theory is the goal of earning a badge will increase motivation for children who want formal recognition. Many video games have elements (including badges) which afford players the opportunity to translate in-game accomplishment to real world recognition. Players can choose which badges to earn or can achieve them through normal game-play.

Abramovich, Schunn, and Higashi (2013) then proceed to highlight the similarities between digital badges in education and merit badges and video-game badges. Digital badges in education may be used to show learning outside the classroom as used with merit badges. Learners can show off their badges on personal profiles like video-game badges. Similarly to video-game achievements, learners may also earn badges on intention or simply as a by-product of learning.

Hakulinen, Auvinen, and Korhonen (2013) also draw the link between digital badges in education, merit badges and video- game achievements by focusing on the concept of gamification. Gamification is a broad concept that uses methods such as leaderboards, achievement badges and point systems to make systems more motivating and engaging (Hakulinen, Auvinen, & Korhonen, 2013).

This link between gamification and badges in education is similar to one of the frames identified by Joseph (2012); but as Joseph (2012) notes, it is important to be skeptical when the claim is made that gamification can replicate the level of engagement found with gaming. Linderoth (2012) provides one reason why this is so: games are built such that progress is not necessarily a result of learning. Thus, relative to education, this undemanding nature of games is what makes them motivating and pleasurable.

2.3 Quantitative Studies on Badges in Education

Given the relative recency of the concept of badges in education. Experimental and quasi-experimental studies of badges are relatively few as of the moment of writing.

Hakulinen, Auvinen, and Korhonen (2013) found that badges could elicit positive behavioral responses from students. These responses though were heavily influenced by learner motivations. Homework contributed 30% to the final grade of computer science minors, while it contributed 20% to the final grade of computer science majors. Thus, computer science minors tended to earn badges that rewarded correctness as they were already predisposed to paying more attention to their assignment grade. Computer science majors tended to earn badges that rewarded timeliness, sometimes at the expense of accuracy.

Abramovich, Schunn, and Higashi (2013) found both positive and negative effects of badges on the motivation of students, depending on the prior knowledge of learners. A major flaw in this study though is the absence of comparison groups. There is no way to ascertain whether the changes in student motivation were due to exposure to badges or exposure to the intelligent tutor system and/or badges as all 51 study participants were exposed to the same treatment.

Hanus and Fox (2015) used questionnaires to test the effect of gamification (using badges and a leaderboard) on intrinsic motivation at four points during the semester. They found that gamification led to a statistically significant drop in intrinsic motivation, but they failed to find any direct relationship between gamification and final exam scores. As badges were used in concert with leaderboards, and there were only two comparison groups – badges combined with leaderboards; and no badges, no leaderboard – it is particularly difficult to identify the exact effect of badges on the intrinsic motivation of students.

Denny (2013) conducted a study to test the ability of badges to motivate students to perform specific learning tasks. Denny (2013) did not find a significant difference between the two groups in the number of questions authored by the students, but found a significant difference in the number of answers provided by both groups. The students in the badge group answered more questions than students in the non-badge group; there was no drop in quality of answers – this contributes to the notion that badges are indeed useful motivators. However, it should be noted that authoring questions requires significantly greater effort than answering questions, and given there was no significant difference in authorship between both groups, it is indeed possible that badges will only serve as useful motivators when the task is relatively easy. This is particularly noteworthy as a survey of the class showed that students felt authoring questions was a more effective way of learning than answering questions.

Of the four quantitative studies reviewed, three provided control groups (Denny, 2013; Hakulinen, Auvinen, & Korhonen, 2013; Hanus & Fox, 2015). Of these three studies, only two directly focused on the effect of badges. The study by Hanus and Fox (2015) combined badges with leaderboards, without a comparison group where only one item was used – the only other comparison group had none of these gamification elements – thereby making it impossible to identify the specific effect of badges.

The studies by Denny (2013), and Hakulinen, Auvinen and Korhonen (2013) provided comparison groups, focused directly on badges, and employed randomization. From both studies, we learn that badges are able to motivate specific behaviors in students. From Hakulinen, Auvinen, and Korhonen (2013), we learn badges are useful for students motivating students to engage in activities they are already motivated to engage in. From Denny (2013), we learn that while badges are useful motivators for some tasks, badges may not be able to encourage students to undertake challenging tasks.

3. Methods

3.1 Homework System

The homework system was hosted on the Moodle Learning Management System (LMS) version 2.7. The Moodle LMS was hosted on an Ubuntu Server 14.04 Long Term Support. The database was MySQL version 5.5.47-0ubuntu.14.04.1. The web server used was Apache/2.4.7 (Ubuntu). The Moodle LMS Essential theme was used for the interface design.

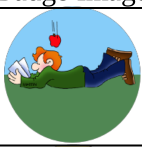
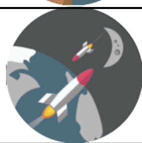
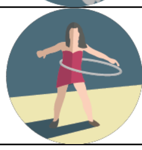
Each course section was administered in a Moodle LMS *course* of its own. The badges were made available to the treatment group using the *badge* feature in Moodle 2.7. Each assignment had about 6 – 9 questions and was assigned using the *Quiz* module. The questions were of the *calculated* question type, with automated assessment – students knew whether they had passed or failed a question instantly. Each assignment question could be attempted an unlimited number of times without penalty.

There were 16 assignments but they had shared submission deadlines. Assignments with shared deadlines in chronological order were: Chapters 5 – 9; Chapters 10 – 14 & 32; and Chapters 15 – 19.

3.2 Badge Design

A formative feedback of badge design was conducted prior to the start of the semester. Using this feedback alongside advice from other studies on badges in education (Abramovich, Schunn, & Higashi, 2013; Denny, 2013; Glover & Latif, 2013; Haaranen, Ihantola, Hakulinen, & Korhonen, 2014; Hakulinen, Auvinen, & Korhonen, 2013; Hanus & Fox, 2015), a full badge system was designed. The look and feel of the assignment chapter badges was designed to reflect the assignment topic. Students in the treatment group were always able to see the available badges at any point in time.

Table 1: Weekly assignment: topics, & badge images

Assignment	Topic	Badge Image	Assignment	Topic	Badge Image
Chapter 5	Motion, Force and Newton's Laws		Chapter 6	Work, Energy, and Power	
Chapter 7	Conservation of Energy		Chapter 8	Gravity	
Chapter 9	Systems of Particles		Chapter 10	Rotational Motion	
Chapter 11	Rotational Motion		Chapter 12	Static Equilibrium and Oscillatory Motion	

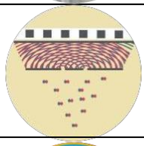
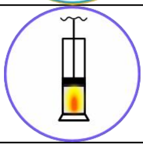
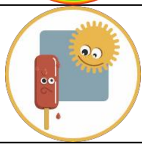
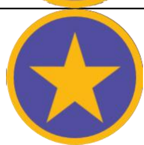
Chapter 13	Static Equilibrium & Oscillatory Motion		Chapter 14	Wave Motion, & Interference & Diffraction	
Chapter 32	Wave Motion, & Interference & Diffraction		Chapter 15	Fluid Motion	
Chapter 16	Thermo-dynamics		Chapter 17	Thermo-dynamics	
Chapter 18	Thermo-dynamics		Chapter 19	Thermo-dynamics	

Table 1 shows the weekly assignment badges. Additionally, higher-level badges were created to motivate students to earn more badges, and to strive for badge accumulation, as shown in Table 2.

Table 2: Higher-level badges with requirements

Chapters	Requirement (Name)	Image
Chapters 5 – 9	Get 4 badges from 5 assignments (Bronze Cup)	
Chapters 10 – 14 & 32	Get 4 badges from 6 assignments (Silver Cup)	
Chapters 15 – 19	Get 4 badges from 5 assignments (Gold Cup)	
All Chapters	Get 3 badges from chapters 5 – 9, 3 badges from chapters 10 – 14 & 32, and 3 badges from chapters 15 – 19 (Star)	
All Chapters	Get 4 badges from chapters 5 – 9, 4 badges from chapters 10 – 14 & 32, and 4 badges from chapters 15 – 19 (Einstein)	

3.3 Requirements to earn a badge

For a student to earn a weekly assignment badge, s/he had two requirements:

- Score full marks on any of the assignment attempts – first, second, or third; and
- The full-mark attempt occurred before a given date – typically one week after the assignment was made available – which was readily visible in the homework system;

Students in the treatment group were provided with an informational document in the system to inform them of these requirements. This full mark requirement was applied because a student's maximum score of three attempts determined the effective score for the student on any given assignment. Without such a requirement, a student could turn in an assignment without taking care to respond to the questions in hopes of getting a badge. Such activity would come without penalty as only the attempt with the maximum grade contributed to the student's effective assignment grade. While this could have placed an extra burden on students who were willing to get badges – correctness in addition to timeliness – an earlier study by Hung (2015) showed that students routinely achieved the maximum assignment score for each assignment. Additionally, the individuals within the physics department who were responsible for the assignment questions in the homework system tried to make the questions relatively undemanding in an attempt to motivate the willingness of students to attempt questions (Hung, 2015). This was because the students enrolled in the course were not physics majors.

3.4 Sample

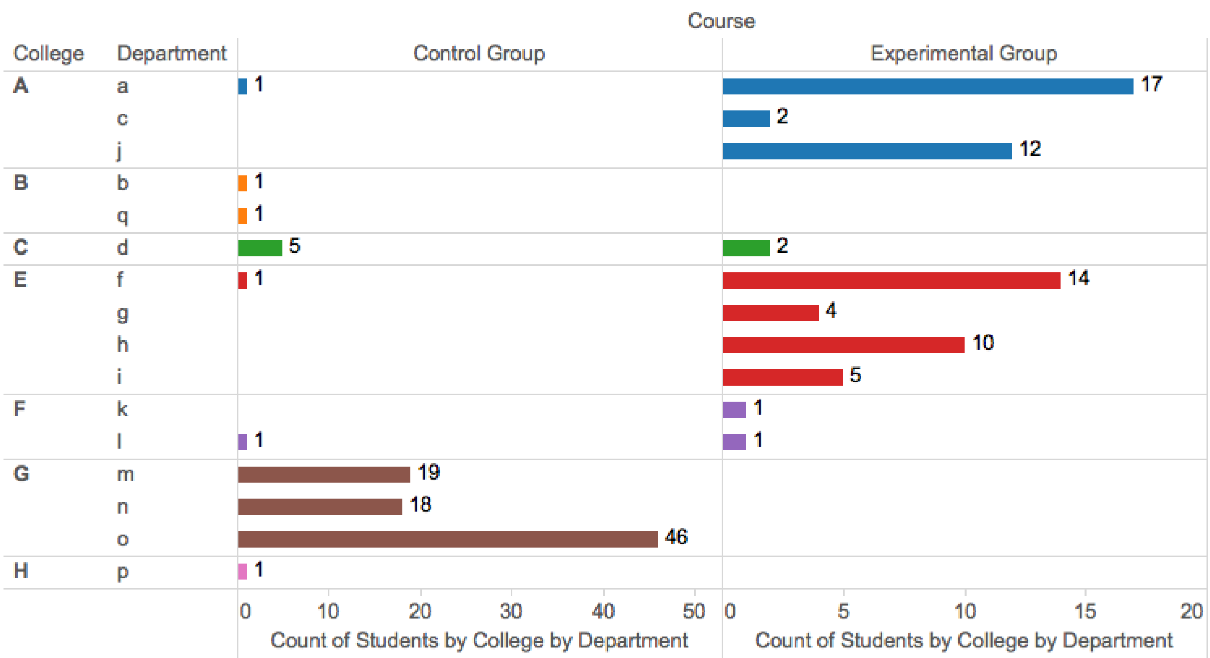
In total, 177 students had registered into both classes at the close of the course add/drop period. Seventy-nine students were in the treatment group, and 98 students enrolled in the control group. Professors within the physics department developed a pre-test to measure students' knowledge of the topics. This pre-test was administered to students before they began assignments. Of the 79 students enrolled in the treatment group, only 70 students were considered as part of the experiment as nine students did not take part in the pre-test. Of the 98 students enrolled in control group, 95 students were considered as part of the study; the other three students did not take the pre-test. Of the 70 students remaining in the treatment group, two students failed to take more than one exam and they were excluded from the analyzed treatment group resulting in 68 students making up the treatment group. Of the 95 remaining in the control group, one student failed to take more than one exam resulting in 94 students making up the control group. Thus the analyzed sample size was 162 students.

The students in both groups came from markedly different colleges and departments within the university – a college contains multiple departments (see Figure 1). Across both groups, there was very little overlap in the colleges. The majority of students in the control group belonged to college G (n = 83, 88.30%), while no student in the treatment group belonged to this college. Students in the treatment group largely came from two colleges: A (n = 31, 45.59%) and E (n = 33, 48.53%).

4. Results and Discussion

4.1 Timeliness

Timeliness of an assignment submission was determined using the positive difference between the time of the assignment submission and the time of the assignment deadline, measured in floating point days.



<u>Figure 1.</u> Count of students in both groups by college by department

The timeliness used for each assignment was the time at which a student achieved her or his maximum score of all the student's attempts. If a student achieved this maximum score on more than one occasion, the earliest submission (maximum timeliness) was selected as the timeliness for the assignment.

Figure 2 shows the distribution of submission times of each assignment by study group; the dotted lines show the deadline to earn a badge for each assignment. As shown, the median is always higher in the treatment group than in the control group. A panel data regression model was used to analyze the effect of course selection on timeliness; with the study group as the independent variable, and timeliness as the dependent variable. Additionally, the scaled pre-test scores of the students were added to the model as a predictor of timeliness.

The resulting panel data regression model was statistically significant (R-Squared = 0.078, Adj. R-Squared = 0.078, F-statistic = 100.49 on 2 and 2372 DF, p-value: < 2.22e-16). As shown in Table 3, course selection had a statistically significant effect on timeliness; being in the treatment group increased the average submission time by about 1.8 days.

Table 3: Coefficients of independent variables in linear panel data model (treatment = 1, control = 0)

	Estimate (days)	*SE*	*t*	*p*
Group	1.84	0.16	11.39	< 2.22e-16 ***
Scaled pre-test grade	0.69	0.083	8.36	< 2.22e-16 ***

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Based on the modelling results, the question arises as to the meaningfulness of a 1.8-day average difference between both groups. Timeliness is a useful translational graduate attribute (Barrie, 2004) – and increase in timeliness as an end is worth it – and the modelling results show the ability of a badge system to positively influence this skill. Whether this improvement stays after badges are removed from a student's digital environment is another question, one that is outside the confines of this study. Additionally, for a treatment that imposes minimal changes to the non-digital dimension of the course, badges appear to be a relatively useful tool.

In relation to the study's primary question: "What is the effect of digital badges on the timeliness of assignment submissions within an undergraduate physics course?", the fact that students in both groups came from markedly different colleges (see Figure 1) weakened the internal validity of the results, and thus, our ability to assign cause and effect. Nevertheless, a statistically significant increase in timeliness was observed in the treatment group.

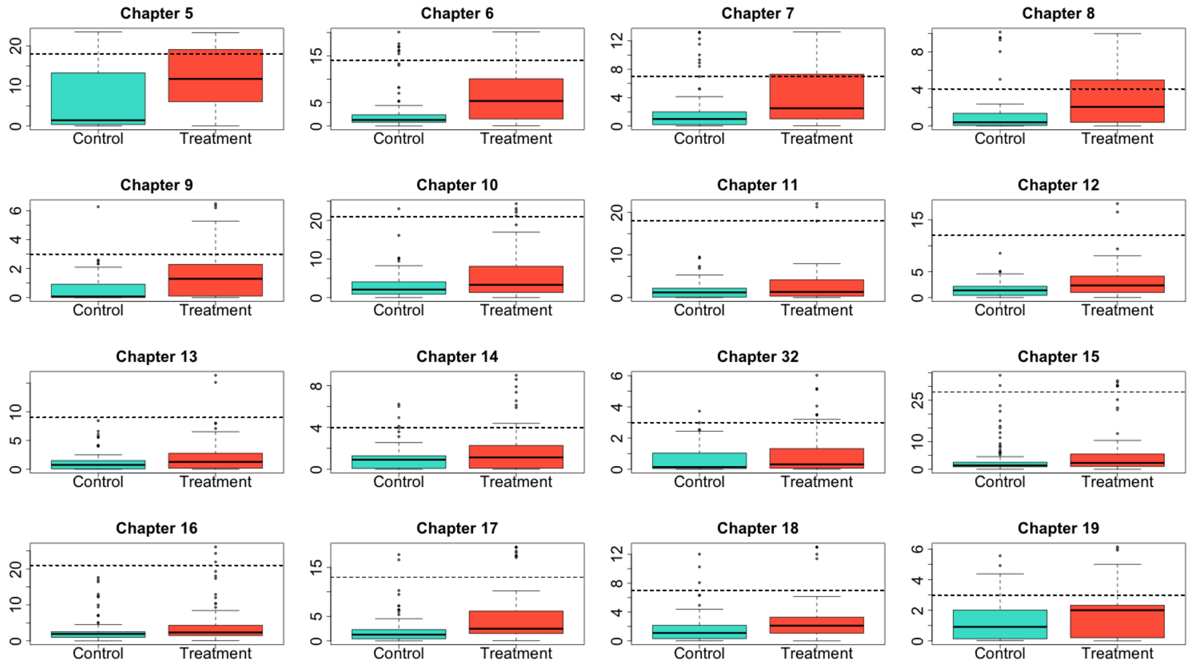


Figure 2. Submission time for each assignment by class showing badge cut-off deadlines. Units: days

Reversing the treatment and control groups and repeating the experiment could resolve this issue. This would be dependent on the expectation that students in a set of colleges are typically attracted to the exact professors involved in both classes. If the results stay the same in terms of treatment and control group, then it is resolved that, the outcomes found at the end of this study are not related to the colleges the students come from but are an effect of badges.

4.2 Badges

In order to find out whether students in the treatment group actively attempted to earn badges, the criteria used to award badges to students in the treatment group was retrospectively applied to the control group to see how both groups fared in terms of acquiring badges.

Table 4: Descriptive statistics and results of Wilcoxon rank sum tests on badge data

Type of Badge	Group	Badge count (Unique earners)	*M*	*SD*	W	*p*
Sum: chapters 5-9 badges	Control	22 (12)	0.23	0.71	2375	0.00015 ***
	Treatment	67 (25)	0.99	1.54		
Sum: chapters 10-14,32 badges	Control	6 (6)	0.064	0.25	2759	0.0080 **
	Treatment	29 (13)	0.43	1.00		
Sum: chapters 15-19 badges	Control	14 (10)	0.15	0.53	2806	0.035 *
	Treatment	31 (15)	0.46	1.01		
Sum: all chapter badges	Control	42 (19)	0.45	1.09	2276	0.00013 ***
	Treatment	127 (31)	1.87	2.92		
Bronze Cup	Control	1 (1)	0.011	0.10	2854	0.0035 **
	Treatment	8 (8)	0.12	0.33		
Silver Cup	Control	0 (0)	0	0	3149	0.24
	Treatment	1 (1)	0.015	0.12		
Gold Cup	Control	1 (1)	0.011	0.10	3136	0.38
	Treatment	2 (2)	0.029	0.17		
Star	Control	0 (0)	0	0	3102	0.097 .
	Treatment	2 (2)	0.029	0.17		

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
No student earned the Einstein badge

Across all the periods in the semester, students in the treatment group never got fewer badges than students got in the control group. To test whether this difference was statistically significant, a two-tailed Wilcoxon Rank Sum test with continuity correction was employed; the badge data was heavily skewed towards zero, as a majority students never earned a single badge.

As shown in Table 4, the mean of badges earned by students in the treatment group across the semester is significantly higher than the mean of badges gained by students in the control group. Thus, it appears that students actively attempt to earn badges when given the opportunity. However, there is no significant difference between both groups in terms of earning the higher level badges except for the *Bronze Cup*.

4.3 Performance on Assignment and Exams.

The performance of both groups on the assignments and exams is reported; however, there is nothing in the literature that suggests improved or reduced performance. The average assignment score was 94% in the control group, and 96% in the treatment group. To test whether the difference in means of exam scores of both groups was statistically significant, a linear regression model with study group as the independent variable was used to predict each exam score. Only for the second exam is there a statistically significant increase in the average grade of a student in the treatment group (see Table 6).

Table 5: Regression results using group (Control = 0; Treatment = 1) to determine exam scores

Exam	Estimate	S*E*	*t*	*p*	Adjusted R-squared
First Exam	2.969	2.824	1.051	0.295	0.00065
Second Exam	4.097	1.898	2.159	0.0323 *	0.02224
Third Exam	2.657	2.720	0.977	0.33	-0.00029

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

5. Conclusion

In this quasi-experiment, badges were added to a general physics homework system in an attempt to improve the timeliness of assignment submissions by students. Our findings show that badges can be used to motivate specific behaviors in students whilst requiring minimal changes to the course structure. These results corroborate results reported by Hakulinen, Auvinen, and Korhonen (2013) and Denny (2013). However, as found by Denny (2013), badges may not be particularly useful in motivating students towards difficult challenges – no student earned the demanding Einstein badge in our study and there was no statistically significant difference between both groups in terms of earning higher-level badges, except for the *Bronze Cup* (see Table 4). It is possible that badges are effective motivators for *low hanging fruit* – beneficial tasks that require little effort; further studies are needed to confirm this.

Despite the fact that badges were not able to influence exam performance of students in this study, results from a survey administered to students in the treatment group within this study showed a positive attitudinal response to the presence of badges within the homework system (Uanhoro, 2016). The reported benefits in terms of learning outcomes are mixed when an online homework system is introduced into the teaching of general physics (Liang, 2002; Demirci, 2007; Gok, 2011; Dufresne, Hart, Mestre, & Rath, 2002). However, the major gains are to be found in improved attitudinal stances towards the course under study (Liang, 2002; Demirci, 2007; Gok, 2011). Hung (2015), whilst studying an earlier iteration of the same course studied in this quasi-experiment, found that students greatly appreciated the homework system. It appears that badges serve to enhance this experience.

Additionally, it might be worth exploring the effects of badges using the switched replication design. This would allow researchers to see whether students retain the behavioral changes they made in the presence of badges once badges are removed.

References

Abramovich, S., Schunn, C., & Higashi, R. (2013). Are badges useful in education?: it depends upon the type of badge and expertise of learner. *Educational Technology Research and Development, 61*, 217-232.

Barrie, S. C. (2004, August 3). A research-based approach to generic graduate attributes policy. *Higher Education Research & Development*, *23*(3), 261-275.

Denny, P. (2013). The Effect of Virtual Achievements on Student Engagement. *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 763-772). Paris: ACM.

Glover, I., & Latif, F. (2013). Investigating perceptions and potential of open badges in formal higher education. *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications* (pp. 1398-1402). Victoria, Canada: AACE.

Haaranen, L., Ihantola, P., Hakulinen, L., & Korhonen, A. (2014). How (not) to Introduce Badges to Online Exercises. *Proceedings of the 45th ACM technical symposium on Computer science education* (pp. 33-38). New York: ACM.

Hager, P., & Holland, S. (2006). Introduction. In P. Hager, & S. Holland (Eds.), *Graduate Attributes, Learning and Employability* (pp. 1-48). Netherlands: Springer.

Hakulinen, L., Auvinen, T., & Korhonen, A. (2013). Empirical Study on the Effect of Achievement Badges in TRAKLA2 Online Learning Environment. *Learning and Teaching in Computing and Engineering (LaTiCE)* (pp. 47-54). Macau: IEEE.

Hanus, M. D., & Fox, J. (2015). Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance. *Computers & Education, 80*, 152-161.

Hung, K. C. (2015). *A Study of Integrating Homework System into University General Physics* (Unpublished master's thesis). National Tsing Hua University, Hsinchu, Taiwan.

Joseph, B. (2012, June 25). *Six Ways to Look at Badging Systems Designed for Learning*. Retrieved February 3, 2015, from Online Leadership Program: http://www.olpglobalkids.org/content/six-ways-look-badging-systems-designed-learning/

Linderoth, J. (2012, March 27). Why gamers don't learn more. An ecological approach to games as learning environments. *Journal of Gaming & Virtual Worlds*, *4*(1), 45-62.

Maidis. (2006, December 26). Horizontal Striped Hot Air Balloons [hot air balloon]. Retrieved May 29, 2015, from https://openclipart.org/detail/18938/
Chapter 17 Badge

Martin, P. (n.d.). Archimedes [Archimedes running]. Retrieved May 29, 2015, from http://greece.phillipmartin.info/greece_archimedes.htm
Chapter 15 Badge

Martin, P. (n.d.). Color Spectrum[Apple falling on Newton's head]. Retrieved May 29, 2015, from http://science.phillipmartin.info/science_color_spectrum.htm
Chapter 14 Badge

Martin, P. (n.d.). Physics [Apple falling on Newton's head]. Retrieved May 29, 2015, from http://science.phillipmartin.info/science_physics.htm
Chapter 5 Badge

Martin, P. (n.d.). Thermometer [Person looking at thermometer]. Retrieved May 29, 2015, from http://science.phillipmartin.info/science_thermo.htm
Chapter 16 Badge

MesserWoland. (2006, July 14). Enema syringe [Enema syringe]. Retrieved May 29, 2015, from https://commons.wikimedia.org/wiki/File:Enema_syringe.svg
Chapter 18 Badge

MoodleBadges.com. (n.d.). Retrieved May 29, 2015, from http://moodlebadges.com/?page_id=17
Bronze, Silver, Gold and Star Badges

Mozilla Foundation. (2014). *About | Open Badges*. Retrieved February 3, 2015, from Open Badges: http://openbadges.org/about/

PrinterKiller. (2011, July 31). Popsicle and the sun [Popsicle and the sun]. Retrieved May 29, 2015, from https://openclipart.org/detail/152863/
Chapter 19 Badge

Rhodeson. (2011, June 12). La Belle France [Man bungee jumping]. Retrieved May 29, 2015, from https://www.flickr.com/photos/rhodeson/5832029034/
Chapter 13 Badge

Saddler, D. (2007, May 16). [Einstein Image Painted on Hazard Marker]. Retrieved May 29, 2015, from https://www.flickr.com/photos/80502454@N00/501890523/
Einstein Badge

Uanhoro, J. O. (2016). *A Quasi-Experimental Study on the Effect of Badges on Timeliness within an Undergraduate Physics Cours* (Unpublished master's thesis). National Tsing Hua University, Hsinchu, Taiwan.