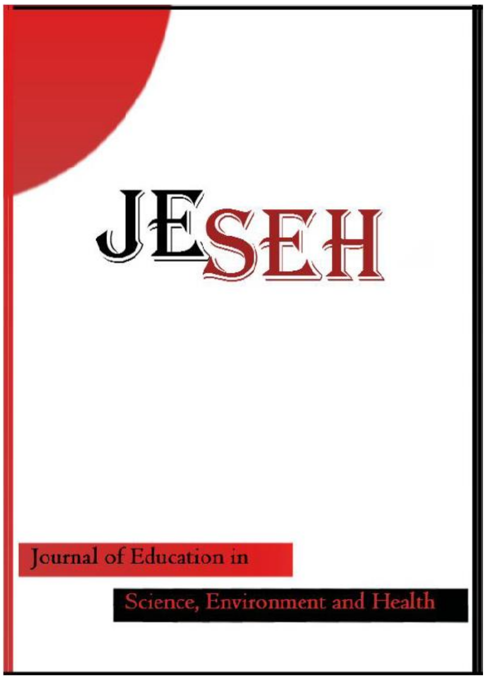

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Promoting Physics Literacy through Enquiry-based Learning Online

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Abstract

In Australia, as in a number of other countries, studies have consistently shown a low enrolment trend towards Physics by students in post-secondary years, due partly to the subject being perceived as conceptually difficult and abstract to grasp. In order to promote Physics literacy, continued opportunities such as online courses for students to engage in Physics education are necessary. For courses that are aimed at reaching out to students with little Physics background, the pedagogy needs to be considered carefully, especially when it is taught entirely in an online learning environment. This research investigated a fully online, inquiry-based course design aimed at motivating students to learn Physics and its impact on students' learning experiences at an Australian university. The research compared the learning experiences of students whose career trajectories are science-related and those who are not in order to assess its effectiveness in promoting Physics literacy. An online survey containing Likert-scale items as well as open questions elicited students' perceptions of the impact of the online course on their learning. The volunteer research participants were 59 undergraduates, where about two thirds of the participants were science students and one-third non-science students. The results showed that students were positive about the pedagogical structure and content in the online Physics course. Except for one item, there were no other statistically significant differences between science and non-science students' responses in the study, suggesting that the pedagogical design catered to the needs of both groups of students, an important element in promoting Physics literacy across a broad range of students.

Introduction

In most countries around the world, an essential outcome of school science education is the development of students who are scientifically literate. Scientifically literate individuals are able to use science knowledge and skills to understand articles pertaining to socioscientific issues in the media and engage in social conversations about ethical and moral issues in order to make informed choices of the way of life that are best suited to them (American Association for the Advancement of Science, 2000; Millar & Osborne, 1998; Office of the Chief Scientist, 2012; Shen, 1975). Developing scientifically literate students is also about preparing the next generation of scientists and engineers to study more advanced and specialised areas of science. Across the disciplines of science, it has been argued that it is impossible to achieve multidimensional scientific literacy in all scientific domains (Bybee, 1997; Hazen, 2002) and that it is possible to be highly literate and develop expertise in one area, even without being career-oriented. In school science however, most primary and junior secondary school curricula aim to develop students' general literacy across the principal science domains of biology, chemistry, Physics and earth and space science. In Australia, as in other countries, studies have consistently shown an enrolment trend away from Physics by students in pre-tertiary years (Lyons, 2006; Rodd, Reiss & Mujtaba, 2013; Victorian Auditor-General, 2012) which implies that the attainment of literacy in Physics is relatively low in post-secondary students. A reason for the low uptake of Physics is the perception of irrelevance and that the discipline is conceptually abstract and a difficult subject to learn (Chief Scientist, 2012; Williams, Stanisstreet, Spall, Boyes & Dickson, 2003). In higher (post-secondary) education, opportunities for students to learn more Physics should to be provided, such as in undergraduate introductory courses where the pedagogy aimed at reaching out to students with little Physics background has to be considered carefully to provide rigour at the same time motivation that will sustain the interest of the students. This research aims to investigate the pedagogical design of a fully online introductory Physics course and its impact on the learning experiences of students at an Australian university. In particular, the learning experiences of science and non-science students are compared to examine the extent of the impact of the course on these two groups of students in developing Physics literacy.

Theoretical Framework Underpinning the Research

Design of the Online Introductory Physics course *Everyday Physics*

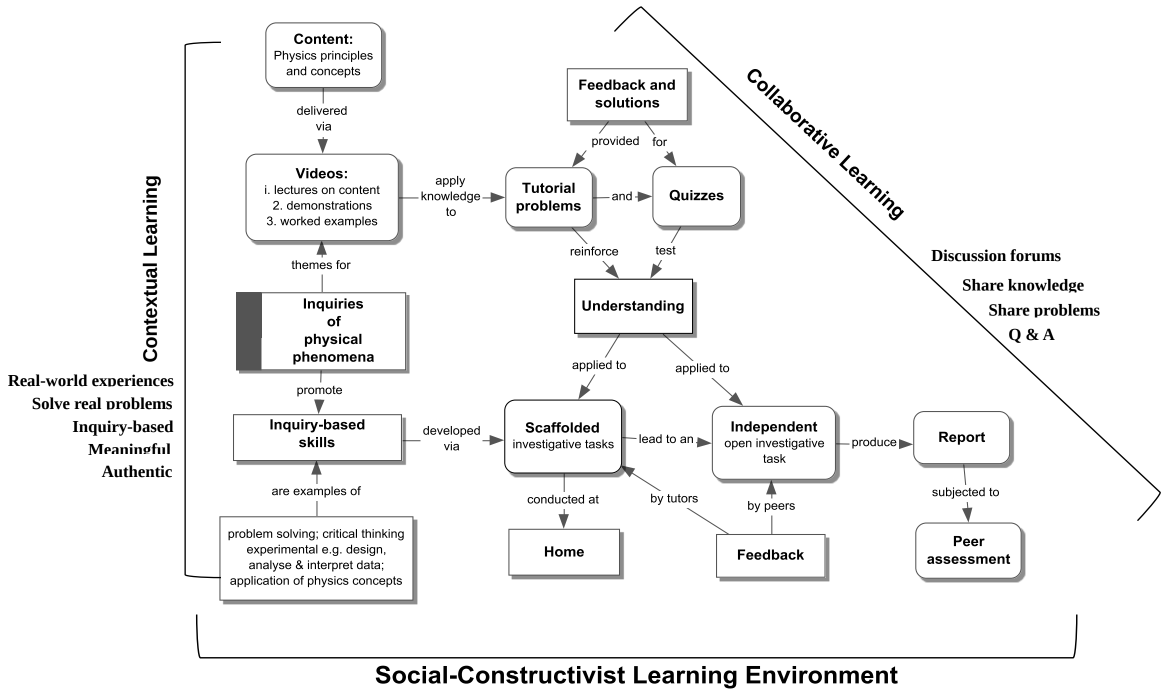

Figure 1. Theoretical framework for the online physics course *everyday physics*

Everyday Physics is a 12-week online introductory Physics course aimed at students who have not studied Physics in high school. Figure 1 shows the main components of the pedagogical design for the course and the theoretical underpinnings for its design, implementation and the research study.

Online learning is the access to learning experiences through the use of a technological platform, e.g. *Moodle* that allows for connectivity and flexibility to support varied interactions that promote learning (Moore, Dickson-Deane & Galyen, 2011). A major benefit of fully online courses is the increased access to courses and learning materials that enable students to learn at times that are suitably integrated into their daily routine and other responsibilities. This advantage was paramount in the decision on constructing the *Everyday Physics* course, which was designed in response to a demand among first and higher year students wanting to study an introductory Physics course but finding it hard to timetable and attend the face-to-face introductory course. The online course was also offered as an elective to students from other faculties, providing the opportunity for non-science students to develop their science literacy, particularly in Physics.

Communication within the course is primarily asynchronous with course materials uploaded onto the course site on *Moodle* and the relaying of messages through the announcement board and/or discussion forums. The social aspect of learning as one of the positive attributes of online learning has been widely emphasised in the literature (e.g. Anderson, 2004; Erdogan, 2016; Author 1 & Author, 2010; Swan, 2003; Zhan, Xu & Ye, 2011). For example, Swan (2003) found that asynchronous discussions were a significant factor in online learning success and that the social presence in an online environment correlated significantly with students' perceptions of satisfaction with and learning from online courses. The benefits as perceived by students in such an environment include a more equal and democratic atmosphere for learning than in traditional classroom discussions, particularly for shy students (Westbrooke, 2006). In addition, asynchronous collaborative learning environments are more conducive to deep learning than synchronously delivered courses as students have the time to self-reflect and think critically about the different perspectives offered by their peers to make judgements that value, support or oppose the different views (Fung, 2004; Stacey, 1999).

Supporters of online learning argue that this type of learning can lead to better learning outcomes. For instance, meta-analysis studies by Means, Toyama, Murphy, Bakia and Jones (2009) of 50 study effects found that students in online learning performed modestly better, on average, than those learning the same material in a face-to-face mode. The researchers found that the average effect size is small (about +.20; medium effect is usually +.40) but significant, in favour of online study conditions.

The pedagogical design of *Everyday Physics* is based on contextual and enquiry-based theories of learning. The course is aimed at providing students with meaningful learning experiences of Physics by situating learning within contexts that are familiar to them. This is done through the everyday applications of Physics in phenomena that the students observe around them. Using an inquiry approach to each phenomenon studied, each week a question that was the focus of the Physics concepts to be studied was asked. Inquiry-based learning is student-centred pedagogy, focusing on questioning, critical thinking and problem solving (Savery, 2006; Marshall, Horton, Igo & Switzer, 2009). Inquiry-based learning uses questions and problems to provide context but does not fit into a more restrictive inductive learning approach. An inquiry-based approach is learner-centred where students adopt more responsibility for their own learning as compared to a traditional transmissive, deductive approach, which has been widely criticized as a key reason for students' declining interest and enrolment in science (Davis, Petish & Smithey, 2006).

In general, inquiry learning is any pedagogical approach that begins with a challenge for which the required knowledge has not been previously provided. The variants of inquiry-based learning differ in the nature of the learner challenge and the type and degree of support provided by the teacher. At the heart of science inquiry-based learning is the idea that students engage in science using the methods and approaches similar to those that scientists use to carry out scientific investigations (Office of Chief Scientist, 2014; Minner, Levy & Century, 2010; Furtak, Seidel, Iverson & Briggs, 2012). In *Everyday Physics*, students are presented each week with a question within contexts that they are familiar with, for example: How does a streetlight work? What decides how fast a river flows? and How does a speed camera work?

A highly contextualised inquiry-based pedagogy motivates and engages students to learn as the learning activities and the problems to be the solved are authentic, relevant and situated within the students' everyday lives (Brown, Collins & Duguid, 1989; Lave & Wenger, 1991). The intended learning outcomes of the course are that students are able to (a) apply Physics principles to everyday phenomena (including solving problems mathematically) (b) develop investigative and analytical skills in experimentations (c) develop as an independent investigator of the physical principles behind phenomena of interest and (d) be aware of ethical and social issues in science, for example the issues surrounding nuclear power and the role Physics plays in the safety of everyday experiences such as the use of transportation and storage of nuclear materials. These are essential elements of being scientifically literate in Physics-related content and issues.

The Use of Instructional Videos

Everyday Physics makes extensive use of video instructions. Technology tools are sufficiently sophisticated for educators to construct instructional e-learning materials that resemble real-time teaching, for example the use of screencast software to capture screen display and annotations of subject matter while simultaneously recording voice-over explanations of concepts. Alternatively, as in the case of this study, live video recordings of the lecturer explaining Physics concepts and showing demonstrations are embedded into *Moodle* as instructional materials for the students to view. An advantage of video recordings is that teaching can be contextual and not confined to the lecture theatre. Video-based online learning is student-centred, allowing for greater access by students at a time and place of their own choosing. Choi and Johnson's (2005) study showed that there was a significant difference in students' motivation with respect to attention, between the video-based and traditional text-based instruction. They found that students' retention and motivation were enhanced using context-based videos in the online courses. Similarly, Chen's (2012) study on the use of video-based instructions showed that the interactive thematic videos fostered more engagement and motivation, enabling the students to acquire and remember more information. The students as a treatment group also obtained higher learning motivation and post-test scores than their peers in the control group.

The video lectures of *Everyday Physics* consist of three components. The first of these is a lecture style section where concepts and equations are presented to students. These videos show the lecturer and important points and equations are edited into the background of the frame. The second component is demonstrations. During these demonstrations concepts are put into practice. The third component is worked quantitative examples. These are recorded with a screen capture program. The solutions are handwritten with an accompanying voice over, showing students how to make use of equations to answer a variety of problems. The course enables students to take control of their own learning. For novice learners, they could view and re-view the videos as often as is required. The detailed solutions to the Physics problems in the tutorial tasks and quizzes scaffold their learning in an explicit manner to reduce cognitive load in the learning (Kalyuga, Renkl & Pass 2010; Sweller 1988). For students who have better prior knowledge and are able to attain understanding quickly, they could move on to the next problems without viewing all the solutions.

Practical Component

As Physics is an experimental science it is very important that investigative type experiments are included as part of the course. This is achieved by setting investigations that the students complete at home. During the course there are six at-home investigations to complete as well as a final report. For the final report, students choose their own topic to investigate that involves an experimental design. Each student's final report is assessed by five of their peers using criteria that are supplied to them. Hence each student receives feedback from five other students. The final mark for the independent report, which has to be submitted via *Turnitin* (software that reports on originality), is decided by the tutor.

Assessment

Each topic has approximately 10 tutorial problems. These are presented to the students as a pdf document. Accompanying these problems are solution videos. Students are encouraged to try the questions before watching these videos which show the step by step method on how to solve a problem. The students' understanding of the course material presented in the lectures and tutorial problems is assessed by online quizzes. There are four online quizzes through the course, one every third week. Students may attempt the questions in the quiz multiple times. There is a 50% penalty for the first two attempts at each part of a question and after that no penalty (and no marks). The parts within a question build on each other. Having the quiz set up this way allows students to continue attempting the earlier parts until they get it correct before moving onto subsequent parts. Once the quiz has closed, worked (videoed) solutions to the quiz problems are released. As most of the quiz questions involve calculations, the students are given randomly generated numbers to try and minimise the risk of students plagiarising each other's work. Students can view the answer to their specific problem by reviewing the quiz after it has closed.

Social-constructivist Learning Environment: Active and Interactive Learning

In the Physics online learning environment, social-constructivist learning theory underpins students' construction of knowledge, individually and socially. Social-constructivism draws on the cognitive (Piaget 1955; Bruner 1960) and social (Vygotsky 1962) theories of learning. It posits that the learner is an active participant in the construction of his/her own knowledge and that prior knowledge and a socially interactive environment influence this learning. In a technologically mediated environment where the interaction is potentially open and non-linear, learners self-direct his/her learning by actively analysing, evaluating and making decisions while manipulating the information (such as the Physics videos, tutorial problems) at hand in order to internalise and construct new knowledge or solve a problem. They seek assistance socially through the asynchronous communication medium of *Moodle* where they interact with the course lecturer, tutors and peers. In the social-constructivist learning environment of *Everyday Physics*, learning is scaffolded through the use of videos and additional resources (e.g. links to simulations), discussions in virtual forums and a peer-assessment task.

The course has a specific online peer-assessment activity where the students' final reports on their investigative tasks are read and provided with feedback by their peers. The value of learning from peers is well documented in the literature (e.g. Blumenfeld, Marx, Soloway & Krajcik, 1996; Havnes, 2008; Kear, 2004). Wen and Tsai (2008) who investigated an online peer-assessment activity found that the quality of group projects and participants' feedback improved, although a decrease in attitudes toward peer assessment was also found. Peer-learning is defined by Topping (2005) as the acquisition of knowledge and skills through the active help and support of people who are equal in status and of similar social grouping but who are not professional teachers. By helping each other to learn, those who help are learning themselves.

The online pedagogical approach to learning has its basis on Vygotsky's (1962) concept of the Zone of Proximal Development (ZPD). ZPD is described as the level of potential development and is the intermediary state between the things that the student is able to do and the things (s)he will be able to do with further development. ZPD is the point where learning takes place and where the learner is able to develop more advanced skills and further knowledge in a topic under the guidance of the educator/tutor and/or in collaboration with peers. Hence the ZPD encompasses cognitive structures that are still in the process of 'maturing' and which become fully developed through the mediating role of 'others' and activities that assist with the development of the individual's learning. Through careful design that considers students' prior knowledge, the educator can create learning activities that fall into the ZPD. For example, the scaffolded investigative tasks in *Everyday Physics* that the students undertake actively are aimed at developing their understanding of design and investigation in scientific experimental work in their ZPD, so that they can independently design an investigative task of a physical phenomenon of choice at the end of the course.

In the scaffolded tasks, appropriate questions are built into the activities to enable the students to engage in metacognition that draws on their existing knowledge to learn the new content. Throughout the course the level of scaffolding for the investigations is slowly reduced. For example in the first investigation students are told explicitly what to plot on each axis of their graphs and stepped through the process of calculating the gradient. By the fifth investigation students are expected to be able to work out what quantities need to go on each axis to produce a graph with the desired gradient. Similarly the tutorial problems and online quizzes that the students undertake on a weekly- and three-weekly basis respectively provide the opportunity to test their understanding and identify their ZPD needs. They seek further assistance to overcome these needs by interacting with the course lecturer, tutors and peers or view the video solutions to the tutorial and quiz problems.

Research Aim and Questions

The aim of the research was to investigate the impact of the pedagogical design of a fully online Physics course on students' learning experiences. The first research question for the study is: What impact does a fully online introductory Physics course that is based on contextual and inquiry-based pedagogy, has on students' learning experiences? The second research question is: What are the differences in the perceptions of science and non-science students of the course? For the first research question, in alignment with the theoretical framework outlined above, we investigated students' post-course perceptions on (i) the online learning materials in helping them learn (ii) peer-peer online collaboration (iii) tutor support (iv) active learning in the online course and (v) their beliefs and attitudes towards the online Physics course. For the second research question, the differences in learning experiences between science and non-science students were examined.

Method

Participants

The online introductory Physics course, based in a large, elite university in Australia, is opened to undergraduate students of science as well as students undertaking a general education elective course from other faculties. In the semester that this research was conducted, 214 students enrolled in the course but 190 completed the course.

Data Collection and Analysis

The research instrument was a questionnaire hosted on *SurveyMonkey* administered to the students at the end of the online course. University ethics approval was obtained prior to inviting students to participate in the questionnaire. The questionnaire consisted of close and open questions where both quantitative and qualitative data were gathered. A breakdown of the questionnaire according to the categories in the first research question is shown in Table 1. Quantitative questions made use of a 7-point Likert scale (1=strongly disagree, 7=strongly agree). On this scale, 4 is neutral and means of 5 and above were considered positive responses while means of 3 and below were considered negative. The items in the questionnaire were adapted from the learning surveys of Clayton (2011) and Author and Author 1 (2009) and validated by the course lecturer and tutors. To avoid conflict of interest and biasedness, the survey was administered by a researcher who did not teach in the course.

The quantitative data was analysed on SPSS. Means and standard deviations were obtained for the items. Each category of items was checked for the reliability of the responses by obtaining the Cronbach alpha value, with values greater than .7 considered as indicating good reliability of the scales. For easier viewing, the means and standard deviations (SD) in the result tables are arranged in descending order of mean value from the most positive to least positive responses for the items in each category. To answer research question two, independent sample t-tests were conducted to elicit differences in responses between science and non-science students. Qualitative data from the open responses were coded and categorised as themes that emerge and the percentage of the responses for each theme were calculated where appropriate.

Table 1. Breakdown of the questionnaire according to the research sub-questions

Research sub-question (topic)	**Quantitative (close questions)**	**Qualitative (open questions)**
(i) Presentation (ii) Online collaboration (iii) Tutor support (iv) Active learning (v) Attitudes and beliefs	5 items 7 items 5 items 7 items 9 items	• Why have you chosen this fully online Physics course to study for this semester? • Any other comments on display and formatting of online learning materials that helped with your learning? • Peer-assessment: Please elaborate on the type of assignment, what you had to do and how beneficial it was for you? • Any other comments about tutor assistance and interactions? • Any other comments about the online course?

Results and Discussion

Demographics

The 190 students who completed the course were invited to participate in the online questionnaire. While 76 students participated in the questionnaire, only 59 responses were considered valid. This represents about 31% return of the total cohort. As shown in Table 2, the number of males and females who participated was 52% and 48% respectively. Ninety-five percent of these students were 25 or below in age.

Table 2. Demographics of research participants (N=59)

Gender		**Age**			**Year of study**				
Male	Female	17-21	22-25	26+	1st	2nd	3rd	4th	Others
52 %	48 %	73 %	22 %	5 %	24 %	15 %	41 %	17 %	3 %

There was a spread in the students' year level of study with first (24%) and third year (41%) students making up about two-thirds of the student cohort. About two-thirds (68%, 40 students) of the participants were in science-based programs while 32% (19 students) were in non-science based degree programs (see Table 3). .

Table 3. Science and non-science degree programs of participants

Types of degree	**Examples of degrees**	**# of Students**	**%**
Science-based degrees	B/Science; MBBS/MD; B/Advanced Maths; B/Medical Science; B/Engineering; B/Computer science;	40	68
Non-science-based degrees	B/Arts; B/Commerce; B/Music; BCom/Law;	19	32
	Total	59	100

Reasons for Undertaking the Online Physics Course

Qualitative analysis of responses indicated four main reasons with respect to why the participants chose to do the fully online Physics course (see Table 4). About two thirds indicated 'convenience and flexibility' (33%) and 'interest and curiosity' (30%) as reasons for undertaking the course. The other two main reasons were to fulfil the general education course requirement (20%) and to prepare for GAMSAT* (12%) exam. Of the 19 non-science degree students, 38% indicated interest and relevance of the course as reasons for studying this course. Examples of quotes are:

> I chose this Physics course as a general education course. When I read the course outline, I found the content to be highly interesting because it is relevant to our everyday lives, as the course name suggests. I also thought the investigations would be interesting and fun to do, coming from a non-science background.

> Because i thought it would be a good course that not only taught us about the concept of Physics but also showed its significance in explaining real life events.

Table 4. Reasons for doing the online physics course

Category	Examples of responses	% of total responses
Convenience and flexibility	- More convenient for me, as I have to balance work and study - Less time spent travelling - Easier to fit in with my busy lifestyle work and uni- especially since I live so far away	33%
Interest and curiosity	- Never studied Physics and the course seems interesting and flexible - I have always been interested in how the things around us work and was motivated to taking an online course to learn it.	30%
To fulfil degree requirement	- To fullfil commerce degree requirement - General education requirements	20%
Prepare for GAMSAT	- To prepare for gamsat and to gain some Physics knowledge - As a way of learning Physics for GAMSAT	12%
Others	- No final exam	5%

Helpfulness of the Online Learning Materials to Students' Learning

As shown in Table 5, the participants were positive about the manner and format of presentation of the online learning materials in helping them learn, in particular they thought that the videos/podcasts were informative and concepts were clearly explained. Issues with navigation were indicated by seven students in the open responses, for example:

> The top right arrows to navigate through sections are really hard to find. It took me a couple of weeks to notice the tutorial solution videos. There are also too many layers of navigation in the left hand side, about 5 different menus. I think this could be designed better.

Independent sample t-test showed no significant differences in the responses between science and non-science students in this category of items.

Table 5. Means and SD for responses to 'online learning materials' items (Cronbach alpha = .798)

Statement	Mean	SD
Videos and podcasts were informative and concepts clearly explained	5.61	1.29
The graphics (photos, graphs, images) were appropriately used to help me understand the topic	5.43	1.29
The text front, colours and style used in the online learning materials fostered easy reading and listening, assisting with my understanding of concepts easily	5.30	1.41
The materials presented on Moodle for this course were motivating	5.18	1.24
The navigation of the site for information and resources was well designed and easy to use	5.16	1.55

* Graduate Admission Medical School Admission Tests

Peer Online Collaboration

Table 6. Means and SD for responses to 'online collaboration' items (Cronbach alpha = .895)

Statement	**Mean**	**SD**
I found that my online opinions were respected by other members in the course	5.16	1.08
The interactions among students on Moodle in the course were beneficial for my learning	5.00	1.75
Students participated actively in discussion forums	4.92	1.86
Students often provided feedback to each other on questions or activities undertaken	4.82	1.51
Students often asked each other for help with activities they were doing	4.59	1.67
Students communicated regularly with each other	4.32	1.92
Students often shared resources and information with each other	4.00	1.77

Table 6 shows that the students were positive about their online postings being respected by their peers (mean=5.16) and that the postings had been useful for their learning (mean=5.00). The students participated actively in the discussion forums (mean=4.92) and that students often provided feedback to each other on questions or activities undertaken (mean=4.82). They were more neutral on other aspects of online collaboration with peers such as the regularity of communication with each other (mean= 4.32), asking each other for help (mean=4.59) and sharing resources (mean=4.00). Analysis of the postings on the discussion forums indicated that most of the discussions were centred around asking the lecturer or their tutor about things they were unsure of in the required tasks or to further clarify something in the content videos. While the Moodle logs show that majority of the students read the forum postings, a smaller number of students (less than 50%) contributed to these discussions. The number of postings appears to increase during weeks where there were investigative tasks due or quizzes to be completed. Independent samples t-test showed no significant differences in the responses between science and non-science students in their perceptions of peer online collaboration.

The final report was a collaborative task that involved independent investigation of a problem. Each student's work was assessed online by and provided with feedback from five peers. Examples of topics that the students chose to investigate were: Calculating the speed of light from microwaves; Effect of Temperature on Bounce Height of Ball; Elastic Constant of a Thera Band; Investigation of Physical Density and Refractive Index; Pendulum Motion in Time Keeping and The Influence of Club Face Angle in Determining the Distance Range of a Golf Ball.

The open question on the peer-assessment task and its benefits was answered by 45 students (76% of the participants). The majority of the responses (58%) were positive and the students valued the experience. For example:

> It was useful in that it gave feedback from multiple sources - not just one tutor.
>
> This was extremely beneficial as it allowed the reports to be reviewed from other people's perspectives. Peers were able to notice things that were missed by individuals looking at their own reports, which allowed each student report to be improved.
>
> I found the comments given by my peers very helpful, allowing me to further improve my report as they picked up errors that I did not realised. It was good to get feedback before actual assessment.

Six of the open responses (13%) indicated negative experiences with the peer-assessment task. For example:

> Read over the feedback my peers gave me, was pretty useless, did not give me feedback via the rubric, just some abstract ideas and thoughts.
>
> I felt like the effort I put in to my draft was wasted on the poor quality feedback I received.

Eleven of the non-science students responded to this open question, of which 55% (6 responses) were very positive about the usefulness of the peer-assessment activities. The other responses were neutral, merely stating what they had to do for the task.

Tutor Support

There were six tutors in the online course. As shown in Table 7, the students were generally positive about their tutors' support, with the majority indicating that the tutors' feedback was useful to identify the things that they did not understand (mean = 5.67), their tutors participated regularly in discussion forums (mean = 5.61) as well as responding promptly to their queries (mean = 5.46). The independent samples t-test showed no significant differences in the responses between science and non-science students in their perceptions of tutor support.

Table 7. Means and SD for responses to 'tutor support' items (Cronbach alpha = .888)

Statement	Mean	SD
The online feedback I received from my tutor helped me to identify the things I did not understand	5.67	1.42
My tutor participated regularly in discussion forums	5.61	1.62
My tutor responded promptly to my online queries	5.46	1.82
My tutor regularly sent me online feedback about my progress	4.61	1.73

A third of the participants (19 students) responded to the open question about tutor assistance. The vast majority were happy with their tutors' assistance and feedback. Some of the students were somewhat confused with whom they should be directing their questions to – the lecturer or their tutor. This is an area that could be clarified in future classes. There were only three somewhat negative responses, for example:

> I didn't find the feedback to the investigations too helpful. The feedback was very short and seemed to presume understanding by the student on the feedback…. but if I needed feedback because I got it wrong, if I don't understand in the first place, a 1-liner will not generally be that helpful.

Analysis of *Turnitin* data, however, showed that many students did not look at the feedback from their tutors, who provided on the *Turnitin* rubric detailed comments on their investigations and why they had lost marks. Less than half the students accessed this feedback, hence continued making the same mistakes in further investigations. This could explain the perceptions of students who thought that they were not given feedback.

Active Learning

Active learning is a crucial component of constructivist learning. The results (see Table 8) show that the students' perceptions of this were overall positive. The responses for the 'active learning' items explored have mean values of about 5 and above, indicating that there is reasonably strong agreement amongst the students that they were learning actively in the course. The students were learning actively by interacting with instructional materials, undertaking quizzes and posting messages where these online resources and activities are located within their ZPD to assist them to develop more advanced skills (e.g. critical thinking, reflective) and further knowledge related to everyday Physics. The students felt that they were in control of their learning (mean=5.47). In comparison with the other items, there appears to be a slightly smaller mean (4.98), for motivation to learn from the feedback responses from the online quizzes. This is because students do not get the feedback until after the quiz has closed (to reduce plagiarism). It would be more motivating if they received feedback while the quiz was still open.

Table 8. Means and SD for responses to 'active learning' items. Cronbach alpha = .935.

Statement	Mean	SD
I felt that I was in control of my learning as I reviewed the online material provided	5.47	1.74
Online quizzes helped me to reflect on concepts taught to better understand the topic	5.39	1.95
I had no problems accessing and going through the online materials on my own	5.29	1.85
Moodle enabled me to learn actively	5.29	1.63
Discussion by posting messages on discussion boards is effective for learning	5.22	1.59
I was motivated by the responses I received from the online quizzes	4.98	2.01

The perceptions of science and non-science students did not show any significant differences in the independent samples t-test in this category of items on 'active learning'.

Attitudes and Beliefs about Online Learning

The attitudes and beliefs of the students about online learning are mostly positive, as shown in Table 9. They were mildly agreeable in their beliefs about being able to learn more with online learning and that they were sufficiently challenged to learn in this online course (mean = 4.85 and 4.68 respectively). The students were, however, satisfied with and enjoyed the learning experience (mean = 5.41 and 5.37 respectively) and that they learnt a lot of Physics in the course (mean=5.58). They agreed quite strongly that online learning approaches can be an effective substitute for normal classroom approaches (mean=5.56) and that online learning is a better way of learning due to the flexibility in learning anywhere and anytime (mean=4.98). In comparing the attitudes and beliefs between science and non-science students, an independent samples t-test indicated that only one item (the slow responses to messages on discussion boards is disruptive to learning and students do not learn well) showed significant differences in the scores for science students (M=3.78, SD=1.97) and non-science students (M=5.05, SD=1.35); t(57)=2.55, p=.013. It is unclear why the non-science students indicated more strongly that asynchronous discussion was more disruptive to their learning. A possible explanation is that with a non-science background, they were more eager to receive feedback or see solutions to problem on the forums.

Table 9. Means and SD for responses to 'attitudes and beliefs' items (Cronbach alpha = .756)

Statement	Mean	SD
I was motivated and sufficiently independent to learn well in this online Physics course	5.68	1.12
I learned a lot about Physics from this online course	5.58	1.66
Online learning approaches can effectively substitute for normal classroom approaches	5.56	1.35
The inquiry-based (i.e. topic based on a question) style of presenting Physics online is a good way to learn about concepts of Physics	5.44	1.66
I am satisfied with my experiences of using Moodle and the online aspect of learning for this course	5.41	1.70
I enjoyed the online learning experiences in this course	5.37	1.71
Online learning is a better way of learning as one can learn from anywhere and anytime	4.98	1.53
I can learn more in online environments	4.85	1.66
I was challenged to learn in this completely online Physics course	4.68	1.61
The slow responses to messages on discussion boards is disruptive to learning and students do not learn well	4.19	1.88

The majority of the student participants agreed that the inquiry-based style of presenting the Physics course was a good way to learn about concepts of Physics (mean=5.44). The endorsement of an inquiry-based approach to introductory Physics education was shown in the responses to the final open question that asked for general comments of the course. Nearly 80% (11 students) of the 14 students who responded to this question commented positively on the structure and content e.g. "better than most hands-on courses" and "I loved this course, at first was overwhelmed by the Physics, but later was invigorated as I found the content interesting and challenging". Further quotes from a science and non-science student are shown below:

> Overall, I was very satisfied with this course. It provided me with a flexible method to learn the content and an enjoyable first experience with an online course. The information, lecture videos, tutorial questions, etc. was sufficient to grant solid understanding of what was required of the course, and the links provided for 'Additional Info' was useful from time to time as well. Probably some more videos on solving tutorial problems. But it was very well structured and nicely balanced (in terms of assessment variety - Practical Investigations, Weekly Quizzes, Peer Review and Final Report). (science student)

> Being a person from a non-science background, I had fun and enjoyed learning the Physics concepts. I also found the tutors were very helpful as they attended to queries very promptly. However, I did find the quizzes difficult at times as it required a lot of problem solving skills that truly tested your understanding of the taught concepts. I found that the video lectures did not sufficiently cover some of the concepts that were brought forward in the quizzes. Nevertheless, it was a great course. (non-science student)

The largely positive responses of the research participants in the study suggest that the inquiry-based learning pedagogy that is situated within contexts that students see as relevant and relatable to their everyday lives was effective in motivating students from across faculties to learn in this online course. The results concord with those in other studies, for example, Sun and Looi (2013) have shown that carefully designed system that delivered a web-based inquiry learning environment could impact positively on students' conceptual, understanding, collaboration, modelling skills and self-reflective skills in science learning.

Other evidence that indicate that the online Physics course and its pedagogical features were appropriate for a range of students and successful in its implementation include,

- the relatively low dropout rate of 11% in the course (214 enrolled, 190 completed)
- 43% females and 57% males enrolled in the course, representing a relatively high number of females for a Physics course
- the enrolled students were from a range of degree programs and faculties, an important step in encouraging more interest in Physics education and increasing scientific literacy amongst non-science students
- the overall positive responses to the learning experiences of the students and the overall lack of statistically significantly different responses to questionnaire items between science and non-science students, indicating that the online course catered to the needs of both groups of students
- the failure rate was 7% which was relatively lower than a similar face-to-face introductory Physics course and
- in the reiteration of the course in the following two semesters, the enrolment increased substantially to around 250 students.

There were however, issues that arose. One of them was plagiarism in the final report, where five students had to be interviewed about their work. Another issue was with the last investigative task on astronomy which required students to actually look at stars. Bad weather and late sunset meant that there were not many nights they could actually view the stars to gather the data. A compromise was made where extension time for this task was given and the best 5 of the 6 investigations were taken for their final mark. In the next reiteration of the course, this task was replaced with an electromagnetic simulation task.

Conclusion

The research shows that a fully online course provided the flexibility and opportunity for students from different faculties to undertake an introductory Physics course. The framework underpinning the design of the course and the layers of scaffolding within the structure of the course benefitted both science and non-science students, which is important to promote Physics literacy amongst a broad range of students. The results showed that students were positive about the pedagogical structure and content in the online Physics course. Except for one item, there were no other significant differences between science and non-science students' responses in the study, suggesting that the pedagogical design (contextual, relevant and inquiry-based), catered to the needs of both groups of students.

A limitation of the study is that the study sample size was relatively small to allow for generalisation across similarly designed online courses. As the course gets reiterated, more research in its sustainability with a focus on the learning outcomes (e.g. products created), including testing under examination. Another aspect for investigation with respect to the home-based Physics experiments is to integrate virtual Physics laboratory simulations into the pedagogical design as an alternative or a supplement to traditional experimentations. While Darrah, Humbert, Finstein, Simon and Hopkins (2014) have shown that virtual laboratories are as effective as traditional hands-on Physics laboratories, the immersion of virtual laboratories in a fully online Physics course needs to be researched to examine if learning experiences are richer that lead to better learning outcomes. An advantage of virtual experimentation is that difficult to measure or gather data could be alleviated and it does not restrict hands-on investigations to the use of only simple and less sophisticated scientific equipment.

In summary, promoting scientific literacy in undergraduate students is important for their future participation as citizens in debates and decision-making about issues that affect their lives. As indicated in the introductory paragraph of this paper, among the science disciplines, Physics is generally the less popular subject chosen by students at the school and university levels. However, a well-designed introductory Physics course as described in this paper provides the motivation for students from cross-faculties to learn more Physics concepts. The motivating features include *relevance* i.e. inquiry that relates to their everyday lives, *challenging* i.e. there is a need to solve problems, *self-directing* i.e. able to view content videos as frequently as required as well as pace the learning according to the students' capability and availability and *collaborative* i.e. socially construct new knowledge.

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