International Journal of Game-Based Learning
Volume 10 • Issue 1 • January-March 2020

Gamification of Formative Feedback in Language Arts and Mathematics Classrooms:

Application of the Learning Error and Formative Feedback (LEAFF) Model

Man-Wai Chu, University of Calgary, Calgary, Canada
Teresa Anne Fowler, University of Calgary, Calgary, Canada

ABSTRACT

The use of computer games in education has been increasing in popularity during the past decade. Game-based learning environments are designed to teach specific knowledge content and skill-based learning outcomes using game elements. One main reason for using game-based learning environments is to increase student motivation and engagement while teaching learning outcomes. Many of the game-based learning environments are designed so that students will reach maximum flow, which is defined as students being so completely immersed in that game that they do not notice that they are learning. These learning environments have been shown to improve many behaviour and cognitive learning outcomes. While game-based learning has many benefits, some educational researchers have indicated that it is often very costly to develop a complex game-based assessment to teach a few learning outcomes. Hence, in some cases it is more beneficial to approach the use of computer games in education using gamification.

KEYWORDS

Formative Feedback, Formative Feedback Model, Gamification, Language Arts, Learning Error, Mathematics

GAMIFICATION

Gamification is designed to use game-based elements to teach students specific learning outcomes (Dicheva, Dichev, Agre, & Angelova, 2015; Mora, Riera, Gonzalez, & Arnedo-Moreno, 2017). A review of the gamification literature highlighted some of the most common game-based elements used in education: points, levels/stages, badges, leaderboards, prizes/rewards, progress bars, storylines, and feedback (Brull & Finlayson, 2016; Nah, Zeng, Telaprolu, Ayyappa, & Eschenbrenner, 2014). Gamification allows educators to integrate a few or many of these game-based elements into a learning environment. Similar to game-based environments, gamification aims to increase student motivation and engagement during their learning by providing challenging goals (Faiella & Ricciardi, 2015).

DOI: 10.4018/IJGBL.2020010101

However, these two approaches differ on their foundations: game-based learning uses the game environment to teach specific learner outcomes, while gamification focuses on using game-based elements in an education context (Nah et al., 2014; Oritz, Chiluiza, & Valcke, 2016). Similar to game-based learning, many studies have indicated that gamification increased students' affect and cognition (Dicheva et al. 2015; Mora et al., 2017).

There are many gamification frameworks that are used to implement game-based elements into various learning contexts (Mora et al., 2017). A systemic review of over 2000 gamification publications revealed that the Mechanics-Dynamics-Aesthetics (MDA) framework is one of the more popular frameworks that is used (Hunicke et al., 2004). The MDA framework is a formal structuralist approach that bridges the complexities of game development, player criticism, and design research by breaking down games into three components: mechanics (i.e., rules), dynamics (i.e., system), and aesthetics (i.e., affective response; Hunicke et al., 2004). Many gamification frameworks, such as the MDA, focus on developing an immersive and interactive learning environment which takes into account all the different and inter-related game components together to form one system. The focus here is on *one* gamified system which is designed with student needs at the forefront (Deterding, Sicart, Nacke, O'Hara, & Dixon, 2011). These gamified systems focus on the holistic picture of gamification which provide students with meaningful choices in the pursuit of interesting challenges instead of the mundane game elements such as points, badges, and leaderboards (Deterding, 2012).

While some gamification scholars have indicated the importance of designing the entire learning environment as one holistic system, others have taken a more compartmentalized approach by integrating a few game-based elements into a learning environment at one time (Mora et al., 2017). While the frameworks that are identified in the literature do not indicate a specific number of game-based elements that should be integrated into a learning environment (Mora et al., 2017), most gamification studies often use two or more elements at the same time to improve students' learning (Dicheva et al., 2015). Although many of the studies that integrated multiple elements into the learning environment produced the desired result of increased understanding of learning outcomes (Abramovich, Schunn, & Higashi, 2013; Morrison & DeSalvo, 2014), a review of these studies indicated a need to investigate each game-based element individually to better understand how each of these elements impacts education (Faiella & Ricciardi, 2015). As such, this study aims to investigate only one game-based element – gamification of formative feedback – on student learning in the classroom.

Gamification of Formative Feedback

Most digital games integrate elaborate feedback into the system which notifies players of their current performance (Despain & Acousta, 2013; Gee, 2007; Rogers, 2010). Formative feedback provided to students during a digital-game environment (e.g., earning in-game money or jewels) is often evaluated, reflected upon, and used by players to enhance their future in-game performance (Gee, 2007; Shute & Ventura, 2013). Literature surrounding game-based feedback has identified some common feedback characteristics: brevity, real-time, and skill-based (Despain & Acousta, 2013; Rogers, 2010).

First, the feedback provided during a game is often very brief and minimal despite being calculated using complex in-game point allocation systems (Shute, Ventura, Bauer, & Zapata-Rivera, 2009). For example, players may receive formative feedback about their performance using a life bar which is a simple bar graph depiction of an in-game avatar's health indicator signifying the amount of damage or number of hits it has received. When the life bar reaches zero, the game is over and the avatar will have to re-start that specific task or level. These life bars are often real-time, which is reflective of players' current health during each moment of the game. Although the player may receive simplistic feedback in terms of a life bar, the mechanism used to calculate the values in the life bar may be highly complex by factoring the quantity and magnitude of each hit received by the avatar. Second, game-based feedback is often a reflection of players' real-time performance. For example, players' life bars are often a real-time indicator of their performance during the specific task. This indicator

is not influenced by previous performance achievements or failures. Third, the feedback provided to students is often focused on specific skills instead of a single task. For example, players may receive in-game points for the skill of being creative instead of focusing on a specific task.

One of the most alluring aspects of game-based formative feedback systems is that players often evaluate, reflect, and use the feedback to improve their performance on future tasks. This self-initiated evaluation, reflection, and use of formative feedback is an important step during the learning process (Leighton, Chu, & Seitz, 2013). Hence, there is a need to investigate this type of game-based feedback so that students may evaluate, reflect, and use the formative feedback to improve their performance in educational environments.

Educational Formative Feedback

Formative feedback is crucial to the process of knowledge and skills acquisition (Leighton et al., 2013; Shute, 2008). The use of formative feedback during learning is complex because it is not only a cognitive process but also requires the consideration of affective dispositions (Immordino-Yang & Damasio, 2007). To facilitate successful and positive experiences of learning, educators need to consider how human emotions enhance or hinder students' use of formative feedback (Lajoie, 2008; Sawyer, 2006). In meeting the goal of developing a learning environment that is sensitive to students' emotions, game-based environments are a powerful ally (Shute & Ventura, 2013). Game-based formative feedback systems are powerful because students are willing to self-initiate evaluation, reflection, and use of the feedback provided during a game. As such, the principles behind these digital game feedback systems are useful in an educational environment to help educators provide formative feedback that is used in a meaningful way.

Research in the realm of formative feedback has often focused on the technical elements of the content (e.g. complexity of feedback) and delivery (e.g., timing) of the feedback provided to students (Kluger & DeNisi, 1996; Shute, 2008). Despite the quantity of research studies conducted on the provision of formative feedback, there is a lack of research to help educators understand students' use of feedback (Harrison et al., 2016; Shute, 2008). However, students' use of feedback is important in terms of improving the acquisition of knowledge and skills during the learning process (Leighton et al., 2013). Students' decisions of whether to use feedback in a meaningful way is often guided by an emotional and cognitive evaluation of the learning environment. A framework that integrates students' evaluation of the learning environment and their use of formative feedback is the learning error and formative feedback (LEAFF) model (Leighton et al., 2013).

Learning Error and Formative Feedback (LEAFF) Model

The LEAFF model outlines that a learning environment deemed emotionally safe by students allows them to feel at ease revealing their misconceptions and learning errors, which is hypothesized to develop more meaningful feedback for students to use during the formative phases of learning (Leighton et al., 2013). When students feel at ease revealing what they do not understand and thus share their misunderstandings, educators can help correct these misconceptions by providing relevant formative feedback that is specifically targeted to the errors revealed. Formative feedback that is deemed meaningful and relevant to students' performances is expected to be accepted and is used by students more readily than other types of feedback (Smith, diSessa, & Roschelle, 1993). The LEAFF model, shown in Figure 1, involves three parts. The first part of the LEAFF model focuses on the instructional climate within classrooms, where educators engage in pedagogical behaviors (e.g., discussing the importance of making errors during the learning process) that either explicitly or implicitly promote safety or risk taking for learners experimenting with new knowledge and skills. Previous studies of the LEAFF model used explicit discussions to convey that errors are a natural and necessary part of learning complex material (Chu & Leighton, 2019; Firestein, 2016; Leighton & Bustos Gomez, 2018). Students who are receptive to these ideas are expected to view their classrooms as emotionally safe.

Figure 1. The learning errors and formative feedback (LEAFF) model. Adapted from Leighton, Tang and Guo (2017). Reprinted with permission.

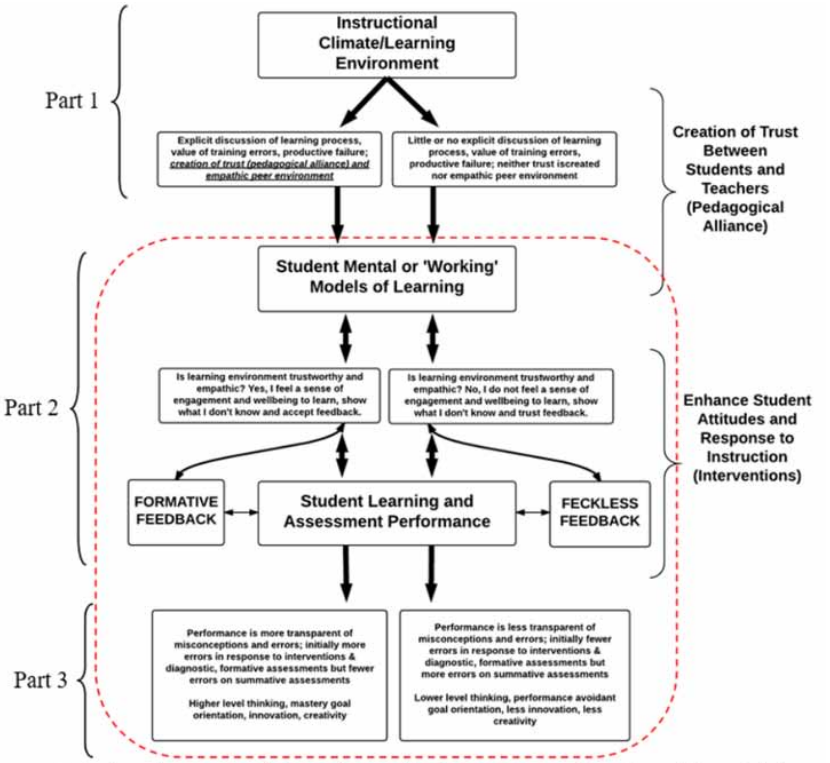

Figure 1. The learning errors and formative feedback (LEAFF) model. Adapted from. Leighton, Tang and Guo, (2017). Reprinted with permission.

This current study focused on the second and third parts of the LEAFF model, which are highlighted using a red dashed outline in Figure 1. In the second part of the model, students develop mental models that represent their learning environments. Mental models are rooted in decades of cognitive science research indicating internal representations that reflect an individual's perception and understanding of the world around them for the purposes of reasoning and problem solving (Johnson-Laird, 1983). Students who view the classroom or learning environment as emotionally safe are likely to possess mental models that provide an internal sense of ease, allowing them to acknowledge learning errors on formative assessments and to use the formative feedback during their learning. Students who feel at ease within their learning environment are likely to make more errors during the training phase of learning because they feel safe taking intellectual risks, and gaining a deeper understanding of the content.

In the third part of the model, it is hypothesized that the early intellectual risk-taking and use of formative feedback allows students who feel safe in their learning environments to make fewer errors on summative assessments (Leighton et al., 2013). Over time, students who feel safe in revealing what they do not understand are expected to exhibit enhanced emotional experiences and improved academic performance. During the second and third portions of the model, it is important to provide students with feedback that they consider formative, so that it will be used. Game-based feedback has been shown to be positively received by players during gameplay as evidenced by their use of the feedback to improve their performance during the latter tasks and levels (Gee, 2007; Rogers, 2010). Hence, utilizing some of the game-based formative feedback design principles may help bolster students' use of educational feedback in the classroom (Despain & Acousta, 2013; Gee, 2007; Rogers, 2010).

RESEARCH QUESTIONS

The main objective of this study was to investigate whether a game-based formative feedback reporting system using classroom-based formative assessments may enhance students' use of formative feedback in the classroom as well as knowledge and skill acquisition during the unit. Specifically, the research questions that guided this study were:

1. How often did students use game-based formative feedback provided in their classroom?
2. How do students use the game-based formative feedback they receive in the classroom?
3. Does the use of game-based formative feedback improve students' achievement during the unit?

Methods

A quasi-experimental design was used to investigate Grade 9 students' use of formative feedback during a unit in both their English (i.e., poetry) and Mathematics (i.e., circle geometry) courses. This study followed a quasi-experimental design because students in the two groups (i.e., comparison and treatment groups) were not randomly assigned. Instead, they were assigned to one of the two groups based on the year they were enrolled in Grade 9 at the school. Data for this study was collected over two years in which the same English and Mathematics teachers taught the same two courses. It was important for the same two teachers to teach the same two courses during the two years to ensure minimal teacher effects that may be associated with differences among teachers. Students in the first year of the study completed all their formative assessments during their poetry and circle geometry units without a game-based formative feedback system. These students received their formative feedback in the form of a numerical grade and written comments on their assessments, which are the typical feedback formats used by the teachers. Students in the second year of the study completed the same formative assessments and received their feedback in both a game-based system and in written comments. The main difference between the two types of feedback received by students is the numerical score versus the game-based rubric indicators. Students in the first year of the study received a numerical score on their formative assessments while students in the second year of the study received game-based rubric indicators on their formative assessments. The frequency of the feedback was approximately the same because it was based on the number of formative assessments that were administered; the same number of formative assessments were used during both years. Detailed information regarding the game-based formative feedback system, which was used as an intervention in this study, is presented later.

Participants

A total of 126 Grade 9 students and their English and Mathematics teachers ($n = 2$) participated in this study over a two-year period. During the first ($n = 69$) and second ($n = 57$) years of this study, students' data was collected during the specified units. Two different cohorts of Grade 9 students participated in this study. Although different students were used during the two years (i.e., students in the first year were in the comparison group while students in the second year were in the intervention group) of this study, they all attended the same middle school and had the same teachers during the specified units. The students who attended this school typically lived nearby because the municipal education system designate students to schools within their neighborhood based on their home address (Calgary Board of Education, 2019). The census data indicated the median household income for families that lived near the school was around $85,500, which is slightly less than the median for the city (City of Calgary, 2016).

The two teachers were both learning resource leaders within the school, which meant they were identified by the principal to be experienced teachers who are tasked with helping other teachers with their classroom challenges and meeting students' academic needs. These two teachers were often invited to visit other teachers' classrooms to offer advice regarding various issues their colleagues

were facing. Additionally, they also worked in small groups during the lunch break with students who were experiencing academic difficulties so that these students may be successful in learning the material they needed.

RESEARCH DESIGN

Before the start of the study, the ethics boards from both the researchers' institution and the students' school district approved the study. Anonymous data (i.e., student achievement data) for the students in the first year of this study were provided to the researchers from the school administrator. Students in the second year of the study were approached by the researchers two weeks prior to the start of the unit being investigated and introduced to this study. During this initial meeting, students were asked to bring home a parent information package and consent form to indicate whether their parents/guardians would allow researchers to collect their child's data for this study. The researchers returned to the school one week prior to the start of the unit to collect the parent consent forms and also invited students to be a part of this study. During this second meeting, the researchers passed out and explained the student ascent forms to indicate whether students would allow the researchers to collect their information. Only students who had both parent consent and student assent forms indicating they allowed the researchers to collect their information had their data collected for this study. The two teachers recommended that all students in the second year of the study receive the gamified feedback because they did not want non-participating students to be identified. Hence, the ethics applications and consent forms focused on asking for permission to collect student data instead of participating in the study (i.e., receiving gamified feedback).

During the two years, the same English and Mathematics teachers taught the same courses to ensure minimal teacher effects that may be associated with differences between teachers. Students in the first year of the study completed all their formative and summative assessments without a game-based formative feedback system while students in the second year of the study completed the same formative assessments, but received their feedback in a game-based system. Since different students were used for the two cohorts for this study, students' English and Mathematics scores before the units used in this research study were collected and used as a baseline measure (i.e., covariate) of potential student differences.

MEASURES USED AND DATA COLLECTED

Specific formative and summative assessment items and tasks used during this study were recommended by the two teachers because they previously used them, with success, in their English and Mathematics units. During the first year of the study, students' achievement records (e.g., students' performance on the formative and summative assessments during the poetry and circle geometry units) were collected. During the second year of the study, students' achievement records during the same two units as well as surveys and open-ended responses investigating student usage of game-based formative feedback were collected. Students' English and Mathematics achievement records prior to the start of the units used in this study were treated as covariates during the analyses. Since the two cohort of students lived near the school, it was reasonable to assume they had similar demographic backgrounds. Background information regarding students' familiarity with technology was not collected despite the formative feedback being returned to students on a digital platform. The school where this study was taking place was part of a school district that encouraged students and/or their parents to regularly check an online platform to receive information regarding students' progress (e.g., achievement records) and school information (e.g., school sporting events). As such, the students were quite familiar with using the digital platform to check their progress and teacher feedback. The six Likert-scale survey items and five open-ended responses administered to students during the study are located in the Appendix.

INTERVENTION: GAMIFICATION OF FEEDBACK

In the game-based formative feedback system, students' feedback was provided using a rubric of *life bars* which indicated whether students were showing limited, moderate, or consistent performances of understanding on each of the specific learner outcomes. The purpose of this gamification intervention was to increase students' use of the formative feedback as a means to improve understanding. Game design principles were used to enhance the feedback provided to students (Despain & Acousta, 2013). The gamification of feedback focused on three areas of game design. First, the feedback provided to students focused on skill-based learner outcomes students were trying to attain instead of each individual task. Second, the format of the feedback was designed using game-design principles so that the indicators students received on each outcome would fluctuate depending on their performance on each task instead of a compounded mark (Despain & Acousta, 2013). For example, if students received a limited indicator on an outcome on the first day, but then received a consistent on the same outcome on the third day followed by a moderate indicator on the fifth day then the students' mark would fluctuate throughout the five days based on their performance of that outcome. This is in contrast to the traditional numerical scores that got compounded to calculate students' final grade in which students' earlier poor performances would effect their final grade regardless of how well they did at the end of the unit. Third, the feedback provided during the gamification intervention focused on using a life bar to showcase student performance instead of traditional numerical or written formats. Figure 2 shows an example of the life bar rubric that was used during the second year of the study. The feedback provided to students using this system focused on rubric indicators (i.e., limited, moderate, and consistent) instead of numerical grades. These three indicators were the only ones used throughout this study and were adapted by the ones used on a formative cognitive diagnostic assessment (Roduta Roberts, Alves, Chu, Thompson, Bahry, & Gotzmann, 2014). Researchers have indicated these indicators are well-received and understood by students and educators when presented on score reports (Roduta Roberts & Gierl, 2010). The rubric criterion consisted of specific skill-based learner outcomes that students are expected to learn according to the program of studies that guided the local education system (Alberta Education, 2007; Alberta Learning, 2000). For example, Figure 2 lists the four learner outcomes that students focused on during the math unit. While these outcomes may seem like they are knowledge, or factual, outcomes, the program of studies highlights the application these outcomes to solve problems which elevates these to be skill-based learner outcomes. Students in the second year of the study had access to this rubric for both their poetry and circle geometry units. This rubric was updated daily to reflect student progress throughout the two units.

Figure 2. Example of the game-based formative feedback life bar system used during the circle geometry unit

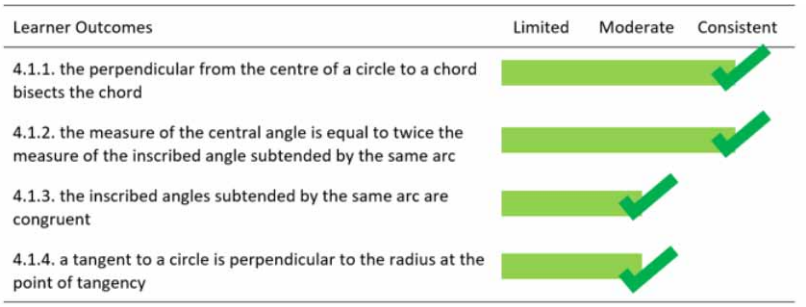

Figure 2. Example of the game-based formative feedback life bar system used during the circle geometry unit

RESULTS

The results of the study are presented in three sections which represent the three research questions that guided this project. Although the researchers sent the survey, shown in the Appendix, to all 57 students who participated in the second year of the study, but only 36 of them completed the survey. Results of the first research question, how often did students use game-based formative feedback provided in their classroom, indicated that most students (88.9%) checked and used the rubric feedback at least 1-2 times each week. Full results are presented in Table 1.

To address the second research question, how do students use the game-based formative feedback they receive in the classroom, both quantitative and qualitative survey was used. The quantitative survey data indicated students found the rubric feedback relatively useful (mean=3.58, SD=1.204) and would want to continue using the rubric feedback for the rest of the year (mean=3.50, SD=1.384) (Table 2).

The qualitative data collected from open-ended survey questions indicated most students had a positive experience with the rubric feedback treatment. The students' responses (n=36) were coded using thematic analysis, which resulted in four main topics: ownership of learning, affect regarding feedback, learning from errors, and explicit correction feedback. A themes are presented in the following paragraphs and summarized in Table 3.

Many students indicated the rubric feedback treatment was beneficial towards developing their *ownership of learning* because it made them aware of their areas of strengths and weaknesses. One student indicated that the treatment "gave me a chance to understand where I can improve and see where I don't need as much review. It made me more aware of what I needed to learn since I was

Table 1. Frequency of items related to students' use of feedback

n=36	Never	1-2 Times a Week	3-4 Times a Week	5-6 Times a Week	More Than 6 Times a Week
1. How often did you **check** the rubric feedback during the unit?	4 (11.1%)	19 (52.8%)	12 (33.3%)	1 (2.8%)	0 (0%)
2. How often did you **use** the information from the rubric feedback?	4 (11.1%)	13 (36.1%)	12 (33.3%)	5 (13.9%)	2 (4.9%)

Table 2. Means and standard deviations of items related to usefulness of feedback

n=36	Mean	Standard Deviation
3. How would you rate the **overall usefulness** of the rubric feedback?+	3.44	0.91
4. How **useful** was the information from the rubric feedback?*	3.58	1.20
5. Would you want to continue having this rubric feedback for the rest of the year?*	3.50	1.38
6. Would the rubric feedback be useful in other classes/subjects?*	3.75	1.23

+The five-point Likert scale used for item 3 is: 1 = poor; 2 = below average; 3 = average; 4 = above average; 5 = excellent

*The five-point Likert scale used for items 4, 5, and 6 is:1 = not at all, 2 = not really, 3 = neutral, 4 = somewhat, 5 = very much

Table 3. Summary of qualitative data

Themes	Sample of Student Data
Ownership of Learning	"gave me a chance to understand where I can improve and see where I don't need as much review. It made me more aware of what I needed to learn since I was constantly reminded" "allowed me to review daily and to insure I understood the topic we were working on." "kept me on top of my work and helped me better understand the work given to me." "really try and understand and put what we learned to work."
Affect Regarding Learning	"I felt motivated whenever I got a moderate or a limited. I felt that I had to work harder to achieve a consistent." "[feel] very good to get my marks back knowing it was not going to affect my grade. It gave me a chance to see how I am doing, but to not worrying [*sic*] about my mark dropping."
Learn From Errors	"I was not as afraid to make mistakes and learn from them." "[know] exactly where you went wrong and will not make the same mistake again." "At the beginning of this [research project] I wasn't doing so good [*sic*] during this unit because I didn't quite understand the concept and structure of the unit. But after getting constant feedback from the [rubric feedback], I started to learn what I needed to work on which ended up resulting in my favor as when the unit final came around I was able to answer each and every question perfectly with a thorough understanding of each question that was asked. At the [beginning] my average was a 77-78 percent but now after the study I got a 93 on the unit final which boosted my mark to amazing proportions."
Explicit Correction Feedback	"explain[ed] what and where I went wrong and the steps I need to take to get the right answer."
Dislike Gamified Formative Feedback	"I felt a little stressed when the rubric marks were returned to me. Even though it did not affect my overall mark I was still stressed out." "I did not really like the idea of being evaluated every day because some days I would not fully understand the concept, but the next day we would have an assessment, on which I would do poorly."

constantly reminded" on areas that needed improvement. This constant feedback led students towards daily reviews which helped them better understand the material. A student responded and said the rubric feedback "allowed me to review daily and to insure I understood the topic we were working on." Another student said the rubric feedback "kept me on top of my work and helped me better understand the work given to me." This deeper understanding also improved students' ability to apply their knowledge to different contexts. For example, one student indicated that the most beneficial part of this rubric feedback was that it made them "really try and understand and put what we learned to work." This additional 'trying' element that many students mentioned was also evident in their positive affective dispositions towards learning with the rubric feedback treatment.

This positive affect regarding learning was mentioned by many students in terms of the rubric feedback motivating students and reducing their stress during the learning phase as they improved their understanding. Some students viewed the rubric feedback as a motivating force that pushed them to review their daily lessons when they did not achieve the top achievement level. One student mentioned that "I felt motivated whenever I got a moderate or a limited. I felt that I had to work harder to achieve a consistent." This type of motivation is consistent with game-based feedback in terms of guiding students towards a higher level of achievement (Shute & Ventura, 2013). The rubric feedback was designed to be formative, which meant the feedback did not have any weight or bearing on students' final unit grade. The achievement levels (i.e., limited, moderate, and consistent) students received on the rubric feedback were designed to provide students with information regarding their current understanding of course material; hence, numerical grades were not provided to ensure the feedback could be used formatively to inform learning. Many students indicated this no-stakes rubric feedback allowed them to "[feel] very good to get my marks back knowing it was not going to affect my grade. It gave me a chance to see how I am doing, but to not worrying [*sic*] about my

mark dropping." This allowed students to showcase their learning errors or misunderstandings on the formative assessments which allowed the rubric feedback to be used to improve their performance throughout the unit.

The use of rubric feedback to inform students how to learn from their errors is important because the errors are an essential part of the learning process (Leighton et al., 2013). Many students indicated that the continuous, no-stakes feedback was beneficial in terms of allowing them to learn from their errors. One student said "I was not as afraid to make mistakes and learn from them." Allowing students with the feedback needed to learn from their errors or mistakes prevented them from making the same mistake later during the unit. Another student indicated that the continuous rubric feedback allowed them to "[know] exactly where you went wrong and will not make the same mistake again." The rubric feedback helped students focus their studies on areas that were identified as weak and allowed them to learn from errors during the learning process. This was capitalized upon by many students who took this opportunity to better understand the different learner outcomes and to be aware of their learning throughout the unit. One student summarized their experience in the following passage:

At the beginning of this [research project] I wasn't doing so good [sic] during this unit because I didn't quite understand the concept and structure of the unit. But after getting constant feedback from the [rubric feedback], I started to learn what I needed to work on which ended up resulting in my favor as when the unit final came around I was able to answer each and every question perfectly with a thorough understanding of each question that was asked. At the [beginning] my average was a 77-78 percent but now after the study I got a 93 on the unit final which boosted my mark to amazing proportions.

This student utilized the rubric feedback to better understand the course material which resulted in an increase in their overall achievement grade.

Although students indicated many benefits of the rubric feedback, they also reported the feedback could be enhanced by including explicit correction feedback such as detailed explanations of learning errors and how they could improve their understanding of the material. Many students indicated that they would have benefitted more from the rubric feedback if it also "explain[ed] what and where I went wrong and the steps I need to take to get the right answer." For this specific project, elaborate feedback was not provided because the system was designed with game-based principles which focused on simplistic performance indicators that encouraged students to evaluate and self-reflect on areas of improvement and real-time notifications that represented students' current achievement levels (Shute et al., 2009).

Furthermore, while many students indicated the benefits of receiving continual rubric feedback, a few of their peers did not enjoy this process by indicating that the they were stressed over the daily formative assessments and did not experience improved understanding because they did not have adequate time to review the material. One student indicated that "I felt a little stressed when the rubric marks were returned to me. Even though it did not affect my overall mark I was still stressed out." This student further elaborates that they preferred the traditional feedback they had received throughout the year instead of the rubric feedback. Another student explained that one source of their stress came from the daily formative assessment used to inform the rubric feedback. They said, "I did not really like the idea of being evaluated every day because some days I would not fully understand the concept, but the next day we would have an assessment, on which I would do poorly." The daily assessments and subsequent feedback added stress to this student when they did not have time to review the daily lesson.

Many students indicated the positive cognitive (e.g., improved understanding), behavioral (e.g., habit of reviewing lessons), and affective (e.g., motivated to learn) benefits of the rubric feedback, but a few indicated this continual formative assessment and rubric feedback was not beneficial for them.

While students' perceptions regarding whether or not rubric feedback was beneficial is important, another measure of student success is often their achievement or final numerical grade.

The third research question, does the use of game-based formative feedback improve students' achievement during the unit, was analyzed using students' achievement scores. The results, shown in Table 3, indicated that students who received the rubric feedback received higher poetry unit scores (mean[m]=80.5747) in their English class when compared to their peers who did not receive the feedback (m=78.7980), but the score difference was not statistically significant (F[1, 106]=2.047, p>0.05). Similar findings were also observed in the Mathematics class. Students who received the rubric feedback received higher circle geometry unit scores (m = 80.9065) in their Mathematics class than their peers who did not receive the feedback (m = 78.2957); again, the score difference was not statistically significant (F[1, 105] = 1.838, p > 0.05). Both of these analyses were conducted using an ANCOVA analysis in which students' grades before the treatment unit were used as a covariate to control for prior group differences between students in Year 1 and Year 2. This indicates a need to accept the null hypothesis, that the use of a game-based formative feedback system did not statistically significantly improve students' grades during the English and Mathematics units investigated during this study (Table 4).

DISCUSSION

This study investigated the effects of a game-based formative feedback reporting system. Specifically, the three research questions that guided this study focused on students' use of the game-based formative feedback, which was split into frequency of feedback and how students used the feedback, as well as its effects on students' knowledge and skill acquisition. The next three sections discuss the results of this study.

Frequency of Using Game-Based Feedback

Most students (i.e., 88.9%) indicated that they checked and used the game-based feedback at least 1-2 times each week. Unfortunately, students in the comparison group, who did not receive the game-based formative feedback, were not asked how often they used their feedback, which prevented inferential statistics from being conducted. The regular use of feedback is consistent

Table 4. Mean and standard deviation of students' grades before and after the rubric feedback treatment

	English (i.e., Poetry)				Mathematics (i.e., Circle Geometry)			
	Mean Grade Before Treatment Unit	Standard Deviation of Grade Before Treatment Unit	Mean Grade After Treatment Unit	Standard Deviation of Grade After Treatment Unit	Mean Grade Before Treatment Unit	Standard Deviation of Grade Before Treatment Unit	Mean Grade After Treatment Unit	Standard Deviation of Grade Before Treatment Unit
Students who Received Rubric Feedback	79.2068	8.4687	80.5747	12.2689	83.8030	11.1968	80.9065	16.4529
Students who Did Not Receive Rubric Feedback	79.1769	9.8883	78.7980	12.7949	83.8205	11.6605	78.2957	19.3070

with recommendations from literature which indicate feedback should be received and reviewed regularly (Black & Wiliam, 1998; Shute, 2008).

How Game-Based Feedback was Used

The quantitative survey results from this study indicated that students found the game-based feedback to be useful (mean = 3.58, SD = 1.204) and would want to continue using this type of feedback in their future courses (mean = 3.50, SD = 1.384). This finding was also supported by students' qualitative written responses in which they indicated mostly positive views towards the game-based feedback. Specifically, the written responses were grouped into four recurring themes: ownership of learning, affect regarding feedback, learning from errors, and explicit correction feedback.

Helping students develop ownership of learning has been identified as a main purpose of education (Rainer & Matthews, 2002). Educational researchers have investigated different ways to improve students' ownership of learning; for example, Deci and Ryan (2017) approached this idea by improving students' internal motivation towards learning while Vu and Dall'Alba (2014) used the authentic learning and assessment environments to help students better understand the importance of learning specific knowledge and skills. The results of this study adds to the literature by showcasing game-based formative feedback as another method to help students develop an ownership of their learning. Students who reported developing an ownership of their own learning using the game-based feedback indicated putting extra effort into understanding and applying their knowledge and skills. The additional effort students report expending on their learning may also be related to their affective dispositions towards learning (Kaplan & Maehr, 2007).

The second recurring theme that came from the results of students' qualitative written responses indicated the game-based feedback helped students develop positive affect regarding learning. Affect has been shown to be an important factor in improving student learning (Kyllolen, 2016). Students reported being more motivated to review and better understand their daily lessons in a low-risk learning environment. The low-risk nature of the learning environment was due to the game-based feedback being designed to be formative, which meant it had no bearing on students' final grades. This high motivation and low-risk coupling provided students the opportunity to better develop their knowledge and skills without penalties related to making errors during the learning process (Leighton et al., 2013; Immordino-Yang & Damasio, 2007).

Making errors and correcting misconceptions are essential parts of the learning process (Leighton et al., 2013). Results from this study indicated that students were not afraid to make errors in this low-risk learning environment and that they learned from these errors. The game-based formative feedback system allowed students to quickly receive feedback that identified any errors in their understanding so that they could address the misconception before moving on to the next concept. This finding is consistent with previous studies that investigated students' willingness to make errors and learn from them (Chu & Leighton, 2019; Leighton & Bustos Gomez, 2017). The LEAFF model hypothesizes that when students are learning in a low-risk and trustworthy environment, they are more willing to show their learning errors which then allows the teachers to correct students' misconceptions (Leighton et al., 2013). Students' willingness to show their errors and correct their misconceptions is a natural part of the learning process (Chu, & Leighton, 2019); hence, it is important for students to view the low-risk learning environment created with the game-based feedback system as a safe and trustworthy environment where they may make errors without penalties and correct misconceptions.

Results of this study also indicated students' preference for receiving explicit detailed feedback that identifies both the error they made and also how to correct their misconception. This finding is not surprising because students may be keen on wanting to understand and revise their errors right away. However, this idea of providing the correct answer to students is contrary to the formative feedback literature that focuses on deep understanding of complex topics (Shute, 2008) and the game-based feedback literature which highlights the need for self-reflection of performance (Gee, 2007). The game-based feedback provided during this study utilized gaming principles by being brief so that it

would encourage self-reflection which is common in a digital game environment (Despain & Acousta, 2013; Rogers, 2010). According to the literature regarding formative feedback, the self-reflection of feedback is often associated with improved understanding of complex topics (Shute, 2008). While the feedback was designed to enhance pedagogy, students indicated that they preferred feedback that was more explicit and direct. This is an interesting finding because it indicates the need to better explain to students the pedagogy underlying the game-based feedback, which is designed to encourage self-reflection and to continually provide students with feedback that warrants self-reflection so that they become accustomed to searching for the correct knowledge and skills to address a misconception. Further investigations are needed to better understand the disconnect between pedagogy of self-reflective game-based feedback and students' preferences for explicit detailed feedback.

The results of this study indicated that students used the game-based formative feedback in a variety of ways that target the process of learning. Improving students' affective dispositions and use of the learning environment to enhance the learning process is important towards achieving mastery of specific knowledge and skills. By improving the process of learning, it follows that students' achievement, in terms of grades, should also increase as it is often used as a measure of knowledge and skill acquisition.

Game-Based Formative Feedback on Students' Achievements

Students' use of the game-based formative feedback system received higher scores in the unit of study when compared to their peers who did not receive the game-based feedback in the same unit. However, when inferential analyses were conducted, this increase in scores did not show statistically significant differences between the two groups. This finding is not consistent with literature which investigates learning environments with enhanced formative feedback systems (Black & Wiliams, 1998; Chu & Leighton, 2019; Leighton et al., 2013). The LEAFF model that was used as a framework to guide this study hypothesized that as students use formative feedback in a meaningful way, they will make more errors during the learning process but have a better understanding of the knowledge and skills taught which results in higher achievement at the end of the unit. However, the findings from this study did not support this hypothesis. Similarly, the results of this study are also contradictory to the findings of Chu and Leighton's (2019) study which indicated that students who received an intervention that focused on receiving and using learning error formative feedback showed statistically significant better performance on complex assessment tasks when compared to students who did not receive the intervention. While the findings from this study are not consistent with the literature, it is interesting because it suggests that the use of game-based formative feedback may not improve students' achievement grades under the circumstances present in this study. For example, students who received the game-based formative feedback were taking five different courses during the semester and only two of them implemented the game-based feedback during a one month unit. Hence, the inconsistency of feedback received among the five courses students were exposed to during a day may have resulted in a smaller effect which was not detected using inferential statistics.

The results of this study was mixed in terms of whether a game-based formative feedback reporting system may enhance students' use of formative feedback in the classroom as well as knowledge and skill acquisition because students reported many affective benefits to this system, but students' grades did not improve a statistically significant amount. Interestingly, this study highlighted the intricate nature of gamified systems. Many gamification scholars indicated the importance of focusing on students' needs when using various game-based design principles to develop *one* game-based learning environment (Deterding, 2012; Deterding et al., 2011; Faiella & Ricciardi, 2015). This learning environment would utilize a variety of principles that focus on improving student learning while engaging them in a state of flow in which students are no longer bored with the learning (Bittencourt, Isotani, Wanick, & Ranchhod, 2018). The mixed results of this study may suggest the importance of studying the whole gamified environment at once instead of pulling out one game-based element – gamification of formative feedback – for each investigation.

IMPORTANCE OF STUDY AND IMPLICATIONS FOR PRACTICE

There is a need to develop and use game-based formative feedback in the classroom because it encourages students to use the feedback in a meaningful way. Considering the large amount of effort and resources placed on formative assessment and its feedback, it is important to develop proper feedback reports so that students may understand the feedback and use it to enhance their areas of weakness (Black & Wiliam, 1998). The game-based formative feedback system used in this study indicated the need to consider digital game design principles when developing formative feedback report systems for educational environments (O'Connor, 2011).

LIMITATIONS AND FUTURE STUDIES

Some of the limitations of this study were the duration of the study and number of courses in which the game-based formative feedback system was administered. First, students received the game-based feedback intervention for only one month during their Mathematics and English classes. The one month period may not have been long enough to detect statistically significant differences in achievement grades. Future studies should consider presenting students with a longer intervention; for example throughout a five month semester.

Second, providing students with enhanced game-based feedback during only two of their five courses may have presented students with different feedback experiences throughout the day. Hence, future studies should consider investigating the integration of game-based formative feedback into students' learning environment by presenting them with this enhanced feedback during all of their courses.

Third, this study only focused on one game-based element instead of investigating a whole gamified system that incorporates several elements focused on student needs. Future studies should focus on investigating one element at a time, but nested within a gamified system that is designed to leverage the benefits of game-based learning environments.

REFERENCES

Abramovich, S., Schunn, C., & Higashi, R. M. (2013). Are badges useful in education?: It depends upon the type of badge and expertise of learner. *Educational Technology Research and Development*, *61*(2), 217–232. doi:10.1007/s11423-013-9289-2

Alberta Education. (2007). *Mathematics kindergarten to grade 9*. Retrieved from https://education.alberta.ca/media/3115252/2016_k_to_9_math_pos.pdf

Alberta Learning. (2000). *English language arts*. Retrieved from https://education.alberta.ca/media/160402/ela-pos-k-9.pdf

Bittencourt, I. I., Isotani, S., Wanick, V., & Ranchhod, A. (2018). Flow experience in learning: When gamification meets artificial intelligence in education. In C. Penstein Rose et al. (Eds.), *Proceedings of the Artificial Intelligence in Education International Conference* (pp. 541–543). London, UK: Artificial Intelligence in Education. doi:10.1007/978-3-319-93846-2

Black, P., & Wiliam, D. (1998). *Inside the black box: Raising standards through classroom assessment*. London: School of Education, King's College.

Boyle, E. A., Hainey, T., Connolly, T. M., Gray, G., Earp, J., Ott, M., & Pereira, J. et al. (2016). An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games. *Computers & Education*, *94*(1), 178–192. doi:10.1016/j.compedu.2015.11.003

Brull, S., & Finlayson, S. (2016). Importance of gamification in increasing learing. *Journal of Continuing Education in Nursing*, *47*(8), 372–375. doi:10.3928/00220124-20160715-09

Calgary Board of Education. (2019, September 13). *Find a school*. Retrieved from https://cbe.ab.ca/schools/find-a-school/Pages/default.aspx

Chu, M.-W., & Chiang, A. (2018). Raging skies: Development of a digital game-based science assessment using evidence-centered game design. *Alberta Journal of Science Education*, *45*(2), 37-47. Retrieved from https://sc.teachers.ab.ca/SiteCollectionDocuments/ASEJVol45No2March2018.pdf

Chu, M.-W., & Leighton, J. P. (2019). Enhancing digital simulated laboratory Assessments: A test of pre-laboratory activities with the learning error and formative feedback model. *Journal of Science Education and Technology*, 1–14. doi:10.1007/s10956-018-9763-z

City of Calgary. (2016). *The city of Calgary community profiles: Varsity.* Retrieved from https://www.calgary.ca/CSPS/CNS/Documents/community_social_statistics/community-profiles/varsity.pdf

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, *59*(2), 661–686. doi:10.1016/j.compedu.2012.03.004

Deci, E. L., & Ryan, R. M. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. New York: Guilford Press.

Despain, W., & Acousta, K. (2013). *One hundred principles of game design*. Berkeley, CA: New Riders.

Deterding, S. (2012). Gamification: Designing for motivation. *Interaction*, *19*(4), 14–17. doi:10.1145/2212877.2212883

Deterding, S., Sicart, M., Nacke, L., O'Hara, K., & Dixon, D. (2011, May). Gamification: Using game-design elements in non-gaming contexts. In *CHI'11 extended abstracts on human factors in computing systems* (pp. 2425-2428). ACM. Retrieved from http://gamification-research.org/wp-content/uploads/2011/04/01-Deterding-Sicart-Nacke-OHara-Dixon.pdf

DiCerbo, K. E. (2015). Assessment of task persistence. In Y. Rosen, S. Ferrara, & M. Mosharraf (Eds.), *Handbook of Research on Computational Tools for Real-World Skill Development* (pp. 780–806). Hershey, PA: IGI Global.

Dicheva, D., Dichev, C., Agre, G., & Angelova, G. (2015). Gamification in Education: A Systemic Mapping Study. *Journal of Educational Technology & Society*, *18*, 75–88. Retrieved from https://www.wssu.edu/profiles/dichevc/gamification-in-education-systematic-mapping-study.pdf

Faiella, F., & Ricciardi, M. (2015). Gamification and learning: A review of issues and research. *Journal of e-Learning and Knowledge Society, 11*(3), 13-21.

Firestein, S. (2016). *Failure: Why science is so successful*. New York, NY: Oxford University Press.

Gee, J. P. (2007). *Good videogames + good learning: Collected essays on videogames, learning and literacy*. New York, NY: Peter Lang Publishing. doi:10.3726/978-1-4539-1162-4

Gee, J. P. (2013). *Good video games and good learning: Collected essays on video games, learning, and literacy* (2nd ed.). New York: Peter Lang Publishing.

Harrison, C., Könings, K. D., Dannefer, E. F., Schuwirth, L. W. T., Wass, V., & van der Vleuten, C. P. M. (2016). Factors influencing students' receptivity to formative feedback emerging from different assessment cultures. *Perspectives on Medical Education*, *5*(5), 276–284. doi:10.1007/s40037-016-0297-x

Hunicke, R., Leblanc, M., & Zubek, R. (2004). *MDA: A formal approach to game design and game research*. AAAI Workshop.

Immordino-Yang, M. H., & Damasio, A. (2007). We feel, therefore we learn: The relevance of affective and social neuroscience to education. *Mind, Brain and Education*, *1*(1), 3–10. doi:10.1111/j.1751-228X.2007.00004.x

Johnson-Laird, P. N. (1983). *Mental models*. Cambridge, MA: Harvard University Press.

Kaplan, A., & Maehr, M. L. (2007). The contributions and prospects of goal orientation theory. *Educational Psychology Review*, *19*(2), 141–184. doi:10.1007/s10648-006-9012-5

Kluger, A., & DeNisi, A. (1996). The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological Bulletin*, *119*(2), 254–284. doi:10.1037/0033-2909.119.2.254

Kyllonen, P. K. (2016). Socio-emotional and self-management variables in learning and assessment. In A. A. Rupp & J. P. Leighton (Eds.), *Handbook of Cognition and Assessment* (pp. 174–197). New York: Wiley. doi:10.1002/9781118956588.ch8

Lajoie, S. (2008). Metacognition, self-regulation, and self-regulated learning: A rose by any other name? *Educational Psychology Review*, *20*(4), 469–475. doi:10.1007/s10648-008-9088-1

Leighton, J. P., & Bustos Gomez, M. C. (2018). A pedagogical alliance for trust, wellbeing, and the identification of errors for learning and formative assessment. *Educational Psychology: An International Journal of Experimental Educational Psychology*, *38*(3), 381–406. doi:10.1080/01443410.2017.1390073

Leighton, J. P., Chu, M.-W., & Seitz, P. (2013). Cognitive diagnostic assessment and the learning errors and formative feedback (LEAFF) model. In R. Lissitz (Ed.), *Informing the practice of teaching using formative and interim assessment: A systems approach* (pp. 183–207). Information Age Publishing.

Leighton, J. P., Tang, W., & Guo, Q. (2017). *Socio-emotional predictors of students' responses to academic errors: An empirical investigation of the LEAFF model.* Unpublished manuscript.

Mora, A., Riera, D., Gonzalez, C., & Arnedo-Moreno, J. (2017). Gamification: A systematic review of design frameworks. *Journal of Computing in Higher Education*, *29*(1/2), 1–33. doi:10.1007/s12528-017-9150-4

Morrison, B. B., & DeSalvo, B. (2014). Khan academy gamifies computer science. Retrieved from http://betsydisalvo.com/wp-content/uploads/2017/11/p39-morrison.pdf

Nah, F. F.-H., Zeng, Q., Telaprolu, V. R., Ayyappa, A. P., & Eschenbrenner, B. (2014). Gamification of Education: A Review of Literature. In *Proceedings of the International Conference of HCI in Business* (pp. 401-409). Springer. doi:10.1007/978-3-319-07293-7_39

O'Connor, K. (2011). *Fifteen fixes for broken grades* (Canadian ed.). Pearson Canada.

Oritz, M., Chiluiza, K., & Valcke, M. (2016). Gamification in higher education and stem: A systematic review of literature. *Paper presented at the 8th Annual International Conference on Education and New Learning Technologies - Edulearn16*. Academic Press. doi:10.21125/edulearn.2016.0422

Rainer, J. D., & Matthews, M. W. (2002). Ownership of learning in teacher education. *Action in Teacher Education*, *24*(1), 22–30. doi:10.1080/01626620.2002.10463264

Roduta Roberts, M., Alves, C. B., Chu, M.-W., Thompson, M., Bahry, L. M., & Gotzmann, A. (2014). Testing expert-based versus student-based cognitive models for a grade 3 diagnostic mathematics assessment. *Applied Measurement in Education*, *27*(3), 173–195. doi:10.1080/08957347.2014.905787

Roduta Roberts, M., & Gierl, M. J. (2010). Developing score reports for cognitive diagnostic assessments. *Educational Measurement: Issues and Practice*, *29*(3), 25–38. doi:10.1111/j.1745-3992.2010.00181.x

Rogers, S. (2010). *Level up! The guide to great videogame design*. Chichester, England: Wiley.

Sawyer, R. K. (2006). Introduction: The new science of learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of: The learning sciences* (pp. 1–16). New York, NY: Cambridge University Press.

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research*, *78*(1), 153–189. doi:10.3102/0034654307313795

Shute, V. J., & Ventura, M. (2013). *Measuring and supporting learning in games: Stealth assessment*. Cambridge, MA: Massachusetts Institute of Technology Press. doi:10.7551/mitpress/9589.001.0001

Shute, V. J., Ventura, M., Bauer, M. I., & Zapata-Rivera, D. (2009). Melding the power of serious games and embedded assessment to monitor and foster learning: Flow and grow. In U. Ritterfeld, M. Cody, & P. Vorderer (Eds.), *Serious games: Mechanisms and effects* (pp. 295–321). Mahwah, NJ: Routledge, Taylor and Francis.

Smith, J. P. III, diSessa, A. A., & Roschelle, J. (1993). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *Journal of the Learning Sciences*, *3*(2), 115–163. doi:10.1207/s15327809jls0302_1

Vu, T. T., & Dall'Alba, G. (2014). Authentic assessment for student learning: An ontological conceptualisation. *Educational Philosophy and Theory*, *46*(7), 778–791. doi:10.1080/00131857.2013.795110

APPENDIX: SURVEY ITEMS

Likert-Scale Survey Items

Please rate the following using the 5-point Likert scale (1 - poor; 2 - below average; 3 - average; 4 - above average; 5 - excellent):

1. How often did you check the rubric feedback during the unit?
2. How often did you use the information from the rubric feedback?
3. How would you rate the overall usefulness of the rubric feedback?

Please rate the following using the 5-point Likert scale (1 - not at all, 2 - not really, 3 - neutral, 4 - somewhat, 5 - very much):

4. How useful was the information from the rubric feedback?
5. Would you want to continue having this rubric feedback for the rest of the year?
6. Would the rubric feedback be useful in other classes/subjects?

Open-Ended Survey Items

7. How could the rubric feedback be changed to make the information more useful?
8. What did you think of being evaluated continually?
9. How did you feel when rubric marks were returned to you knowing that it did not affect your overall mark?
10. Did it make you more aware of the need to learn?
11. What was the most beneficial part of being in this project?

Man-Wai Chu's research focuses on using innovative assessments, such as interactive digital environments, to measure students' performance-based skills in the classroom and on standardized tests. An extension of her research with these assessments has led her to studying students' development of mental models and their associations with affective variables that enhance assessment performance; this research is guided by the Learning Errors and Formative Feedback (LEAFF) model. Man-Wai approaches her research using a variety of quantitative methods such as such as repeated measures design, Hierarchical Linear Modeling, Structural Equation Modeling, and Bayesian Network Modeling.

Teresa Anne Fowler is a current doctoral candidate at the Werklund School of Education and her research area intersects with masculinities, Whiteness, and complacency. Her work uses Bourdieu's theory of cultural reproduction to understand how patriarchal power is reproduced in schools and sports.