Engaging Female Students in the Learning of Physics

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ABSTRACT

Many institutions have proposed curriculum frameworks that include skills and competencies beyond the cognitive domain, so as to better prepare our children for a globalised and inter-connected world. For instance, the framework proposed by the Partnership for 21st Century Skills, (P21, 2009) includes broad areas like Life Skills, and the Information, Media & Technology Skills. More recently, the Ministry of Education, Singapore, unveiled a new framework (MOE, 2010) to "enhance the development of 21st century competencies in our students", which includes Social & Emotional Competencies as well as Information & Communication Skills.

We would like to share some instructional and assessment practices in a physics course for female students in our high school through the use of authentic or context-based tasks. These practices would be classified using the P21 framework to reflect on the specific student learning outcomes. The discussion would focus on building the students' competencies in the use of ICT (such as web 2.0 tools) and well as engaging them through current and real-world issues (such as environmental and career issues). The specific learning and teaching issues pertaining to female learners in physics and their implications for curriculum development would also be discussed.

Keywords: Female physics students, context-based learning, ICT, humanistic approach

INTRODUCTION

Our school, Nanyang Girls' High School (NYGH), runs an Integrated Programme (IP). Our female students studied four years before joining our partner school Hwa Chong Institution (college) without the need for them to sit for the GCE 'O' level examinations.

From observations and research, we realize that there could be subtle differences in the manner our female students learn physics compared with male students in other schools. Such differences, if not taken into account in designing and implementing the physics curriculum, would have an impact on our students learning and performance and ultimately their choice of related subjects at the college level.

The physics curriculum in schools has been strongly influenced by the male perspective, from the historical development of physics as an academic discipline to its real-life applications in the field of science and technology, and inevitably due to the male dominance in physics-related careers such as engineering.

In an extensive review of the research into the participation of girls in physics in the United Kingdom, Murphy & Whitelegg (2006) reported several factors which influenced students' course choices, with regards to physics in particular, and indicated differences between girls and boys. These factors include prior achievement, physics learning experience, and physics self-concept. They found significant evidence that "a context-based or humanistic curriculum increases students' motivation and enjoyment of physics, especially for girls." They define a context-based/humanistic curriculum as a "view of physics knowledge and an approach to teaching and learning where the teacher guides students but students have responsibility for, and autonomy in, their learning."

"The strategies that maintain students' autonomy and responsibility for their learning include investigative laboratory work, group and class discussions where alternative views are considered and valued, problem-solving and project-based activities where students are the decision makers, and creative writing involving a wide range of genres in which science understanding is communicated to the public. There is emerging evidence that these strategies impact positively on the achievement levels of girls as a group relative to boys" (Murphy & Whitelegg, 2006).

In a study by Krogh and Thomsen (2005), it was reported that girls predominantly favoured the humanistic aspects of learning; for their learning goal was to help people. Hence, they will need to make their own connection to relevance in order to create personal meaning from seemingly abstract activities in the physics classroom. This further set them at a disadvantage in the learning of physics via the traditional approach.

Aikenhead (2005) presented some possible characteristics of a humanistic perspective in school science; some of which include:

- citizen preparation for the everyday world,
- savvy citizens cognizant of the human, social, and cultural dimensions of scientific practice and its consequences,
- knowledge about science and scientists,

- moral reasoning integrated with values, human concerns, and scientific reasoning,
- seeing the world through the eyes of students and significant adults.

These contrasted starkly with the traditional science courses in schools which are characterised by:

- preprofessional training for the scientific world,
- canonical abstract ideas (curricular content) most often decontextualised from everyday life but sometimes placed in a trivial everyday context,
- knowledge of canonical science,
- solely scientific reasoning using scientific habits of mind,
- seeing the world through the eyes of scientist alone.

We explored ways to improve our physics curriculum for our students based on what educational research have found about gender differences in learning physics. In particular, we have explored the use of physics in real-life context to better engage our students in the learning of physics, as well as provide a holistic physics education for our students to face challenges in the future. We have used formative assessment to enhance our students' learning throughout the physics programme. The pervasive use of web 2.0 tools, such as Facebook, by teenagers has made it necessary to incorporate related ICT skills in the curriculum, to better engage our students in their learning.

With effective instructional practices in mind, we attempted to use the framework proposed by the Partnership for 21st Century Skills (P21, 2009) to help us analyze and fine-tune our instructional and assessment practices. The framework proposes a few key elements which describe the "knowledge, skills and expertise students should master to succeed in work and life in the 21st century". Besides the Core Subjects, the framework also suggests several 21^{st} Century Themes, including environmental literacy, to be woven into the Core Subjects. A second key element is Learning and Innovation Skills which includes creativity and innovation, critical thinking and problem solving, as well as communication and collaboration. Another key element is Information, Media and Technology Skills which includes information, media and ICT (Information, Communication and Technology) literacy. The fourth key element is Life and Career Skills which includes flexibility and adaptability, initiative and self-direction, social and cultural skills, as well as leadership and responsibility.

The P21 framework (P21, 2009) also outlines elements which are "critical systems necessary to ensure student mastery of 21st century skills". This include 21st Century Standards which encourage engaging "students with the real world data, tools and experts they will encounter in college, on the job, and in life" as they "learn best when actively engaged in solving meaningful problems".

On hindsight, we broadly classified the instructional and assessment practices we have implemented under "Social/Learning Skills" or "ICT". To better define the learning outcomes of these practices, we associated each practice with specific labels of the key elements in the P21 framework as described previously.

This is shown in Table 1 on the next page.

Table 1. Instructional and Assessment Practices & the P21 Framework

Instructional and Assessment Practices	"Social/Learning Skills"		"ICT"	
	Content/Skills description	**P21 framework labels**	**Content/Skills description**	**P21 framework labels**
Sec 2 Lessons (humanistic approach): • History of development of a physics concept "inertia" and • newspaper articles on real-life issues • *Research on effectiveness of these lessons was carried out by Mr Tan BH*	History of science: challenges faced by great scientists; Socio-scientific issues: discussion of real life issues based on physics concept	Life and Career skills: • Flexibility and adaptability 21st Century Standards: • Engaging students with real world data		
Sec 3 SIA*: • Green TEA (Textbook Extension Activity) • *Implemented by Mr Ang JL and colleagues*	Research on Environmental issues; Project management	Core subjects and 21st Century Themes: • Environmental literacy Learning and Innovation Skills: • Creativity and innovation • Critical thinking and problem solving • Communication and collaboration Life and Career skills: • Flexibility and adaptability • Social skills • Productivity and accountability	Use internet research; Use blogs or wikis as online journals to document the process of research and collaboration	Information, Media and Technology Skills: • Information literacy • Media literacy
Sec 4 SIA*: • Physics in Research and Practice • *Implemented by Mr Ang JL and colleagues*	Real life applications of physics; Achievements, challenges, and career issues faced by female scientists/engineers; Project management	Learning and Innovation Skills: • Critical thinking and problem solving • Communication and collaboration Life and Career skills: • Flexibility and adaptability • Social skills • Productivity and accountability 21st Century Standards: • Engaging students with real world data	Use internet research	Information, Media and Technology Skills: • Information literacy
Sec 4 Online Assignment: • Online discussion on the physics of "electrical circuits" • *Implemented by Mr Ang JL*	Evaluate given conceptions of physics and discuss online	Learning and Innovation Skills: • Critical thinking and problem solving • Communication	Use of wiki as online discussion forum	Information, Media and Technology Skills: • ICT literacy

* SIA: Student Initiated Assessment

In the next section, we would discuss the above four instructional and assessment practices carried out in recent years.

METHOD, RESULTS & DISCUSSION

1 Secondary 2 Lessons (a humanistic approach)

1.1 History of Science & Socio-scientific Issues

The use of History of Science (HOS) and Socio-Scientific Issues (SSI) was explored to enhance the girls' learning of physics. According to Atkin (2007), the HOS approach is a highly effective way to engage the learners both cognitively and emotionally on the role of human beings in the development of scientific ideas. He proposed that contemporary social issues be explicitly addressed in the class, including those currently faced by the students themselves so as to address the relevance of what they learn in class to their own lives.

The history of science has many episodes which highlight the different viewpoints and reasoning of scientists. Many of these early scientists' ideas grew out of individuals' everyday interactions with the environment. Some of these ideas are similar to those of current students in our class. By introducing these ideas to students, they can draw parallels between their alternative conceptual understanding and scientists' reasoning in the history of physics (Seroglou and Koumaras, 2001). It would be comforting to these students to know that others had thought the same way, and they would then not feel guilty of holding such thoughts (Monk and Osborne, 1997).

A more humanistic approach on the teaching of Newtonian dynamics was trialled on 3 Secondary 2 (or Grade 8) classes to study its effect both on the motivation of girls towards the learning of physics and their achievements. During the course, the history of the development of the concept of inertia was used to introduce the topic of Newtonian dynamics. The struggles and difficulties that Galileo and Newton had to overcome in conceptualizing his ideas presented a more realistic perspective of science by portraying these great thinkers as human beings with feelings and weaknesses like the students themselves. Discussion of socio-scientific issues was also incorporated as a strategy to enhance their motivation to learn physics content. In this case, newspaper reports on “the use of seat belt in school buses” and “transport of workers” on the back of lorries were brought into the class for discussion. These human related issues were explored to engage girls who were more morally sensitive and advanced in moral reasoning.

The change in the students’ motivation towards learning physics after the humanistic course was measured using the Students’ Motivation Towards Physics Learning (SMTPL) scale which was adapted from the motivation questionnaire developed by Tuan, Chin and Shieh (2005). The change in achievement of the learners was also investigated using their results in achievement tests. Besides obtaining quantitative data, short interviews were also carried with students in the experimental group to find out more about how they feel after attending the humanistic physics course.

1.2 Results of the Humanistic Approach

The descriptive statistics of the mean scores and standard deviation scores of the experimental group (n=77) in the SMTPL pre-test is shown in Table 2. The strong correlation (r > 0.27) between the motivation scales with these students' pre-test physics achievement is similar to those reported by Tuan, Chin and Shieh (2005).

Table 2. Pre-test mean scores and standard deviation scores of the experimental group (*n* =77) in the SMTPL questionnaire.

Scales	Minimum	Maximum	Mean	Standard. Deviation
Students' Motivation towards Physics Learning (SMTPL)	88	161	126.87	14.35

The results of paired samples t-test of the pre-test and post-test scores of students in the experimental group in the SMTPL questionnaire indicate that there is no significant difference in the pre-test score (126.87) and post- test scores (127.31) of experimental group in the SMTPL questionnaire. The post-test mean score of 127.31 of the students in the experimental group was also not statistically significantly different from the mean score of 125.62 of the control group.

The mean score difference of 0.98 between the post-test and pre-test Physics Achievement scores of the students in the experimental group was not statistically significant from that of the control group.

From the interviews of the students about their learning experience in the humanistic physics course, the students reflected that they enjoyed the stories and felt that the stories helped to engage them in the lessons. However, there was no change in the liking for the subject after attending the course. They were also satisfied with their scores in the physics post-test and all four students interviewed expressed that they would continue to take up physics course in the next academic year.

1.3 Discussion

Much was learnt in designing and sourcing for possible materials for teaching this topic using the humanistic approach; and the same approach and procedure of designing a humanistic course could also be adopted for many other topics in the local physics syllabus. With the ever expanding information on the World Wide Web (WWW), many more content materials on the history of science and socio-scientific issues could be adapted for use in the classroom. Rapid technological advancement allows current affairs and happenings in the society including socio-scientific issues to be available anytime of the day at anywhere on media rich platform like YouTube on the WWW on the click of a button. By harnessing the power of technology, such enhancement to the content materials for the teaching of physics with a humanistic approach of teaching and learning physics would be able more effective in touching both the heart and mind of the learners.

While results from this study show that the use of a humanistic approach did not seem to enhance the motivation of girls in learning physics; from another point of view, it would still be equally worthy to adopt the humanistic approach if our intention was to maintain the motivation of girls in learning physics rather than to increase their motivation. If their interest in the subject can be maintained, it would already be an improvement over the current trend of girls dropping out from the physics courses as they progress in their academic grades.

In the review of context-based/Science-Technology-Society(STS) approach on students' understanding of science or attitudes to science by Bennett, Lubben, Hogarth (2007), it was also found that context-based/STS approaches are as effective as conventional approaches in developing the students' understanding of science. However, the use of context-based/STS approaches may not produce any enhancement in the students' understanding of science.

The qualitative responses from the students in the interview also indicated that this approach was able to better engage them and also add variety to their learning experiences. The students enjoyed the readings and discussions, although they also showed concern that such content was not tested in the formal academic assessment. This is the reality in the perception of the students and other stakeholders. Unless they are able to view education more holistically, the assessment mode may need to change with the change in instructional approach for them to be receptive to the humanistic approach.

Besides pen-and-paper written tests, our school also employs an alternate mode of assessment called the Student-Initiated Assessment (SIA) for each subject.

2 Secondary 3 SIA

The SIA assigned for secondary 3 students was a textbook extension activity named Green TEA. Secondary 3 students were given the opportunity to propose and explore the application of physics in environmental issues. Topics include solar cells, fuel cells, desalination, satellite imaging and noise pollution. Groups of about 3 students proposed a topic of research to embark on.

The assessment involved 4 tasks: a proposal, journal writing, poster and presentation, over a period of 28 weeks. Evaluating the learning process experienced by the students was an important component in the assessment. This was achieved with the assessment of online journal writing, as part of the assessment rubric. We looked for evidence that the journal is updated in a regular manner, that all members contribute, and that the journal is used effectively as a means of sharing information, discussion and decision making.

At the end of the SIA, a survey (Ang, 2008) was conducted to find out the challenges faced by each group in completing the online journal task. A total of 89 groups were surveyed. Some learning points were:

1. Over half the groups (62%) felt that they have adequately posted online records of their groups' discussions. These records included choice of topics, brief minutes of meetings, suggestions for poster design, decisions on work allocation, etc. as observed in their online journals.
2. Online journal writing provided a convenient means to shift the focus from the products to the process of learning, allowing regular monitoring and feedback from teachers. Qualitative as well as quantitative data for assessment of journal writing could be collated.
3. The students had little difficulty in setting up their online journals (using web 2.0 platforms) and fulfilling most of the requirements for posting entries on their group journals. Their journals displayed some efforts to include notes on group discussions, decision making, and evaluation of materials. Over the course of the project, there was also a gradual transition from "cut and paste" practice (superficial postings) to more original evaluation of materials, comments, ideas and discussions (more substantial postings).

4. The teacher supervisors observed that there was a need to heighten students' awareness of copyright issues with regards to use of materials from other websites, so as to reduce the incidents of "cut & paste" practice and to educate students on acknowledging the sources of their materials.

3 Secondary 4 SIA

For secondary 4 students, the physics SIA was entitled "Physics in Research and Practice". Each group of 3 students has an option of doing either task 1 (review a article in a popular science magazine on physics-related research efforts or practice in the real world) or task 2 (do a write-up on a female scientist or engineer involved in physics-related research or practice in the past or present, including her achievements and challenges faced).

The assessment rubric focused on the overall organisation of the write-up, the communication of ideas in the area of physics principles and challenges in the research or challenges faced by practising female scientists (or engineers). The last item of the assessment required each group of students to provide oral feedback via a viva. The group had to demonstrate a good knowledge of the science article or scientist (or engineer) chosen for their write-up.

Through this SIA, the students were exposed to the exciting real-life applications of physics and engineering, and their impact on society. The students also had the opportunity to find out about the career options open to females in physics-related fields. The viva also allowed the teacher to engage in a deeper conversation with the students about challenges faced by female scientists (or engineers) and clarify misconceptions that might discourage such “male-dominated” career options in the future.

4 Secondary 4 Online Assignment

The use of asynchronous discussion is explored to facilitate the learning of physics concepts via a social constructivist approach (Ang, 2009). An online physics forum in the form of a wiki was set up to engage a group of secondary 4 students to explore the nature of electrical circuits, to explain and elaborate on their observations, through a series of electrical circuit problems (in series, parallel, and combinations).

A practice problem was provided for students to practise their posting of comments in a less threatening environment, like a “sandbox”, for “newbies” to try out the online features new to them. A FAQ (Frequently Asked Question) section was added to the discussion forum to guide the students in the rationale behind the forum and the proper use of the forum.

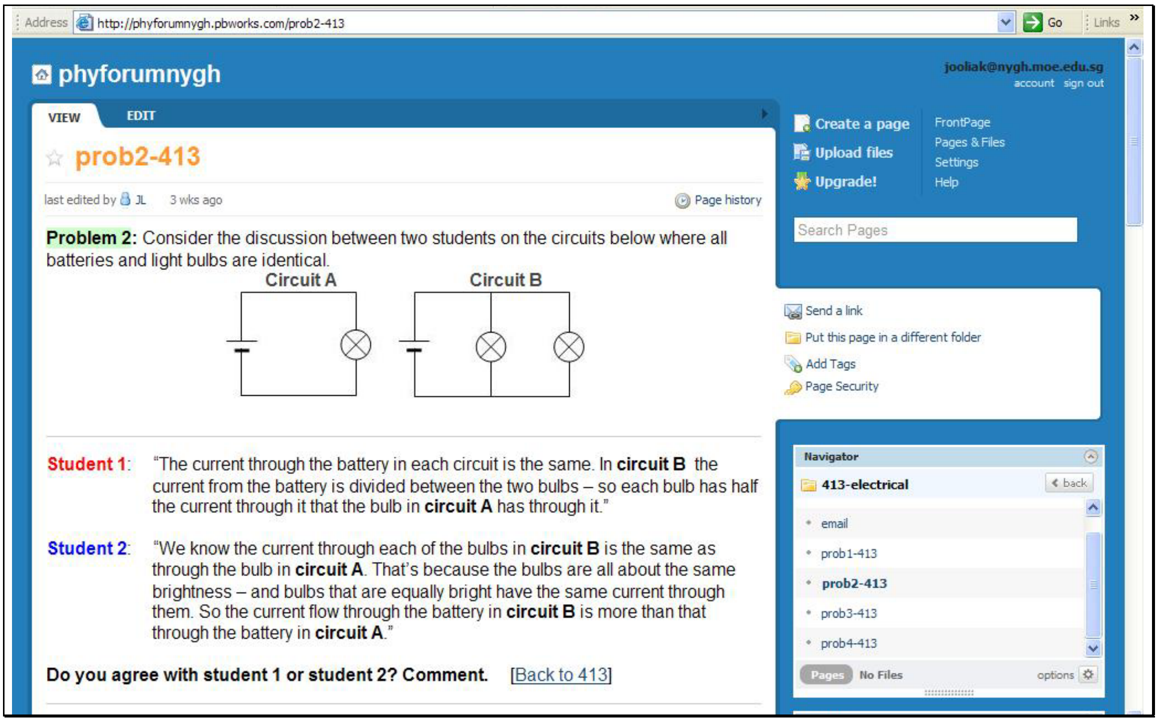

Figure 1 (Ang, 2009)

Figure 1 above shows a screenshot of the discussion forum set up for half a class (first trial group) to use at the beginning of this project. Figure 2 below shows some students' responses to an electrical circuit problem posted on the wiki.

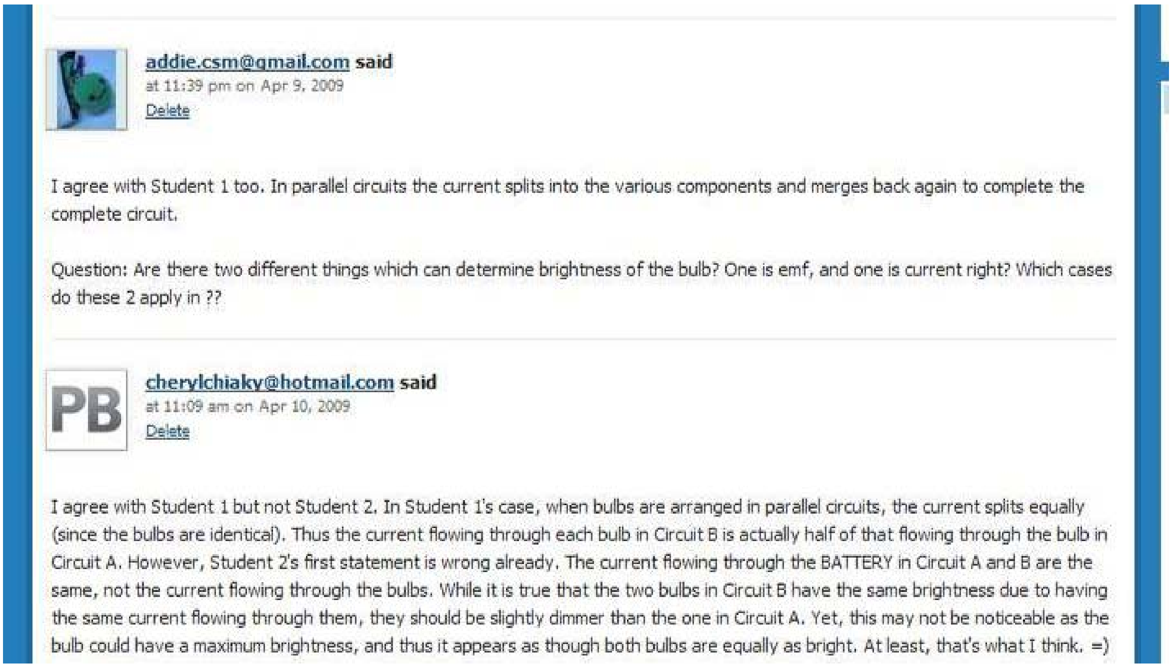

Figure 2 (Ang, 2009)

In the first phase of implementation of the discussion forum, the students took some time to warm up before posting their comments on the forum. They started with direct comments on the problem per se. With encouragement, they began to engage in some critical thinking about each problem task as well as commenting on their classmates' postings. By the end of the given period, most students in the group had fulfilled the quota of comments or responses expected of them.

Some learning points:

1. The frequency and quality of response in the asynchronous discussion could be improved if some class time was devoted to facilitating the first online interactions by bringing the students to the computer laboratory.
2. Allowing for real time participation and on-site teacher modeling of online response and facilitation would help to allay any reservation the students might have with a not-so-familiar mode of learning. This might help to boost the subsequent participation after curriculum time, outside the classroom.
3. Analysis of the comments revealed a variety of alternative conceptions that students have, and also indicated whether their ideas shifted or were modified by the comments from other participants, or how they convince others of their own beliefs.

With some fine-tuning, this mode of learning might be extended to other topics with significant alternative conceptions, for independent learning beyond the classroom, with teacher facilitation. This mode of online discussion has potential for students to engage in critical thinking by challenging their own beliefs through online interactions and reflections using asynchronous discussion.

CONCLUSION

In the study of Secondary 2 lessons conducted using a humanistic approach, although the results were not conclusive, we should continue to explore on its usefulness as its potential should not be ignored. Nor should we use the humanistic approach in an entire physics curriculum, for each approach and strategies have their merits. The participation of the students in the activities in the humanistic approach would add variety to the learning process, making lessons more interesting.

The instructional and assessment practices we have described provide a variety of ways to better engage our female students in deepening their understanding and interest in the learning of physics. Future research, from both external and in-house studies, would look into the factors that motivate the girls to learn physics. This would support the evaluation of our current practices as well as the introduction of future innovations. The P21 framework (2009) would be used as a guide to benchmark and improve our educational practices that would contribute to a more holistic physics education, beyond the emphasis on content knowledge, and towards the acquiring of social and learning skills, and the use of ICT.

We are beginning a process of reviewing our physics curriculum, instruction and assessment with the objective of infusing humanistic elements of content knowledge to provide our students with a better physics learning experience. Such a meaningful experience would hopefully translate into better student achievements in the subject, and a greater interest in physics-related careers in the future.

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