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Evaluating the use of a Personalized Learning Management System to Increase Student Enrollment in High School Physics (Evaluation, Diversity)

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An Evaluation of a Digital Learning Management System in High School Physics Classrooms

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Abstract

Consistent with the majority of provinces across Canada, the enrollment in senior level high school physics in Alberta has significantly lagged behind enrollment in commensurate chemistry and biology classes. Furthermore, there is significant gender disparity in high school physics classrooms; the majority of students are male. Since engineering faculties depend on these students for their enrollment, to foster diversity in their own student population, engineering outreach programs are often aimed at providing university led in-class presentations / demonstrations in K-12 classrooms. Although met with some anecdotal success, enrolment issues may be more effectively 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 themselves in a manner that appeals to their daily instructional needs and to the learning needs of the diverse student population.

An award winning personalized learning management system (PLMS) developed by leading STEM not-for-profit organization is under investigation. This system is a 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, all integrated through teacher views that produce dynamic project-based 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 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. This study will first present the results of attitudinal and learning style surveys that were conducted in local junior high schools that correlate learning style profiles, gender, and attitudes towards Physics. Informed by these results, specific physics modules designed by the authors have integrated into the PLMS and are used to enhance learning in targeted junior high school classrooms. Survey data that includes attitudinal markers, learning style profiles, gender, and assessments of knowledge gained, will be analyzed and presented. It is expected that these results will be used to further refine the PLMS. Ultimately, the potential to improve the engagement in physics content by a more diverse student group by the adoption of the PLMS in the classroom will be highlighted.

1. Introduction

The 2013 Report on the Pan-Canadian Assessment of Science, Reading, and Mathematics [1] 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 [2] 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 [3] and [4] 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 [5] that this traditional teaching style does not address the diverse learning styles of students today and it has been shown [6] that there are differences in engagement between genders that are not addressed by more conventional instruction methods.

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. The PLMS differs from learning management systems such as Canvas [7] in that it focusses on providing diversified learners with adapted learning resources. Previous research conducted by the authors [8] 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. Two key elements of the newly developed physics content within the PLMS are the focus of this study; project based learning (PBL) modules and digital learning modules. PBL modules are one of the key learning tools within the PLMS that have 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 teachers and other areas of the PLMS. Additionally, teachers can use the PBLs independently of the PLMS to supplement traditional classroom instruction. The digital learning modules engage the students in the foundational aspects of the content through videos, interactive tutorials, and digital experimentation.

This study is focused on teaching grade 8 students Mechanical Systems, as per Alberta's program of studies using elements of the PLMS. Key elements of the unit are related to the students both in a PBL framework that incorporates physical game development and play, and in a virtual framework. To evaluate the need for such learning tools, this paper first presents the results of attitudinal and learning style surveys that were conducted in three classrooms prior to the introduction of elements of the PLMS. The researchers used the Felder-Silverman Index of Learning Styles (ILS) survey [9], widely used in understanding the learning styles of engineering students at the post-secondary level. 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. Currently a digital learning module designed to engage students in Mechanical Systems is being evaluated in classrooms. Elements of this digital module are presented in this paper. Conclusions will be drawn regarding the potential benefits of the use of the GBL-PBL and the virtual game play 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 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 [2] 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.

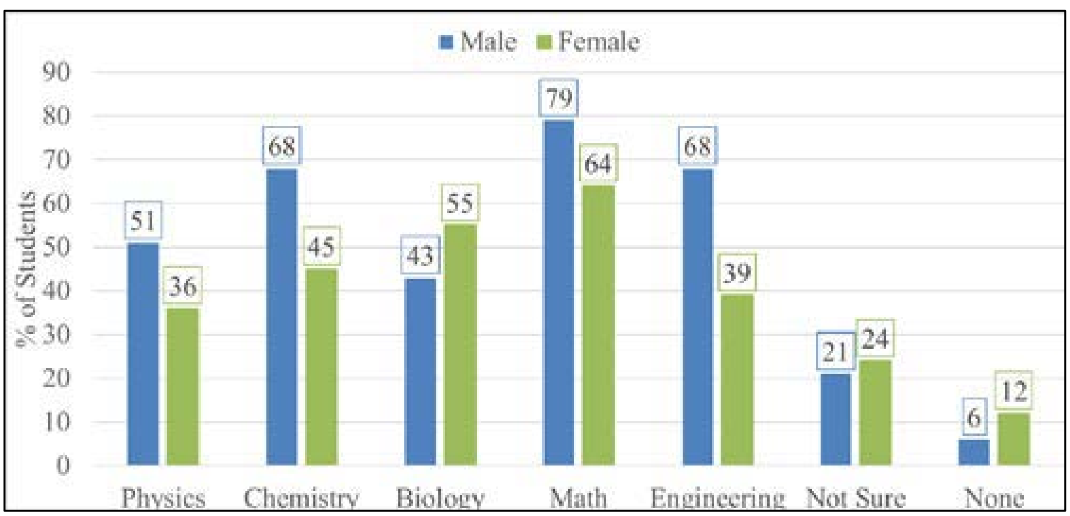

Fig. 1: Students high school subject preferences

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.

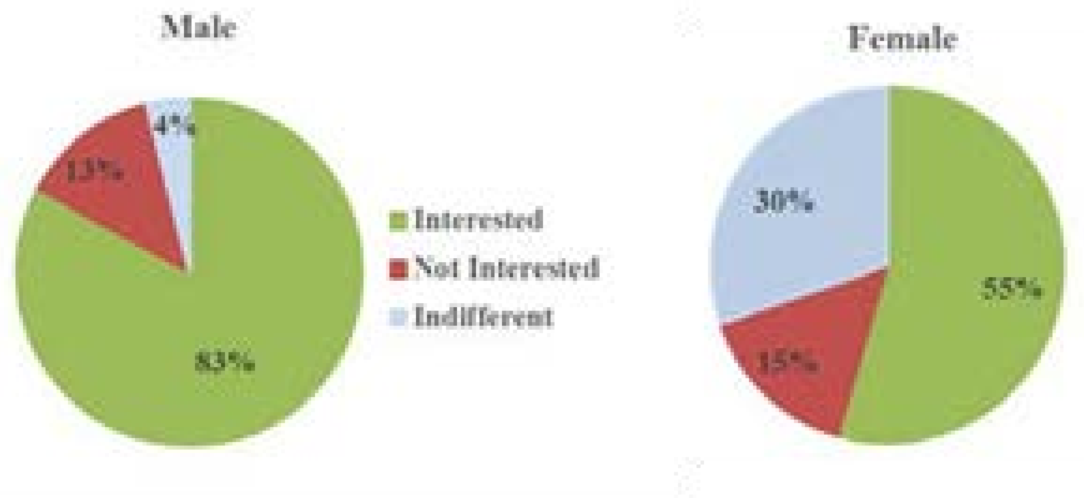

Fig. 2: Interest in science by gender

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 [10], [11], and [12]. 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 [12] model and Kolb's [11] 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. These four dimensions (and their associated contrasting learning styles) are: Processing (Active/Reflective); Perception (Sensing/Intuitive); Input (Visual/Verbal); and Understanding (Sequential/Global). 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 [13] 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 exhibit 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.

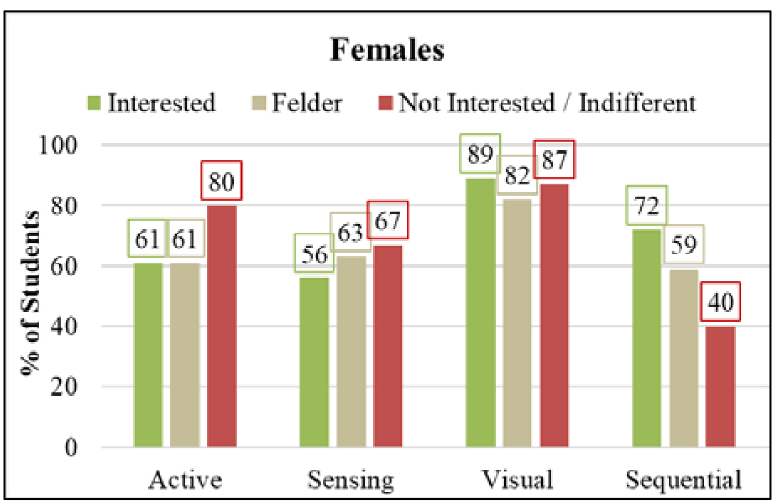

Fig. 3: Female students learning styles by interest.

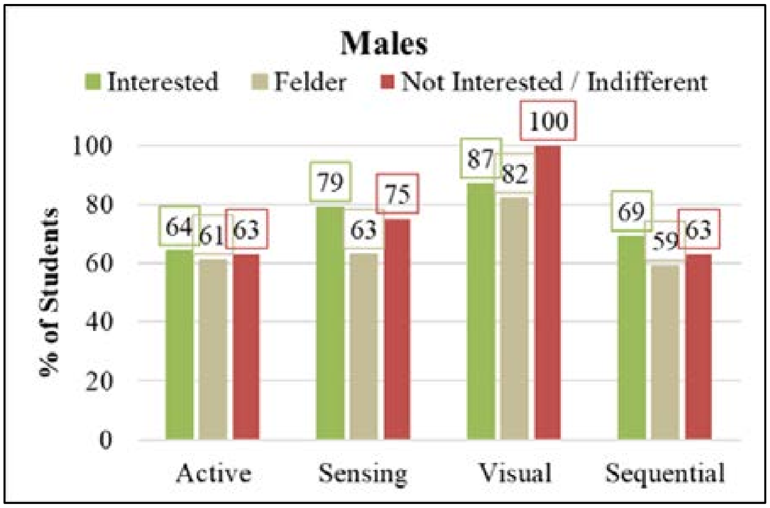

Fig. 4: Male students learning styles by interest.

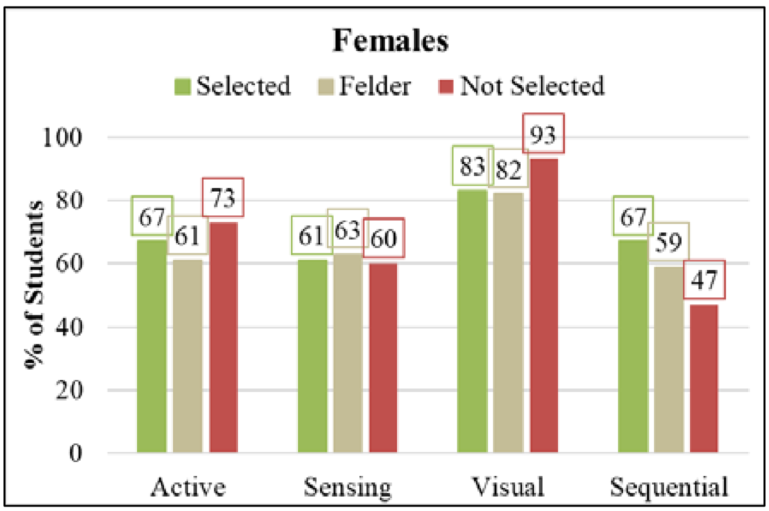

Fig. 5: Female students learning styles by those who selected science and/or engineering.

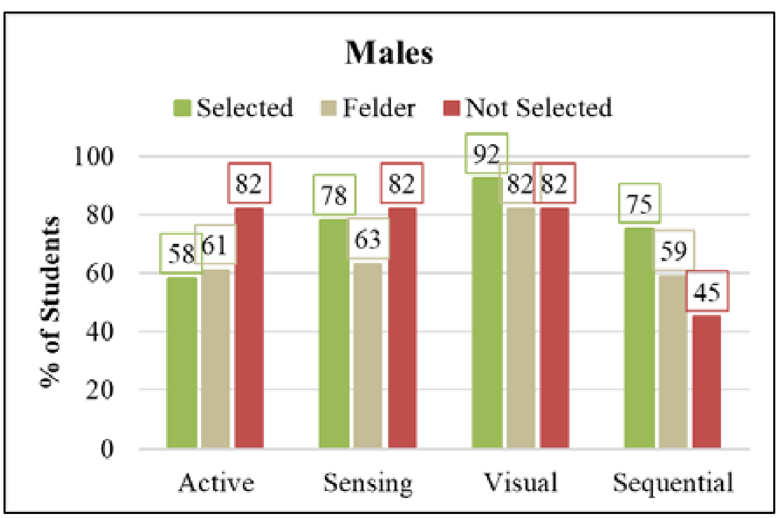

Fig. 6: Male students learning styles by those who selected science and/or engineering

3. The Project Based Learning Module

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, [14] 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 [15] 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 [16] 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.

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, which 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, the number of responses was too low to draw significant conclusions. 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 [14]-[16]. 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. Virtual Learning

Apart from the PBL module, which provides an opportunity for students to apply the knowledge that they gained in the classroom, the PLMS provides tools for content delivery. Newly developed modules designed to deliver simple machines content associated with hydraulics and levers are currently being executed in grade 8 science classrooms and the results are being evaluated by the authors. In the hydraulics module, students have the ability to learn about the real life applications of hydraulics through a professionally developed video. For example, in one video (snapshot shown in Fig. 7) a car mechanic enthusiastically talks about hydraulics as he shows the viewer the hydraulic system in an automobile. The more theoretical content is available through interactive tutorials and virtual experimentation. Specifically, an avatar walks the students through a tutorial that gives the basics of hydraulics including work done, and mechanical advantage (Fig. 8a). Students then experiment with virtual pistons, changing the load, piston surface areas, and seeing the effects on mechanical advantage (Fig. 8b). Finally, to apply the knowledge, students can play a game that involves various content related challenges. Similarly, to engage students in simple levers, students participate in a virtual tutorial that is aimed at giving them an experience of the three classes of levers. Subsequently, the students apply their knowledge through a lever related "Wheres Waldo" type of game (Fig. 9). Although the student results from the virtual content are not yet available, feedback from the teachers has been overwhelmingly positive. Specifically, the teachers view these materials as excellent materials to "drive home" concepts that they are teaching in their classroom. Pre surveys that include attitudinal questions and content knowledge assessment are currently being conducted by the students. After the students complete the approximately 3-4 classroom hours - worth of on line content, post attitudinal surveys and content assessments will be conducted by the students and analyzed by the authors.

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Fig. 7: Snapshot from video on hydraulic system applications

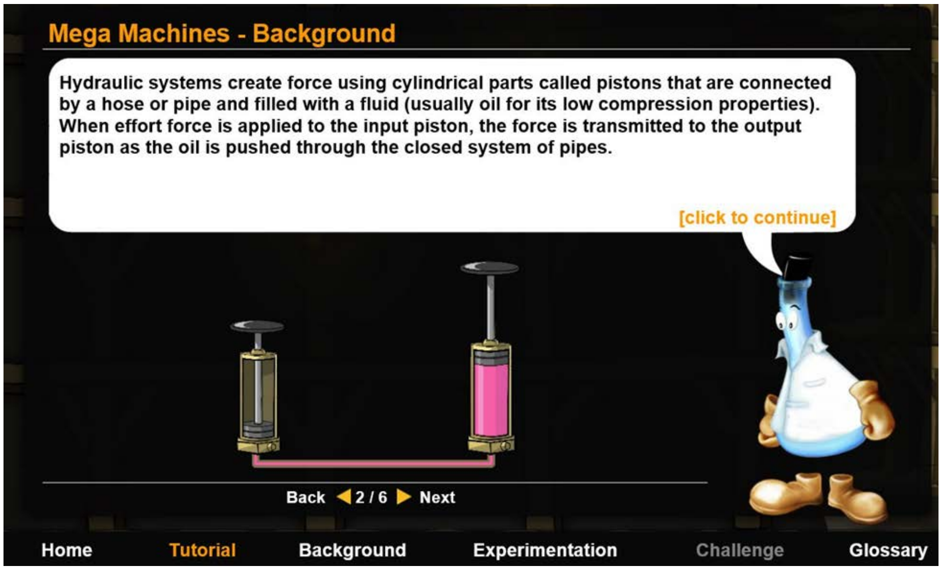

Fig. 8a: Part of tutorial on hydraulics

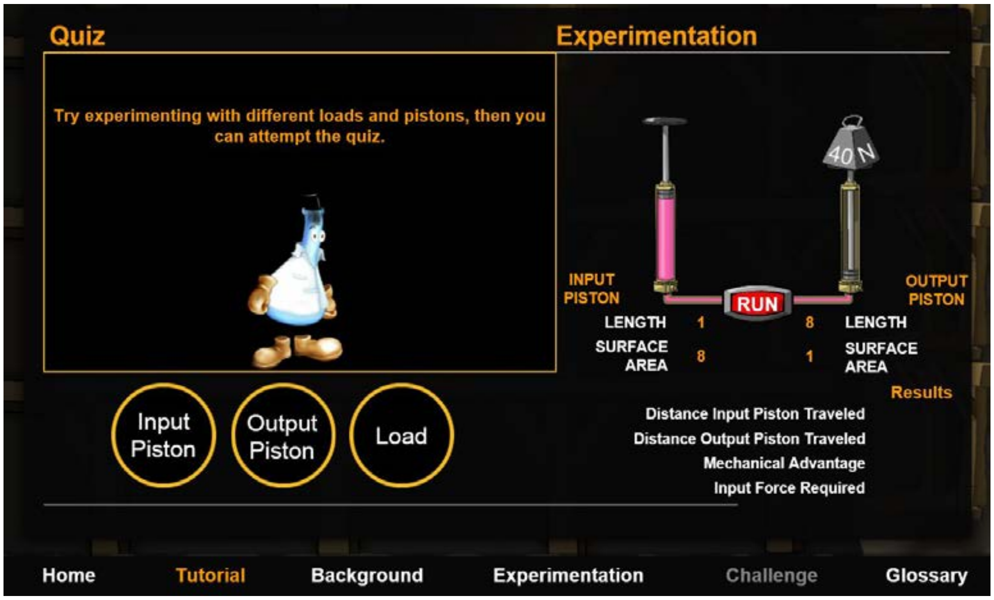

Fig. 8b: Part of virtual experimentation with hydraulics

Fig. 9: Game on Levers

5. Conclusions and Current 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 digital content, 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.

Finally, key elements of the PLMS virtual learning modules associated with hydraulics and levers were presented. The response from the teachers of these virtual supplementary tools has been very positive. Currently, students from three classrooms are completing surveys that are aimed at assessing the student's content related knowledge, their attitudes towards physics, and results will be correlated with gender. The 3-4 classroom hour content will then be delivered and post assessment surveys will then be completed. It is expected that these digital modules within the PLMS will demonstrate appropriate pedagogical support of diversified learners. Furthermore, it is expected that an attitudinal shift in students will result, thus positively impacting student outcomes.

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