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Examining Student Engagement During a Project-Based Unit in Secondary Science

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Abstract To investigate any possible differences in student engagement between project-based learning units and non-project–based learning units, this triangulation design-convergence mixed methods study followed a grade 10 teacher and her students as they completed science units on chemistry, aquaponics, and genetics. Student engagement was measured in multiple ways using observed on-task behaviour, student perception surveys, and student interviews. Results reveal significant differences in observed on-task behaviour between project-based and non-project–based activities. However, student perceptions of engagement did not significantly improve with project-based learning. Instead, student perceptions of civic engagement emerged as a critical point of examination.

Résumé Afin d'analyser les différences possibles, dans le degré d'engagement des étudiants, entre les unités d'apprentissage par projet et les unités qui ne sont pas fondées sur des projets, cette étude de triangulation des approches (design, convergence, mixte) a suivi une enseignante de 10^{ième} année et ses étudiants qui complétaient des unités d'apprentissage scientifique en chimie, en aquaponie et en génétique. On a mesuré l'engagement des étudiants de multiples façons : observation des comportements pendant les tâches, enquêtes sur la perception des étudiants et entrevues d'étudiants. Les résultats révèlent des différences significatives dans les comportements pendant les tâches entre les activités d'apprentissage par projets et les autres activités. Toutefois, la perception qu'ont les étudiants de leur propre engagement ne présente aucune amélioration significative lors d'activités d'apprentissage par projets, alors que leur perception de l'engagement civique ressort comme point critique d'analyse.

Keywords Project-based learning · Secondary science instruction · Student engagement · On-task behaviour · Mixed methods research

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Introduction

Twenty-first century learning is a key phrase in education and the workplace that reminds us of the very different world we live in today. On average, the amount of knowledge that exists in the world is now estimated to be doubling every year (Coles et al., 2006). “As a consequence…schools must teach disciplinary knowledge in ways that also help students learn how to learn, so that they can use knowledge in new situations, and manage the demands of changing information, technologies, jobs, and social conditions” (Darling-Hammond & Adamson, 2015, p. 27). As a result, Ministries of Education and teachers are seeking ways of having students *work* with knowledge rather than just *receive* it. This has led to a resurgence of interest in inquiry, problem, and/or project-based activities that emphasise students’ abilities to think critically, work collaboratively, and produce projects relevant to the world outside of the classroom.

Project-based learning (PBL) is recognised as an instructional model that realises that “the context of learning is provided through authentic questions and problems within real-world practices” (Kokotsaki et al., 2016, p. 1) and enables students to work together towards a final end product. A large secondary school in British Columbia received funding from the provincial Ministry to implement PBL (Allen, 2015) at a school-wide level. This article overviews what we learned about PBL in relation to three key questions: (a) How does the instruction for a project-based unit vary, if any, from the instruction in a classroom where a project-based unit is not implemented? (b) What does student engagement look like during a project-based unit rather than during a unit of study that does not include project-based learning? (c) Does the use of PBL influence student engagement?

Literature Review

PBL is a pedagogical approach involving the creation of a final product that facilitates the use of hands-on activities in the classroom in order to stimulate learning connected to the real world (Bernstein, 1998; Blumenfeld et al., 1991; Dewey, 1916/1966; Krajcik & Blumenfeld, 2006). While it is a fairly general term (Fischer, 2013), PBL generally includes student-led elements and cooperative learning. By incorporating transferable skills into the classroom, students are able to learn the required information in an applicable way. In addition to learning these crucial skills, PBL strives to engage students in the classroom. More engaged students often result in more learning with students who are more successful in their education endeavours (Thijs & Verkuyten, 2009). Mioduser and Betzer (2007) found that “PBL engages…students as active agents in a learning process characterized by recurrent cycles of analysis and synthesis, action and reflection” (p. 61). Due to the multifaceted, collaborative, hands-on approach of PBL, teachers often utilise PBL as a strategy to increase student engagement. The concepts of *exploring*, *analysing*, and *creating* are encouraged through PBL to “produce enjoyable and unusual final products (Beckett et al., 2016)” (Al-Balushi & Al-Aamri, 2014, p. 213). PBL activities involve these entertaining and exciting approaches in hopes of stimulating the interest and engagement of the students.

Student engagement can vary depending upon how it is measured. Traditionally, engagement has been measured by looking at achievement (through test scores and attendance), but Taylor & Parsons (2011) argue that researchers measuring student engagement should be more concerned with indicators such as time spent on task and interest level. Using indicators such as these can help teachers understand how to best incorporate PBL in their classrooms. This article strives to demonstrate how PBL may or may not affect students’ engagement using multiple measures.

PBL and student engagement

Student engagement during PBL lessons has been measured in a variety of ways. When measuring PBL in high school science classrooms through classroom observations (coding both engaged and disengaged behaviour) and open-ended questionnaires, Beckett et al. (2016) found that students were very engaged when they participated in "hands-on investigations of real-world project activities" (p. 995). Meanwhile, Hugerat (2016), who also measured student perceptions by using a Likert response questionnaire, found that "students who learned sciences by project-based teaching strategies perceived their classroom learning climate as significantly more satisfying and enjoyable, with greater teacher supportiveness, and the teacher–student relationships as significantly more positive" (p. 383). Studies using surveys (Likert scale measuring student agreement with statements) such as those by Moiser et al., (2016) and Tauro et al., (2017) also revealed a significant, positive relationship between PBL and engagement.

Based on a review of the literature, student engagement during PBL has only been measured through classroom observations (of on-task behaviour) and surveys/questionnaires of student perceptions. While student perceptions provide evidence on how students feel about engaging in PBL activities, the measurement of on-task behaviour by researchers has added value to studies that reveal a positive correlation between student learning and on-task behaviour; the more on-task the student, the more learning occurs (Gupta & Pandey, 2016; Lewis et al., 2015). However, debates continue as to how to best measure student engagement, especially in relation to PBL.

What measures of student engagement matter most?

Psychological research regarding student engagement examines a variety of internal and external factors including interest, state of mind, investment, attending to task, etc. (Christenson et al., 2012; Saito, 2017; Wang & Degol, 2014); it is a multi-faceted construct that presents researchers of PBL with the challenge of deciding *what* to measure and *how* to measure it. For this research, we were interested in students' perception of engagement and observations of student on-task behaviour. Student interest (or perception of interest) was important as we wanted to know if students enjoyed PBL activities more than other activities. The more enjoyable students found science, the more likely they would be to continue to engage in scientific activities in the future (Bajko et al., 2016; Sammel et al., 2018). On-task behaviour was important given the links research has made between on-task behaviour and learning (Halliday et al., 2018). Because we were looking at whether PBL was more enjoyable than other, more traditional (e.g. textbook work, completion of labs, note-taking) secondary school science activities, as well as whether students were more or less on-task during PBL activities, we needed measures of student engagement during both PBL and non-PBL activities. This was the only way to evaluate whether PBL was *more* beneficial. This added focus goes well beyond much of the existing research into PBL.

For example, Beckett et al. (2016) and Boaler (1998) measured student engagement through classroom observations and student surveys; however, they only looked at PBL units of study. As such, they could comment on whether students were engaged while participating in PBL activities, but not whether students were *more* engaged because of participating in PBL. At the least, these studies attempted to triangulate their data sources, recognising that student engagement is a complex concept. Studies such as Hugerat (2016), Moiser et al. (2016), and Tauro et al. (2017a) only used one datum source, providing a limited view of student engagement. Further, even studies using classroom observations (e.g. Fogleman et al., 2011; Liu, 2004) focused on a narrative description of what students were doing and whether they seemed engaged. This limits the ability of researchers to identify any significant differences between student engagement during PBL and non-PBL activities. Given the work of Fogleman et al. (2011), the ways in which teachers implement PBL appear to directly impact student engagement and learning. As such, the experience of one teacher in one classroom using PBL cannot be compared with another teacher's in a different classroom not using PBL. While that also technically means that one teacher in one classroom using PBL cannot be compared with another teacher in a different classroom using the same PBL unit, attempts to limit the variables as much as possible are needed.

Our study attempts to address these methodological concerns to some degree. To address triangulation, we used both classroom observations and student surveys. As well, we observed and had students complete the surveys both before and after a PBL unit. This meant that we observed both PBL and non-PBL units. In addition, all of this work were done with the same teacher and the same group of students. As such, this mixed methods study aims to examine student engagement, in its complexity, to provide detailed recommendations regarding PBL and student engagement.

Methodology

To examine student engagement, a variety of data sources are required. As such, this is a mixed methods study (Greene et al., 1989). As noted by Greene et al., mixed methods research emerged out of post-positivist concerns around issues of validity; given the multitude of perspectives, how can researchers be confident in their findings? To address this concern, mixed methods research is grounded in the principles of triangulation (Mathison, 1988) and multiplism (Mark & Shotland, 1987). Consequently, this study includes data from both researchers and students (multiple viewpoints) and uses multiple sources (observations, surveys, and interviews) to triangulate. Beyond these fundamental principles of mixed methods, Greene et al. (1989) emphasise that mixed methods research must include both qualitative and quantitative data while ensuring that "neither type of method is inherently linked to any particular inquiry paradigm" (p. 256). In mixed methods, depending on the questions under investigation, qualitative or quantitative data are used when relevant. Consequently, this study focuses on the type and source of each datum; identifying whether the datum is qualitative or quantitative in nature is secondary.

Finally, Greene et al. and Creswell & Plano Clark (2007) emphasise the importance of clearly identifying a design model for mixed methods research. This study utilises a triangulation design-convergence model (Creswell & Plano Clark, 2007).

Using this study design, we sought to answer the following questions:

1. How does the instruction for a project-based unit vary, if any, from the instruction in a classroom where a project-based unit is not implemented?
2. What does student engagement look like during a project-based unit rather than during a unit of study that does not include project-based learning?
3. Does the use of PBL influence student engagement?

Consequently, this study examined engagement in both PBL and non-PBL instruction in a grade 10 classroom (single case) using multiple measures (observations, surveys, and interviews). We worked with this secondary school teacher and her 30 grade 10 students as they made their way through three units of instruction in the fall of 2017. This large school, with just over 600 students, was located in the Lower Mainland of British Columbia. We collected data at the beginning, throughout, and after the completion of the PBL unit from three different sources: classroom observations (completed by the researchers), student interviews, and student surveys.

These three data sources were analysed independently and then compared to identify salient, prevalent, and contrasting ideas.

> Classroom observations (qualitative and quantitative): In order to make connections between student engagement and PBL, comprehensive classroom descriptions were gathered to reveal if there actually was a difference in instruction, along with a coded record of on-task behaviour for pre-selected 11 students[1]. Consequently, this required classroom observations during both the PBL unit and two non-PBL units (before and after the PBL unit). An observation record (see Appendix A) was used to: (a)

[1] Originally, 12 students were involved; however, 1 student withdrew from the project part way through and all data related to this student were destroyed.

gather a quantitative record on engagement levels for the 11 pre-selected students, (b) maintain a narrative record describing the class activity, and (c) record any use of PBL as described by Allen (2015)[2]. The researchers co-observed the same first few lessons to ensure consistency in their coding. This was determined via comparison and discussion after each lesson. The subsequent observations were then completed by one researcher at a time. See Table 1 for a detailed look at the 11 students. Data were entered by the researcher every 5 min for the full-length of each classroom observation. SPSS data software was used to generate descriptives for all measures and to evaluate measures for significant differences using a chi-square.

Student surveys (quantitative): All students in the class completed a survey regarding their perceptions of learning and engagement both before and after the PBL unit. An ANOVA analysis was completed to identify any significant differences in student perceptions.

Student interviews (qualitative): To report on any changes in student perceptions of engagement, pre- and post-PBL interviews took place with 11 students. These students were purposively selected by the classroom teacher to include mixed ability levels (i.e., students with prior academic performance in the excellent, average, and below average ranges) and consistent attendance. These students were interviewed by one of the researchers prior to the PBL unit to demonstrate their perceptions of learning science before the PBL unit. They were then re-interviewed by one of the researchers after the PBL unit to re-assess their perceptions of learning science having just completed a PBL unit. The questions that were asked were quite general, leaving it up to each student to actually reference PBL activities. This also enabled a comparison between pre- and post-PBL units as the same questions were asked. We also sought some similarities between the interview questions and the survey questions to enable a triangulation of responses.

Results

Analyses were completed separately and, as a result, are reported here separately. These include detailed descriptions of both the PBL and non-PBL units, analyses of observed on-task behaviour as a measure of student engagement, analyses of student surveys regarding student perceptions of engagement, and a comparative analyses of 11 student interviews regarding perceptions of engagement.

Classroom Observations

The observation records enabled both a narrative description of the three units, including a record of activities, as well as a quantitative recording of student engagement. Each is reported on separately below.

Unit Descriptions Both quantitative and qualitative data were gathered to describe the units. Qualitative descriptions were included in the observation records. These enable a description of the types of activities as well as the type of teacher involvement. Quantitative data was gathered to report on the amount of time spent on different types of activities. Both qualitative and quantitative data are reported below.

Non-PBL units We observed the grade 10 science class for four lessons[3] before their PBL unit on aquaponics and for five lessons after their PBL unit was completed. During these non-PBL lessons,

[2] Researching, questioning, critiquing, real-world connections, and collaborating.
[3] Each lesson lasted for approximately 80 min.

Table 1 Demographic information on 11 observed students

Student*	Gender	Ethnicity	Previous performance**
1	F	S. Asian	High
2	F	S. Asian	Middle
3	F	S. Asian	Middle
4	F	S. Asian	Middle
5	M	S. Asian	Middle
7	F	Caucasian	Low
8	F	Caucasian	Low
9	M	S. Asian	High
10	M	S. Asian	High
11	M	S. Asian	Low***
12	M	S. Asian	High

*Student 6 is excluded because they withdrew part way through the study

***High*, previous grades averaging B+ or higher; *Middle*, previous grades averaging C–B; *Low*, previous grades averaging C or lower

***Designated learning disability

students were working on chemistry (before) and genetics (after) units. The outcomes addressed during these units are detailed in Table 2.

Each of these units lasted between 3 and 4 weeks (14–18 classes). We observed lessons throughout each week of each unit, ensuring that we were present for a variety of different classroom activities. There were a large number of similarities between the two non-PBL units. Both involved textbook readings and questions, direct instruction, lab or problem solving work, YouTube clips (e.g. Amoeba Sisters), quizzes, and videos (e.g. genetic engineering). A breakdown of time spent on different types of activities during these non-PBL units can be found in Table 3. During these non-PBL units, students were seated in rows and the teacher spent the majority of her time either directing activities or checking in on individuals or pairs of students while they worked through questions or problems. Each class followed the same pattern: (a) presentation of information through lecture, video, or reading; (b) pair/small group work on problems or observe experiment completed by teacher; and (c) individual work in textbook or quiz/test. The students were assessed on their responses to individual questions, quizzes, lab reports, and the course final interview[4] (as opposed to a final exam).

PBL unit: Aquaponics The aquaponic unit occurred over 24 classes with an additional day dedicated to a field trip involving a working aquaponics company and a presentation regarding hydro dams. Just prior to the unit, students had two lessons learning how to work effectively in groups. As a result, students were prepared to work in groups of four or five throughout the PBL unit. Observations were completed for every class including the field trip. The PBL unit was larger than the two non-PBL units and, as a result, more concepts were covered. The concepts that were addressed throughout the PBL unit included the following:

Acid-base chemistry

[4] Students were given three possible questions for each unit of study during the Science 10 course. They were randomly asked one of the three when they started the interview. These questions were open-ended requiring students to apply knowledge to provide specific recommendations and detailed explanations. Students were given multiple lessons to research and prepare for the questions and they were allowed to bring in their notes to the interview. Throughout the interview, the teacher asked many questions to clarify answers and have students explain their thinking. The teacher commented that it was very easy to identify those students who had done their own preparation and knew the content as they were able to answer her clarifying extension questions. Those that had not were not able to explain their thinking.

Table 2 Non-PBL unit outcomes

	Chemistry	Genetics
Outcomes	Rearrangement of atoms in chemical reactions Law of conservation of mass Energy change during chemical reactions	DNA structure and function Genes and chromosomes Simple patterns of inheritance Mechanisms for the diversity of life Applications of genetics and ethical considerations

Local and global impacts of energy transformations from technologies
Practical applications and implications of chemical processes, including First Peoples' perspectives
Make observations aimed at identifying their own questions, including increasingly complex ones, about the natural world
Social, ethical, and environmental implications of the findings from their own and others' investigations
Find solutions to problems at local and/or global level through inquiry
Communicate scientific ideas, claims, information, and perhaps a suggested course of action, for a specific purpose and audience, constructing evidence-based arguments and using appropriate scientific language, conventions, and representations.

The driving question for the unit was: How does perspective change the way we use energy in Canadian society? Students answered this question in multiple ways including a video log (vlog), a letter to a stakeholder, and the development of a website on aquaponics. The primary project for this PBL was the creation of a working aquaponics system. An aquaponic system makes it possible to grow vegetables without the addition of water or fertiliser. Instead, the water used to nourish the plants is cycled from a fish tank where the bacteria plus fish excrement (ammonia) become the plant fertiliser. The only additive to this system is fish food.

The unit itself progressed through three distinct phases. The first phase (eight lessons) focused on learning about energy uses and its connection to a global food crises, as well as the gathering of materials for the aquaponics system. During this first phase, each class involved watching videos, posing questions to each other, completing journal entries, and reviewing different websites for information, along with prepping materials. The second phase (eight lessons) had each group trying to create a working bell siphon for their aquaponics system. This involved a great deal of problem solving and retesting various solutions: success was not a given. Once the siphon was working, students then began their chemical testing so as to achieve the right balance of bacteria to support their fish and vegetables. Their chemistry had to be consistently accurate before fish entered the system. In addition, students also watched a few videos on bell siphons and competed log entries in Google Classroom. The third, and final, phase (nine lessons plus a field trip) had students using what they had learned to complete the assessment pieces for the unit. These included their vlog, stakeholder letter (advocating for the use of aquaponics), and website (on how to create your own aquaponics system locally).

Table 3 Percentage of time observed by activity type in non-PBL units

Type of activity	Percentage of time observed
Direct instruction (teacher led)	29
Independent work	43
Collaborative work	28

Table 4 Percentage of time observed by activity type in the PBL unit

Type of activity	Percentage of time observed
Direct instruction (teacher led)	17
Independent work	4
PBL-related activities	79
Independent research/questioning/critiquing	5*
Making real-world connections	13
Collaborating on a task	17
Combination of researching, connecting, and collaborating	44

*Percentages are out of total amount of time. For example, 5% of the time in the aquaponics unit was spent on independent research/questioning/critiquing

Throughout this unit, the students were engaged in a variety of PBL activities as well as direct instruction and independent work. Given that they were working in groups, there was very little work done independently (see Table 4 for a breakdown of time by activity type). As a result, the role of the teacher focused on facilitating group work rather than checking accuracy of student work (which occurred during the non-PBL units). For the PBL unit, students were assessed on their website details, perspective letter, vlog, and end-of-term interview (as described earlier). Students were not assessed on whether their aquaponics system (the actual project for this unit) actually worked.

Observed On-Task Behaviour The observation records enabled a quantitative recording of student on-task behaviour. Throughout the PBL and non-PBL units, we observed and coded the on-task behaviour of 11 students. When examining these data, several tests (using a chi-square given the statistically significant differences (p=.000) revealed by Levene's test for homogeneity) were relevant. We looked at whether there were significant differences in the level of observed on-task behaviour between the PBL and non-PBL units overall, in relation to gender, in relation to particular students, and in relation to activity type. Overall, when comparing the percentage of observed on-task behaviour between the PBL (82%, N=3208) and non-PBL (77%, N=1036) units, students were significantly more on-task during the PBL unit (X^2 (1, N = 5239) = 16.492, p = .000).

When examining observed on-task behaviour by gender, there were significant differences. Overall, males were observed as on-task more than females (X^2 (1, N = 5239) = 24.586, p = .000). This significance was sustained even when looking at the observed on-task behaviour during the non-PBL unit (X^2 (1, N = 1341) = 13.048, p = .000), and the PBL unit (X^2 (1, N = 3898) = 11.772, p = .001). When looking at differences in observed on-task behaviour between the PBL and non-PBL units for females only, results reveal significantly more on-task behaviour for the PBL units: X^2 (1, N = 2800) = 14.635, p = .000. In contrast, when comparing on-task behaviour between the PBL and non-PBL units for males only, results reveal no significant differences: X^2 (1, N = 2439) = 2.163, p = .141. Consequently, males were observed significantly more on-task in science class regardless of the type of instruction; however, females were observed significantly more on-task during the PBL unit.

When examining observed on-task behaviour of individual students (see Table 5 for a complete list), only three students demonstrated significant differences in on-task behaviour: student 1 (high), X^2 (1, N = 419) = 19.257, p = .000; student 7 (low), X^2 (1, N = 426) = 3.272, p = .046; and student 11 (low with learning designation), X^2 (1, N = 516) = 7.293, p = .006. It is of interest to note that two of three students with low previous academic performance were significantly more on-task during the PBL unit than non-PBL units, as well as the only student with a designated learning disability. In contrast, student 1 was the only one of four students with a high previous academic performance to demonstrate a significant increase in observed on-task behaviour during the PBL unit.

Table 5 Percentages and significance of on-task behaviour by student for the PBL and non-PBL units

Student*	Percentage on-task		df	X^2	p (2-tailed)
	PBL	Non-PBL			
1	90	75	1	19.257	.000**
2	84	77	1	3.001	.057
3	87	86	1	0.039	.475
4	89	86	1	0.939	.207
5	81	83	1	0.233	.372
7	66	57	1	3.272	.046**
8	65	60	1	1.346	.146
9	88	83	1	1.462	.147
10	87	85	1	0.331	.332
11	84	73	1	7.293	.006**
12	84	89	1	1.474	.143

*Student 6 is excluded due to withdrawal from the study

**Significant difference in observed on-task behaviour

Classroom observations note that, in the post-non-PBL unit (genetics), this student was moved to another area of the classroom with different students nearby. When we look at student 1's performance within each unit (the pre-non-PBL unit on chemistry, PBL unit on aquaponics, post-non-PBL unit on genetics), additional information comes to light. Table 6 demonstrates that, after being moved in the post-non-PBL unit, student 1's observed on-task behaviour drops significantly while there is no significant difference between this student's observed on-task behaviour during the pre-non-PBL unit and the PBL unit itself. These results illustrate that student 1's observed on-task behaviour showed no significant changes between the pre-PBL and PBL unit (X^2 (1, $N = 412$) = 2.150, $p = .112$), similar with the other high academic students. In contrast, there were significant differences only when the post-non-PBL genetics unit was included. As such, the differences in this student's observed on-task behaviour may have had more to do with the seating situation than whether the unit was PBL or not. Consequently, the overall improved levels of observed on-task behaviour during the PBL units are due to improved engagement for students with previous low academic performance only. This observation is worthy of continued examination in future studies.

When we analysed the effects of different activities in the PBL and non-PBL units (see Table 7), there was a significant difference in only the collaborative activities (X^2 (1, N = 1040) = 3.078, p = .047). Consequently, observed on-task behaviour was consistent for direct instruction and independent work, but when students were collaborating they were more on-task during the PBL unit.

Table 6 Student 1's observed on-task behaviour by all three units

Unit types	On-task behaviour (%)	X^2	df	N	p (2-tailed)
Pre-non-PBL PBL	84 90	2.150	1	55 357	.112
Pre-non-PBL Post-non-PBL	84 68	4.096	1	55 75	.033*
PBL Post-non-PBL	90 68	25.894	1	357 75	.000*

*Significant difference in observed on-task behaviour

Table 7 Percentage of observed on-task behaviour by activity for PBL and non-PBL units

Activity type	Non-PBL (%)	PBL (%)
Direct instruction	92	89
Independent work	70	70
Collaboration	73	78**
Research/question/critique		73
Real world		81
PBL Combination*		84

*Combination of research, question, critique, real world, and/or collaboration

**Statistically significant, $p < .05$

Student Surveys

Given the complexity when it comes to measuring student engagement, additional data was gathered beyond observed on-task behaviour. We used student surveys, administered to all science 10 students in the class, to quantitatively examine student perceptions of engagement. Students completed the same survey before and after the PBL unit to illustrate whether there was any *change* in students' perceptions of usefulness, enjoyment, and value of science (see Table 8 for complete results). Results reveal no significant differences in student perceptions after having completed the PBL unit, with one exception. When compared to student perceptions before the PBL unit (M = 2.87, SD = .548), students felt they were significantly more aware of local and global problems after (M = 3.37, SD = .597) having completed the PBL unit on aquaponics ($F(1, 40) = 7.949$, p = .007). These results are in contrast to the significant differences in observed on-task behaviour. While students appeared more engaged when evaluated by on-task behaviour, they did not perceive an improvement in engagement themselves.

Table 8 Mean and standard deviation of student survey responses before and after PBL unit

Survey question	Before			After		
	N	*M**	SD	*N*	*M**	SD
I like learning	23	2.96	.562	20	3.10	.553
I like school	23	2.61	.722	20	2.75	.716
I think my science teacher is interesting	23	3.13	.548	19	3.16	.375
I like learning science	23	2.96	.706	20	2.85	.489
I am good at science	23	2.83	.717	18	2.94	.416
I think science is fun	23	2.87	.694	20	3.05	.686
I used what I learned science in my everyday life	23	2.13	.815	20	2.20	.696
I consider myself a good communicator	23	2.83	.834	20	2.95	.887
I am aware of local and global problems	23	2.87	.548	19	3.37**	.597
I consider myself an agent for social change	23	2.39	.783	19	2.53	.513
I am good at solving problems	23	3.00	.739	19	2.95	.524
I work well with my peers in the classroom	22	3.09	.750	19	3.37	.597
I work well with my science teacher in the classroom	23	3.35	.487	19	3.26	.452

*Survey was measured using a Likert scale (1 = strongly disagree; 4 = strongly agree)

**Significant difference $p = .007$; no other differences were significant

Interviews

To contrast the quantitative survey data on student perceptions, we asked our 11 pre-selected students qualitative questions regarding their perceptions of engagement. During the pre- and post-PBL unit interviews of the 11 pre-selected students, we asked questions in relation to student perceptions of engagement. These questions were as follows:

1. If someone from another country asked what types of things you do in science class, what would you tell him/her?
2. In your experience has your science classes helped you with problems that come up outside of class? How or why not?
3. Have you ever learned/experienced something in science class that changed how you viewed the world? Changed how you do things? Please describe. If not, why not?
4. Is school giving you what you think you need right now? For the future? If so, how? If not, why not and what do you need instead?

These general questions were used to see if students brought different activities in the post-PBL interview that related to the PBL unit itself. While the first question provided a baseline of what students characterised as science class activities, the second and third questions examined perceptions of student engagement in relation to how those activities impacted their views of science in school contexts and of science in the real world (value and importance). The fourth question moved more broadly to look at school in general to see if student perceptions of school were altered based on their PBL experience. These four questions around engagement attempted to capture students' feelings and perceptions of the activities and experiences prior to and after the PBL unit.

Describing science All 11 students indicated a general interest in science both before and after, although to varying degrees of detail. Seven of the 11 students, when asked about describing the types of activities they do in science, noted that science was engaging both pre- and post-PBL. One student commented that science was "mixing cool chemicals together to make a lot of fun things" (student 2, pre-PBL) and "aquaponics [is] a new way of farming and…it's very engaging…because you learn more on your own" (student 1, post-PBL). Another student noted that science is when "we do a bunch of fun stuff like making foam…bombs. Overall, it's a very fun class" (student 11, pre-PBL) before the PBL unit and after, stated "we go on fun field trips" (student 11, post-PBL). The degree of engagement post-PBL was slightly higher as reflected in the length of student responses; they provided ample details in their answers about what they did in the PBL unit. We interpret this as an indication that they were engaged in the activities during the unit to the extent that they were able to recall specific moments and experiences. For example, one student explained in detail her engagement with the topics and content in the unit:

> We are learning about aquaponics and the way it can affect the way we live because aquaponic systems, if they were set up in more places, it could probably help the environment more because the fish are in stable environment, the plants are in a stable environment, and there's no use of pesticides or anything else harmful for us (student 7, post-PBL).

In response to the question regarding whether science helped students solve problems outside of class, responses showed some variety.

Is science helpful? Before the PBL unit, five of the 11 students reported not perceiving science as helpful in solving problems outside of class before the PBL unit (e.g. "not really, I don't use science in my life" (student 1, pre-PBL)), three students commented that science was only useful to answer questions in science (e.g. "like things I learned if someone asks…I can tell them" (student 7, pre-PBL)), two commented on learning useful things last year in relation to pollution and global warming, while only one student felt they had learned something in science this year that was useful outside of class: "it helps me understand chemicals better..like gas…I know there's things in them that might blow up" (student 2, pre-PBL). In contrast, after the PBL unit had been completed, four students could share how science helped them solve problems outside of class. For example:

> Student 5, post-PBL: "While I'm in science class I think about outside of my class, like in my house, what kind of electricity we use and stuff and how we can make it better at our house by using wind power or something."
> Student 9, post-PBL: "It teaches you about what you should or should not do so how much water you should consume, if you're polluting so much how to decrease your footprint, carbon footprint, so like once I just felt energy free one day and I didn't turn on the lights for a full day, or the electricity."

While the application of problem-solving beyond the classroom may not directly indicate higher engagement in the classroom, it does intimate that students were focused on these problems and engaged in them enough to view them as *real-world* issues. This sentiment was consistent in responses to the next question on world views.

Does science change your view of the world? When asked about science changing their view of the world, students were more positive both before and after the PBL unit. Prior to the PBL unit, only four students did not perceive what they had learned in science as influencing their view of the world (e.g. "No, I don't think so" (student 1, pre-PBL)). Of the other seven students, five students referenced a video they had seen the previous year on climate change and how it changed their view of the world. For example:

> Probably last year in grade 9 I watched a documentary, the Leonardo Dicaprio documentary about the world climate thing. It just opened your eyes on how the world is changing and how it's changed over the past few years and if we don't take care of it very well how it might ruin the whole world…Now I like to carpool a lot with my friends. Before we used to take multiple cars to one place but now I'm like "No there's 5 of us and we can fit into this SUV." (student 2, pre-PBL)

The other two students referenced discussions on pollution (student 10) and an electricity project (student 11). In contrast, after the PBL unit, all students provided specific examples of how what they had learned in their aquaponics unit changed the way they viewed the world. For example:

> Student 1, post-PBL: "It has. I'll use less water sometimes or I'll tell my family too because I learned about all this stuff that's happening around the world and how...if we need to save water and I started thinking about that and I started trying to use less water."
> Student 4, post-PBL: "It changed the way I look at agriculture. I want to change how I would plant and stuff…in my family, I have to explain to them why it is important."

Consistently, interviews revealed that students overall were engaged in the issues surrounding farming, the environment, and the role that aquaponics could play in addressing global warming and other environmental issues.

Is school giving me what I need? This engagement was further evidenced in students' responses to the final question: Is school giving me what you think you need right now? The pre-PBL unit responses for all 11 students were generally consistent with their post-PBL unit responses—they found school generally useful to their futures. However, interestingly, the majority (nine of the 11) of students expressed the value of learning through PBL as what they thought they might need for the future. Student 4 commented that, "it taught me the problems happening around this world that relate to weather, farming, and energy. Basically, those three things and it really changed my view on stuff because now I'm more conscious about what's happening and I want to make a difference. I want to be living in the proper way and not impacting the Earth" (post-PBL). Another student suggested science was teaching her "global warming and everything … that's going to help me in the future because that gives me a perception…we are pretty much the future generation so the way we are going to treat the world is how it's going to be for everyone else" (student 7, post-PBL).

Student 10's responses reflected the subtle yet noticeable shift in responses, stating "I think school is doing a good job right now. I think it's enough that we need to learn" (pre-PBL), and then commenting, " I think school's giving us what we need like especially this system that we made…I feel like this is a good way of learning because we get to experience what we are learning about. If we would have just learned about how to make an aquaponics system and not actually make it, we wouldn't be experiencing that but now that we are we really get to learn about it" (student 10, post-PBL). The experience of building the aquaponics system deepened this student's engagement to the extent that whatever was learned was considered more useful and important to that student's sense of what an education ought to provide. The students who did not perceive school as useful to them stated so in both pre- and post-PBL responses—they simply did not see the value of what they were learning regardless of the PBL unit. Overall, the four questions focusing on students' perceptions of engagement revealed a generally higher sense of engagement in school, in activities associated with the PBL unit, and in the value of what was learned through the unit.

Discussion

This study sought to explore student engagement in relation to PBL and answer three questions. Our first question focused on whether there were differences between units using PBL and non-PBL instruction. This question, we believe, was a priori to examining student engagement during PBL in the classroom to ensure that actual instructional differences existed between PBL and non-PBL instruction. This is a step we found is missed by researchers who examine PBL without making and reporting observations comparing the actual instruction that takes place in a non-PBL classroom with the same teacher. Our results revealed significant differences between PBL and non-PBL classroom units. There was significantly more time spent on independent and teacher-directed activities in the non-PBL unit compared with the researching, critiquing, collaborating, and questioning that occurred in the PBL unit. In addition, during student collaboration, the teacher was focused on ensuring that each project was progressing during the PBL unit, as opposed to focusing on whether answers were correct during group work during non-PBL instruction.

Our second question sought to describe student engagement during a PBL unit of instruction. Using a measure of on-task behaviour, we observed students to be more on-task during a PBL unit of instruction, specifically during collaborative activities. These results are similar to those reported by Beckett et al. (2016) and Boaler (1998), two of the only studies that specifically reported on observed student on-task behaviour. The increased student focus during PBL collaborative activities aligns with the results of Al-Balushi and Al-Aamri (2014), Beckett et al. (2016), and Mioduser & Betzer (2007) who discuss specific benefits for the process of investigation and collaboration during PBL activities. However, our results were impacted by gender with only females showing increased on-task behaviour during PBL activities compared with non-PBL activities. A few studies examining gender and PBL activities have shown similar results. For example, Vaz et al., (2013) used an alumni survey to reveal that females found PBL activities in engineering to be of greater interest than their male counterparts. As well, Kilgore et al., (2007) reported that first-year female engineering students were more successful at working within a context (similar to that of PBL), while Kassab et al., (2005) reported that female PBL peer leaders were more successful than male PBL peer leaders when working on engineering problems.

However, these three studies are specific to engineering and involve university students. As a result, additional studies should be completed examining potential gender effects in relation to PBL in high school settings.

In contrast, the results in relation to our third question contrast studies that have reported on student engagement during PBL units. We compared, using a variety of measures, student engagement prior to, during, and after the PBL unit. While our observations of student on-task behaviour illustrated an increase in student engagement during PBL activities, our surveys and interviews did not match this increase. In contrast, an examination of the surveys revealed that students did not perceive any increase in engagement, while an examination of the one-on-one interviews only demonstrated a minimal amount of improved student perception towards science, school, or PBL. This is in contrast to almost all studies examining student engagement (Boaler, 1998; Fogleman et al., 2011; Hugerat, 2016; Lou, 2004; Moiser et al., 2016; Tauro et al., 2017b). One reason for this discrepancy is the lack of measures taken before and after a PBL study to determine if any *differences* were revealed. In contrast, most studies use only a post-PBL measure. Consequently, while these studies may be reporting that PBL was favourably received, they are unable to verify whether PBL was *more* favourably perceived than non-PBL instruction. Our results, using pre- and post-PBL measures, as well as multiple measures of student engagement, challenge how results from earlier studies have been interpreted and reported.

The one significant increase in student perception, measured through both pre- and post-PBL surveys and interviews, focused on increased value and knowledge students perceived in relation to local and global problems and their ability to use what they had learned in terms of future learning or future applications in the *real world*. Rather than perceiving the added benefits of engagement broadly, students in this study perceived very specific added benefits in relation to their ability to understand and respond to more global needs. Their focus was on engagement as citizens rather than engagement as interest. This specific aspect of civic engagement is not discussed in the PBL literature. Instead, we find reference to civic engagement in literature pertaining to science education. This literature in relation to science education indicates that hands-on learning in science correlates strongly with increased civic engagement (Fensham, 2006; Fitzgerald, 2012; Hassard, 2008).

The question then emerged for us: Why does participation in PBL activities generate such perceived added benefits for students? One possibility may be in the types of activities that characterise PBL units of study. As shared by students: “You learn more through the way we’re learning because you learn on your own instead of the teacher telling you what to learn” (student 1, question 9, post-PBL) or, “we figured out ways to help the environment out to help figure out why climate changes is happening and how to teach people how to keep the water clean” (student 8, question 9, post-PBL). Both students suggest that they play an active role in their learning by being the leaders of learning and teaching others. This finding is consistent with Mioduser & Betzer (2007) claim that students need to play an active role in learning and Beckett et al. (2016) assertion that engagement requires hands-on investigations into real-world issues. To further investigate this, we would need to compare engagement on a similar topic using PBL and not using PBL. For example, the non-PBL unit students experienced focusing on classifying chemicals and exploring chemical reactions could have been contrasted with a PBL unit on creating a cleaning agent that was effective but also environmentally sustainable. Would their perceptions still be more in favour of PBL when the topic remains a constant? This would be an interesting next step.

Our results, while they challenge the rosy view of PBL that students simply find it engaging (but not necessarily more engaging than other non-PBL activities), also reveal an exciting area in need of further study. Similar to the work being done in science education, PBL needs to be explored in relation to its ability to civically engage students with the world outside of their classroom. The connections between on-task behaviour, hands-on learning of real-world issues in science class, and engagement have been expanded through this study.

Final Thoughts

The strengths of this study fall on the use of multiple measures of student engagement (observed student on-task behaviour, student perception surveys, student perception interviews) that occurred both before and after a PBL unit on aquaponics. While the data set was quite large, it is still only based on the observations of 30 students in a single class in an agriculture-based city. In addition, the non-PBL units were not the same as the PBL unit (e.g. comparing the teaching of genetics to aquaponics); results may have been different if we had been able to study the same teacher teach the same unit in two different ways. While we did attend to both academic and gender diversity, we did not gather data related to socio-economic status. In addition, this PBL study occurred in a science 10 classroom and did not involve other subject areas. Given these limitations, generalisations need to be made cautiously.

Our results do provide caution for other researchers. It is important to complete detailed classroom observations, there is value in following a single teacher and group of students through both PBL and non-PBL units (to compare differences not impacted by different teachers), and multiple measures of student engagement are needed both before and after the PBL unit under investigation.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Al-Balushi, S.M., & Al-Aamri, S.S. (2014). The effect of environmental science projects on students' environmental knowledge and science attitudes. *International Research in Geographical and Environmental Education, 23*(3), 213-227.

Allen, C. (2015). PBL planning guide: A planning, resource, and reference companion to the Intro to PBL workshop. Seattle: PBL Consulting, Inc.

Bajko, R., Hodson, J., Seaborn, K., Livingstone, P., & Fels, D. (2016). . Edugamifying Media Studies: Student Engagement, Enjoyment, and Interest in Two Multimedia and Social Media Undergraduate Classrooms. *Information Systems Education Journal*, *14*(6), 55-72.

Beckett, G. H., Hemmings, A., Maltbie, C., Wright, K., Sherman, M., & Sersion, B. (2016). Urban high school student engagement through CincySTEM iTEST projects. *Journal of Science Education and Technology*, 25, 995–1007.

Bernstein, R.J. (1998). Community in the pragmatic tradition. In M. Dickstein's (Ed.) The revival of pragmatism: New essays on social thought, law, and culture. Duke University Press, Durham, pp 141–156.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. Educational Psychologist, 26, 369–398.

Boaler, J. (1998). Open and Closed Mathematics: Student Experiences and Understandings. *Journal For Research In Mathematics Education*, *29*(1), 41.

Christenson, S., Reschly, A., & Wylie, C. (2012). *Handbook of research on student engagement*. New York: Springer.

Coles, P., Cox, T., Mackey, C., & Richardson, S., (2006). The toxic terabyte: How data-dumping threatens business efficiency. *IBM Global Technology Services, July 2016*. Retrieved June 12, 2018 from http://www-935.ibm.com/services/no/cio/leverage/levinfo_wp_gts_thetoxic.pdf. Accessed July 2017.

Creswell, J.W., & Plano Clark, V.L. (2007). Designing and conducting mixed-methods research (2nd edition). Thousand Oaks: Sage.

Darling-Hammond, L., & Adamson, F. (2015). *Beyond the bubble test: How performance assessments support 21st century learning.* Toronto: Jossey-Bass.

Dewey, J. (1916/1966). Democracy and education: An introduction to the philosophy of education. New York: Free Press.

Fischer, C. (2013). Project- Based Learning. Research Starters: Education (Online Edition).

Fensham, P. (2006). Research and boosting science learning: Diagnosis and potential solutions. https://research.acer.edu.au/cgi/viewcontent.cgi?article=1013&context=research_conference_2006. Accessed July 2017.

Fitzgerald A. (2012) Teaching for student engagement in science. In A. Fitzgerald's (Ed.) Science in primary schools (pp. 34–52). Rotterdam: Sense Publishers.

Fogleman, J., McNeill, K.L., & Krajcik, J. (2011). Examining the effect of teachers' adaptations of a middle school science inquiry-oriented curriculum unit on student learning. *Journal of Research in Science Teaching, 48(2),* 149–169.

Greene, J.C., Caracelli, V.J., & Graham, W.F. (1989). Toward a conceptual framework for mixed-method evaluation designs. Educational Evaluation and Policy Analysis, 11(3), 255–274.

Gupta, M., & Pandey, J. (2016). Impact of Student Engagement on Affective Learning: Evidence from a Large Indian University. *Current Psychology*, *37*(1), 414-421.

Halliday, S., Calkins, S., & Leerkes, E. (2018). Measuring preschool learning engagement in the laboratory. *Journal Of Experimental Child Psychology*, *167*, 93-116. doi: https://doi.org/10.1016/j.jecp.2017.10.006

Hassard, J. (2008). The art of teaching science: Inquiry and innovation in middle school and high school. New York: Oxford University Press.

Hugerat, M. (2016). How teaching science using project-based learning strategies affects the classroom learning environment. Learning Environments Research, 19, 383–395.

Kassab, S., Abu-Hijleh, M., Al-Shboul, Q., & Hamdy, H. (2005). Gender related differences in learning in student-led PBL tutorials. *Education for Health, 18,* 272-282.

Kilgore, D., Atman, C.J., Yasuhara, K., Barker, T.J., & Morozov, A. (2007). Considering context: A study of first-year engineering students: Research brief. *Journal of Engineering Education, 96,* 321-334.

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project based learning: A review of the literature. *Improving schools, 19,* 267-277.

Krajcik, J.S., & Blumenfeld, P. (2006). Project based learning. In R.K. Sawyer's (Ed.) Cambridge Handbook of the Learning Science (pp. 317–333). New York: Cambridge University Press.

Lewis, S., Freed, R., Heller, N., & Birch, G. (2015). Does Student Engagement Affect Learning? An Empirical Investigation of Student Involvement Theory. Academy Of Business Research Journal, 2.

Liu, M. (2004). Examining the performance and attitudes of sixth graders during their use of a problem-based hypermedia learning environment. *Computers in Human Behavior, 20*, 357–379.

Mark, M.M., & Shotland, R.L. (1987). Alternative models for the use of multiple methods. In M.M. Mark & R.L. Shotland's (Eds.), *Multiple methods in program evaluation: New directions for program evaluation 35* (pp.95-100). San Francisco: Jossey Bass.

Mathison, S., (1988). Why triangulate? *Educational Researcher, 17*(2), 13-17.

Mioduser, D., & Betzer, N. (2007). The contribution of project-based-learning to high-achievers' acquisition of technological knowledge and skills. International Journal of Technology and Design Education, 18(1), 59–77.

Moiser, G., Bradley-Levine, J., & Perkins, T. (2016). Student Perceptions of Project Based Learning within the New Tech School Model. *International Journal Of Educational Reform, 25*(1), 1–14.

Saito, A. (2017). Measurement and Analysis of Student (Dis)engagement in Higher Education: A Preliminary Study. *IAFOR Journal Of Education, 5*(2). https://doi.org/10.22492/ije.5.2.01.

Sammel, A., Townend, G., & Kanasa, H. (2018). Hidden Expectations Behind the Promise of the Flipped Classroom. *College Teaching*, *66*(2), 49-59.

Tauro, F., Cha, Y., Rahim, F., Rahul, M.S., Osman, K., Halim, L. et al. (2017a). Integrating mechatronics in project-based learning of Malaysian high school students and teachers. *International Journal of Mechanical Engineering Education, 45*, 297–320.

Tauro, F., Piscopia, R., & Grimaldi, S. (2017b). Streamflow observations from cameras: Large-scale particle image velocimetry or particle tracking velocimetry? *Water Resources Research,* 53, 10374–10394.

Taylor, L. & Parsons, J. (2011). Improving Student Engagement. *Current Issues in Education, 14*(1), 1–18. Retrieved from https://cie.asu.edu/ojs/index.php/cieatasu/article/view/745. Accessed July 2017.

Thijs, J., & Verkuyten, M. (2009). Students' anticipated situational engagement: The roles of teacher behaviour, personal engagement, and gender. *Journal of Genetic Psychology, 170*, 268-286.

Vaz, R.F., Quinn, P, Heinricher, A.C., & Rissmiller, K.J. (2013). Gender differences in the long-term impacts of project-based learning (ID#6899). Proceedings of the American Society for Engineering Education Annual Conference & Exposition, Atlanta, GA.

Wang, M., & Degol, J. (2014). Staying Engaged: Knowledge and Research Needs in Student Engagement. *Child Development Perspectives*, *8*(3), 137-143.