EXAMINING THE USE OF A PERSONALIZED LEARNING MANAGEMENT SYSTEM (PLMS) TO INCREASE STUDENT ENGAGEMENT IN K-12 PHYSICS.

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Abstract – *Motivated by the drive to impact the quality and diversity of students applying to engineering schools, this study evaluates a component of a Personalized Digital Learning Management System (PLMS) that has been designed to increase student engagement in K-12 Physics. In particular, a non-traditional project based learning module, with roots in game-based learning, has been developed and executed in grade 8 science classrooms. Pre and post survey data that includes attitudinal markers, learning style profiles, gender, and assessments of knowledge gained, are analyzed and presented. Results suggest that students who are more interested in science, physics and engineering tend to have learning styles that require programming that is more active and less sequential than traditionally delivered. This is particularly the case for female students. The non-traditional game based project acted to provide these types of learning opportunities and post survey data showed a very high level of student engagement. Results obtained will be used to further refine the PLMS.*

Keywords: Engineering Outreach, Junior High Science, Learning Styles, Game Based Learning, Project Based Learning

1. INTRODUCTION

The 2013 Report on the Pan-Canadian Assessment of Science, Reading, and Mathematics [4] states that Alberta leads the nation for science performance among grade 8 students. However, the majority of these students are not choosing to take physics in high school and as a consequence, enrollment in senior level, high school physics in Alberta has significantly lagged in comparison to chemistry and biology. In 2010 the Natural Sciences and Engineering Research Council (NSERC) of Canada [12] reported that the number of diploma exams completed in Alberta in physics was only 21% of the total diploma exams written in the major sciences. Furthermore, the enrollment of females in Alberta senior level physics classes has hovered around 38% between 2005 and 2010. Since a credit in senior physics is normally required for entrance into engineering programs across the country, it is a concern that engineering programs are losing students because of enrollment levels in high school senior level physics. Consequently, the potential for females entering engineering is also reduced as only a fraction of that 38% will choose the vocation.

Numerous studies such as those in [2] and [5] have pointed to an array of factors that contribute to the attrition of these potential engineering students. The associated disengagement has been attributed to a "one size fits all", linear model of instruction that is often adopted in schools and universities. Subjects are often taught independently (i.e. put in silos) with subject specific textbooks to support learning. Theory is often emphasized over practical application. It has been found in studies such as [13] that this traditional teaching style does not address the diverse learning styles of students today. Furthermore, it has also been shown[5] that there are differences in engagement between genders that are not addressed by more conventional instruction methods.

Some engineering faculties in Canada are re-evaluating the current entrance requirements and the subsequent ramifications of compromising the high-school physics prerequisite, considering instead to teach the content in university. In a more feasible and collaborative approach to positively impact enrollment, engineering outreach programs aimed at providing supplementary content in K-12 classrooms have become common place. In such programs, university faculty and students provide curriculum-based demonstrations or career talks in K-12 classrooms. Although these programs are met with some anecdotal success, they do not globally address the daily issues associated with traditional teaching methods in K-12 classrooms. Enrolment issues may be better addressed by engineering academics if their efforts were directed toward providing research support in the evaluation of educational tools that may support school teachers in delivering content in a manner that appeals to their daily instructional needs and to the diverse learning needs of the students.

Students in today's K-12 space are digital natives, having been born in a generation that has always had technology integrated into their daily lives. Digital engagement is thus a critical component in making content relevant and ensuring the interest and attention of students in K-12. As a result, digital learning tools are being integrated at all levels of education, leveraging technology for maximum learning impact. Furthermore, digital tools have the potential of rapid and wide integration into classrooms.

For this study, interested parties of engineering university academics and K-12 Science, Technology, Engineering, and Math (STEM) researchers have partnered to evaluate components of a digital and dynamic learning tool that can grow as teachers and researchers continue to define best practices in education. This award winning digital Personalized Learning Management System (PLMS) has been developed by a leading Canadian STEM educational not-for-profit organization. The system supports personalized curriculum based hypermedia instructional tool for K-12 educators and students. Being digitally based, it has the potential for rapid integration into classrooms. The tool appeals to digital natives (students), and incorporates: mind mapping (discovery based learning), experts on call, gamification, and project based learning (PBL) lesson plans. The system encourages an interdisciplinary approach that requires students to draw on multiple subject areas simultaneously to solve real world problems. Previous research conducted by the authors [14] has indicated that in the context of learning style models, the PLMS provides a balanced approach to learning and therefore should be a very useful learning tool in the physics curriculum.

The PLMS has been piloted in over 100 classrooms during a two-year span within Canada and the United States. After having used the platform to deliver certain non-physics related content, teachers completed a survey and in-depth interview. Initial feedback from the first phase of the PLMS was positive. Teachers interacting with the PLMS have indicated that "[it] provided [teachers] with new ideas and ways to teach science content", and that it "offered…students exposure to more career and real-life applications." One teacher said that, with the PLMS, "students are learning about science through interaction on multiple levels, not just listening and taking notes". Another teacher spoke to the value of the PLMS to engage students in immersive self-directed learning.

Drawing from the success of the current PLMS, the physics related content is expanding and concurrently being evaluated. One of the key learning tools within the PLMS is a library of project based learning (PBL) modules that has been created in collaboration with subject matter experts from industry and academia. These PBLs give the students the opportunity to apply the subject material that they have gained from other areas of the PLMS. Additionally, teachers can use the PBLs independently of the PLMS to supplement traditional classroom instruction. A key area of focus is this study was the development of PBLs that incorporate design thinking and game-based learning (GBL).

Several research studies provide insight into how GBL may increase student engagement. Yasmin and Burke, [15] suggest that given a learning outcome of creating genuinely playable science related game, students can develop a conceptual understanding of subjects such as mathematics and science, and the dynamics of teamwork and task prioritization. They suggest that this game based learning outcome will result in more genuine and collaborative learning experiences than if subject based learning outcomes are targeted alone. Relatedly, Marchetti and Valente [10] suggest that board game design functions as a pedagogical tool for fostering critical thinking on subject material, since in doing so students actively express their understanding of a subject by designing and building new artifacts. They emphasize that physical board game design may provide richer learning support than digital games since digital games tend to impose on the students the features and gameplay previously decided on by the designer. Chiarello and Castellano [3] agree that the use of games can be particularly helpful in the understanding and learning of abstract concepts. They suggest that game design and play have been tested as effective learning tools due to their immersive nature, their support of learning by doing, and that they allow for downtimes for reflection.

This study is focused on teaching grade 8 students Mechanical Systems, as per Alberta's program of studies, in a PBL framework that incorporates game development and game play. This paper first presents the results of attitudinal and learning style surveys that were conducted in three classrooms prior to the introduction of the PBL. The researchers used the Felder-Silverman Index of Learning Styles (ILS) survey [7], widely used in understanding the learning styles of engineering students at the post-secondary level. It should be noted that the survey was slightly adjusted to target younger students. The analysis of the results will focus on correlating students' learning styles with gender and attitude towards physics. The PBL will then be presented along with classroom results. Conclusions will be drawn regarding the potential benefits of the use of the a GBL-PBL within the PLMS in K-12 classrooms. Finally, the ongoing research activities being conducted are discussed.

2. EVALUATION OF THE CLASSROOM

Since impacting high school physics enrollment is the objective of this work, junior high science classrooms were targeted for this study. It should be noted that the school that was accessed in this study is one of the leading grade 7-12 schools in the province of Alberta where high academic performance is stressed and generally obtained. Three teachers and five grade 8 classrooms (n = 92 students) were engaged to determine what correlations exist between their attitudes towards science, learning styles, and gender. The students were given a multi-part survey to self-report on gender, respond to attitudinal questions towards science, and to complete the ILS survey. This section details the results of the surveys.

2.1. Pre PBL Attitudinal Survey Results

The attitudinal survey included questions relating to the student's perceptions on (i) the disciplines of science that they were interested in pursuing in high school, (ii) their general interest level in science (iii) the relative difficulty level of science (iv) the relevance of science in their everyday lives and in the industry, and finally (iv) on their perception of gender equality in science.

Figure 1 shows the results of the question related to what students are interested in pursuing in high school. The subjects listed are those that are typically enrollment requirements into engineering in university. Engineering was also listed as a subject since the school has an engineering institute that students can participate in when in high school. It should be noted that students were permitted to select multiple subjects. Figure 1 suggests that of the three pure sciences, male students were most likely to take chemistry and least likely to take biology in high school. The figure also indicates that apart from biology, male students were more interested in continuing studies in science, math, and engineering than female students. Similar to the diploma exam statistics reported in [12] by NSERC, the female students were most likely to take biology and least likely to take physics in high school. The low interest in physics by female students is matched by an almost equally low desire to pursue engineering content in high school. It is encouraging to note that when surveyed those students who answered gender related questions felt that females at their age were encouraged to pursue science related careers.

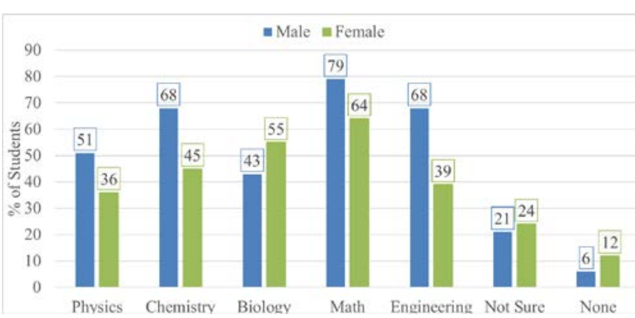

Fig. 1: Students high school subject preferences

Figure 2 shows the relative interest of the male and female students in science. Although on average there was a greater percentage of students interested in science than not, gender disparity was evident in those students that were interested in and indifferent to science. In particular, there was a 1.5:1 male to female ratio of those who were interested in science, and 7.5:1 female to male ratio of those who were indifferent to science. Interestingly when surveyed, more male (34%) than female (30%) students felt that science was hard. The percentage of students who were not interested in science was approximately the same for both genders.

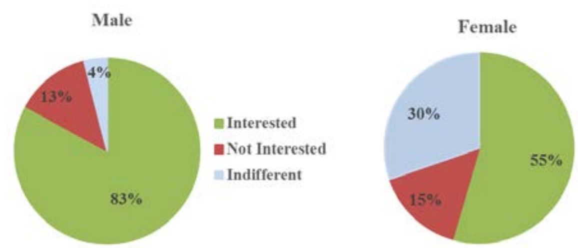

Fig. 2: Interest in science by gender

2.2. Learning Style Profiles of Students

Apart from the Felder-Silverman learning model, numerous learning style models have been proposed such as those found in [6], [9], and [11]. All models classify students according to scales that are defined based on the way learners receive and process information. The FSLM incorporates some elements of the Myers-Briggs [11] model and Kolb's [9] experiential learning model. The main reasoning for its selection in the DLMS evaluation is that it focuses on aspects of learning that are significant in engineering education.

The FSLM consists of four dimensions, each with two contrasting learning styles: Processing (Active/Reflective); Perception (Sensing/Intuitive); Input (Visual/Verbal); and Understanding (Sequential/Global). A summary of the learning styles is as follows:

- Active learners are those who learn by trying things out, enjoy working in groups. Reflective students learn by thinking things through, prefer working alone or with a single familiar partner.
- Sensing students are concrete thinkers, practical, oriented toward facts and procedures. Intuitive students are abstract thinkers, innovative, oriented toward theories and underlying meanings.
- Visual learners prefer visual representations of presented material, such as pictures, diagrams and flow charts. Verbal students prefer written and spoken explanations.
- Sequential learners demonstrate a linear thinking process, learning in small incremental steps. Global learners use a holistic thinking process, learn in large leaps.

Each of the 44 questions within the associated ILS survey is designed to place the learner's preference within each of the four dimensions. It should be noted that some of the ILS questions were slightly modified so as to be more understandable and applicable to grade 8 students.

Results of the female and male students learning style profiles separated by interest in science are compared to baseline engineering students' data in Figures 3 and 4 respectively. The baseline engineering student data was taken from Felder and Spurlin [8] which is a compilation of the results from ILS surveys conducted by engineering students at ten different North American universities. Within the four dimensions, engineering students tend to have preferences for Active, Sensing, Visual, and Sequential learning styles. It should be noted that these results were simply plotted as a point of interest and authors acknowledge that learning styles of young students evolve with time.

Figure 3 suggests that the largest difference in learning style profiles between the females who are interested in science and the engineering students is that there is a larger percentage of interested female students who are sequential learners. More significant differences exist between females who are not interested in science and those who are or engineering students. Of note, female students who are less interested in science tend to be more active and more global (vs. sequential) learners than engineering students or females who are interested. This result suggests that a greater number of female students may benefit from the game-based PBL that is more conducive to the nature of active and global learners than traditional teaching methods.

Figure 4 suggests that a larger percentage of male students who are not interested or indifferent to science are visual (vs. verbal) and global (vs. sequential) than those that are not. It is difficult to compare the males learning style profile to the engineering students since a greater percentage of males, whether interested in science or not, exhibited more active, sensing, visual, and sequential profiles than the engineering students.

Results of the female and male students learning style profiles separated by whether or not they selected to pursue physics and / or engineering in high school are compared in Figures 5 and 6 respectively. The major commonality between the figures is that students, whether male or female, who are interested in pursuing physics and / or engineering in high school tend to be more active and more global (vs. sequential) than those who are not. These results suggest that traditional teaching methods may benefit from tools that address the learning needs and engage the active and global learners.

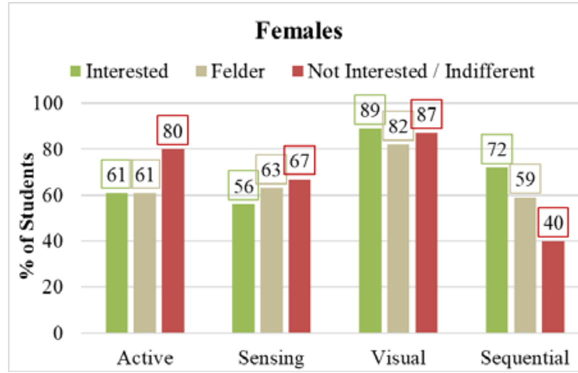

Fig. 3: Female students learning styles by interest.

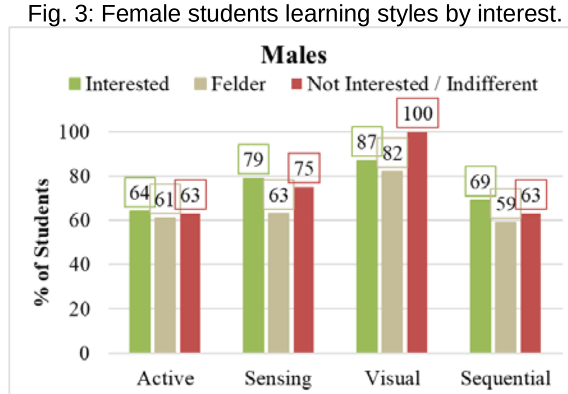

Fig. 4: Male students learning styles by interest.

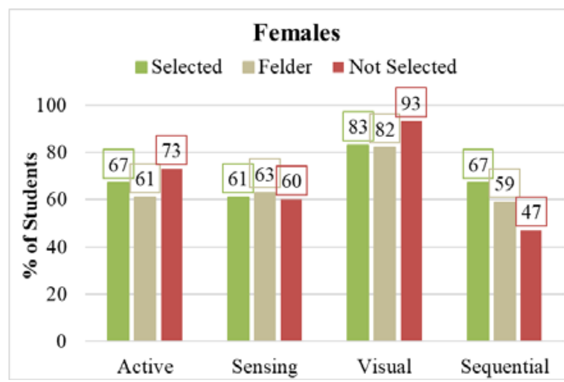

Fig. 5: Female students learning styles by those who selected science and/or engineering.

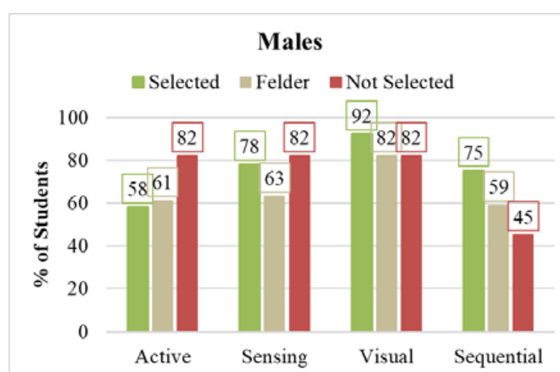

Fig. 6: Male students learning styles by those who selected science and/or engineering

3. THE PROJECT BASED LEARNING MODULE

The simple machines module in the grade 8 curriculum is comprised of content associated with levers, pulleys, gears, and hydraulic and pneumatic systems. Relatedly, students gain an understanding of force transmission, work, pressure, gear ratios, and mechanical advantage. This machine related content was delivered in a traditional manner in the classroom periods that ran concurrently with the seven - sixty-minute design lab segments allocated for the application of the PBL. In the PBL sessions, students were tasked with designing and building a board game geared towards teaching game players the concepts of simple machines. Apart from content related outcomes at the targeted level of application, the game based PBL module also promoted outcomes of learning game design methodologies and soft skills such as communication, teamwork, and time management. These sessions were conducted over a period of 3-4 weeks in place of associated labs that had previously been given to the students to supplement the lectures.

During the PBL sessions, the students worked in groups of four that were assigned by the teachers at tables in the school's design lab. At the start of the project, subject matter experts were brought into the classrooms to teach the students about design thinking in the context of board game design. Students were given three associated tasks to complete before games were built. In the first task students identified the key elements that make a good board game and the learning outcomes of their game. In the second task, students brainstormed in their groups to identify their desired game mechanics and theme. Students were urged not to simply make a trivia game but to use machines in their game play. This session was guided by a list of suggested questions associated with game design. In the third task, students developed the specific rules and format of their game, and sketched out their game pieces. Following this design stage, students were given materials and time to build their board games. The school had a solid inventory of materials, including 3D printers, that students could access to build their games. Additionally, students could bring materials from home if desired. The final stage of the project involved a game play session where students played games designed and built by other groups.

A post game survey was provided to the students with a goal of observing student attitudinal shifts in science after the PBL was completed. Unfortunately, although given pressure from the teachers to fill out the survey promptly, the number of responses at the time of writing this paper is still too low to draw significant conclusions. It is hopeful that these numbers will increase.

Students and teachers were observed during and interviewed after the PBL was executed. The major successes and challenges of the application of the PBL are summarized below.

Major Successes:

- Researcher noted students demonstrated gathering new information, problem solving, idea integration, idea improvement, creating new and creative works, examining underlying concepts, making connections, and knowledge manipulation in their game development. Students also demonstrated teamwork, conflict resolution, and time management.
- Teachers liked the hands-on nature of the PBL that allowed students to make connections between science and design. They welcomed the opportunity for soft skill development that the project afforded.
- Student Engagement:
  - Researcher noted that overall 80-100% of students were engaged in the task.
  - Teachers perceived that their students were excited about the project, and enjoyed it.
  - Two teachers noted the project worked to engage students that were normally passive. One noted that parents had commented on a positive shift in their child's attitude towards science during the PBL application.
  - The majority of the students interviewed enjoyed the project and appreciated its hand-on interactive nature.
  - Many students expressed that they would enjoy science more if such types of learning opportunities were more regularly presented.

Major Challenges:

- Many of students believed (and all teachers agreed) that they would have benefitted more from the project if the associated concepts were taught before the PBL was started.
- All teachers felt that the project was not a suitable substitute for regular labs. The loss of the labs hindered the students overall understanding of simple machines.
- Teachers felt that length of the project was too long and should be shortened.

In summary, the non-traditional physics learning opportunity afforded by the game based PBL project worked well to engage students in this physics related subject material. It is not surprising that the students and /or teacher's comments reflect some of the benefits of GBL suggested by researchers in [3], [10] and [15]. Furthermore, from the point of learning styles, the PBL was designed to be balanced such that it would appeal to the diverse learning styles of the students. Specifically, due to its nature, the project is suitable to active learners but allows reflective learners time between classes to think things through. It is hopeful that the PBL suited those learners who were not interested in or did not select science or engineering as choice subjects in high school that tended to be more active than their more interested classmates. Similarly, the game development necessitates both the practical nature of the sensors and supports the innovative nature of the more intuitive students. In the GBL module, visual learners create their preferred representation of concepts, while verbal learners interact in their groups. Finally, the project is suitable for global learners as key concepts from game development and classroom instruction help form their understanding of the global picture. It is suspected that the global learners who were not as interested in science (particularly females) responded well to the GBL module. It is suspected that most of the students who commented on the fact that subject material should be taught before the GBL module was executed, were sequential learners. This may be verified when more post survey results are obtained. It should be noted that if used in conjunction with the PLMS, all learners would have the opportunity to access content related material at any point during the game development.

The major challenge noted with the GBL module is the fact that the project was not a suitable replacement for the laboratory component of the class and students suffered as a result. It should be noted that in general, the PLMS and the components therein are intended to supplement the vital delivery of content by the teachers. This concern, coupled with the suggestion that the project should be shortened, suggests that in the future the PBL should be used strictly as an added learning resource that should be promoted, as intended to be, primarily on the basis of increasing student engagement. If used in conjunction with the PLMS, the teachers would have the ability to set project timelines and deliverables that are most suitable to their classroom. For example, a shorter version of the PBL could be selected by the teacher as a simple design project that is initiated in class, but conducted like many other group projects out of class. Alternatively, a full game design project, as conducted for the simple machines unit, could be selected to supplement other physics related materials where a hands-on laboratory component is not available. These results suggest that a large amount of teacher flexibility should be at the forefront of all PBL designs within the PLMS.

4. CONCLUSIONS AND ONGOING RESEARCH

The pre PBL survey highlighted the gender disparity in the interest level of these grade 8 students in science, physics, and engineering. Although most students agreed that female students were encouraged to study science and both groups felt that science had the same difficulty level, the male students showed a much higher interest in science and in pursuing physics and engineering in high school than females. Learning style data was analyzed to determine if students learning styles had bearing on their interest in these areas. Results suggested that all students who showed little or no interest tended to be more global learners than sequential learners. This result was more obvious for the female students than the males. Additionally, results indicated for the most part that there was greater lack of interest in active learners than in reflective learners. Definitive correlations could not be made between interest level and learning preferences within the visual/verbal and the sensing/intuitive dimensions. These results suggest that traditional teaching methods may benefit from tools that address the learning needs of and engage the active and global learners.

The non-traditional game based PBL was delivered in the five classrooms over a span of 3-4 weeks where 7 sessions were devoted strictly to the project. Students were tasked with designing a board game that aimed to teach game players about concepts associated with simple machines. The observing researcher, students, and teachers, agreed that the project was successful in engaging the learners in content application and other softer skills. It was also concluded that the project nicely supported active and global learners, who had shown a relative disinterest in science, physics and engineering in the pre-PBL surveys.

One of the major challenges noted in the PBL application were that some students and all teachers would have preferred to have had the simple machine content delivered before, instead of concurrent with, the execution of the PBL. It is concluded that the students who indicated this concern were more sequential learners as opposed to global learners. It is noted that if the PBL is executed in conjunction with the PLMS, all students would have on-line access to supplementary learning materials. The second major challenge was that the PBL was not found to be a suitable replacement for the simple machine laboratories that were historically conducted during this unit and the length of time spent on the PBL should have been reduced. This result emphasized that the game based PBL in this case should be reduced and promoted as a student engagement tool that students can work on outside the classroom, or executed in other physics related subjects where laboratories are not present. In either case, designers of the PLMS will prioritize flexibility in the associated PBLs so that teachers can tailor them to meet their classrooms needs.

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