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Self-regulation and autonomy in problem- and project-based learning environments

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Abstract

Investigations of the relationships between contexts in which learning occurs and students' behaviours, cognitions and motivations may further our understanding of how instruction is related to students' development as self-regulated learners. In this study, student self-regulated learning strategies in problem-based learning and project-based learning environments were examined to determine whether student self-regulation outcomes differed depending on the instructional design. Quantitative results showed that student motivations and behaviours were not statistically different in the two settings. Differences in cognitions associated with self-regulated learning were, however, observed in the two settings, with students in the project-based environments reporting higher levels of elaboration, critical thinking and metacognition. In addition, students in the project-based courses reported higher perceived autonomy support, or the degree to which they perceived their instructors provided them with supportive opportunities to act and think independently compared to students in the problem-based courses. These findings indicate that different non-traditional student-centred learning environments may support different outcomes related to self-regulated learning.

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Autonomy, problem-based learning, project-based learning, self-regulated learning

What is self-regulated learning?

Self-regulated learning (SRL) refers to student control of the learning process. Zimmerman (2000) defines SRL as '... self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals' (p. 14). Pintrich (2004: 387–88) defines four assumptions of SRL: (a) learners are active participants in learning, constructing meaning from information available in the environment in combination with what they already know; (b) learners can control and regulate aspects of their thinking, motivation and behaviour and in some instances, the environment; (c) learners compare progress towards a goal against some criterion, and this comparison informs them of the status of progress towards the goal and (d) self-regulatory mechanisms mediate between the person, the context and achievement. Students who are self-regulated set goals and then choose strategies that they believe will help them achieve those goals. They monitor their progress toward achieving the goals and then evaluate the efficacy of their strategies. Because conditions for learning change constantly, a self-regulated learner adjusts to new conditions, adapts goals and makes tactical choices to work towards realization of those goals (Hadwin et al., 2001).

Learning is not solely dependent on solitary action by the student in response to instruction. It depends on an interaction among external environmental factors and the student's pre-existing knowledge, beliefs and values as well as interactions among and between students, and between students and the instructor. When teachers select pedagogies, they make decisions about what types of student learning they want to support and what instructional context best supports that learning (Pintrich, 2000).

Different instructional contexts activate different goals, student expectations and student behaviours (Vermunt and Vermetten, 2004). Vermunt and Vermetten's (2004) work in SRL suggests that different teaching strategies can be distinguished on a range from 'strongly teacher-regulated to shared regulation to loosely teacher-regulated' (p. 363). The more loosely teacher-regulated the context is, the more the student needs to regulate; the more strongly teacher-regulated the context, the less need for student regulation. However, how a student navigates this complex of internal and external regulation may depend on both the instructor's teaching strategies and the student's learning strategies (Vermunt and Vermetten, 2004). Where they complement each other, a state of congruence exists; when they are not compatible, Vermunt and Verloop (1999) describe the outcome as 'friction', which has two forms – constructive and destructive. Constructive friction occurs when the incompatibility between teaching and learning strategies results in the student learning new approaches to thinking and learning. Destructive friction can occur when teachers take over for students who are employing learning strategies that the teacher feels will not lead to a positive outcome, or when the students do not have the level of self-regulatory skills that the teacher assumes they have. Both situations result in students using thinking and learning strategies on their own, but destructive friction may result in affective responses from students that negatively impact engagement and intrinsic motivation. The teacher who intends to help students internalize self-regulatory behaviours needs to be cognizant of the students' affective as well as cognitive states, and monitor the effect of the instructional context on students, adjusting and adapting when needed.

How might instructional contexts influence self-regulation and student autonomy?

Helping students to engage in behaviours that support their own learning is a goal for most instructors. One key component to helping students develop these propensities lies in what Ryan and Deci (2000) refer to in self-determination theory as supporting the psychological need for autonomy. Autonomy can be defined as 'action that is chosen; action for which one is responsible' (Deci and Ryan, 1987: 1025). Students exercise autonomy when they make choices and act on those choices. Teachers support student autonomy when they recognize the student's perspective and goals, and when they allow students to make choices that are in concert with those perspectives and facilitative of their goals. Who makes decisions about what will be learned, how it will be learned, for what purpose and to what extent it will be learned is at the heart of motivation to learn. Ryan and Deci's (2000) self-determination continuum, ranging from amotivation to extrinsic regulation (controlled) to intrinsic regulation (autonomous), speaks directly to the idea of 'ownership' with regard to motivation to learn. It is well established that the more student ownership there is in learning, the more engagement there will be, and the more engagement there is in learning, the deeper the learning (Blumenfeld et al., 2006). Creating learning environments that encourage student ownership, however, continues to challenge teachers from kindergarten through post-secondary experiences.

Both self-regulation and self-determination theories acknowledge the impact of the environment on individuals striving towards autonomy. Ames (1992) delineated core characteristics of classroom environments that enhance student engagement in learning, including the design of the tasks and autonomy support. Tasks that are relevant, meaningful, encourage the use of effective learning strategies, and present realistic challenges tend to create conditions that are conducive to student engagement in learning (Alexander and Wade, 2000). Allowing students to become part of the decision-making process and helping them develop self-regulation and self-monitoring skills also promote engagement and persistence at learning (Ratelle et al., 2007; Taylor and Ntoumanis, 2007).

Situating problem-based and project-based learning in the support of self-regulation and student autonomy

Problem-based learning (PBL) and project-based learning (PjBL) are two student-centred pedagogies that are well-positioned to support self-regulation. Both formats are based in constructivist theory (Savery and Duffy, 1995), and both fall on the more loosely teacher-regulated end of Vermunt and Vermetten's (2004) range. Critical features of PBL are that students actively engage with authentic tasks that become the vehicles for further learning; students determine what they will need to know and how and where to find it; they constantly monitor their understanding; the use of collaborative teams is integral and the instructor provides appropriate scaffolding and acts as a mentor who pushes the students to deeper learning through questioning and challenging assumptions (Barron et al., 1998; Savery and Duffy, 1995). PBL relies on the use of authentic but simulated problems that students, with the appropriate assistance from the teacher, can solve together. There are specific content objectives with each problem. In most PBL environments, students seek out materials needed to understand and solve the problem. Students work in groups and receive assistance and feedback from the instructor during tutorial periods (Loyens et al., 2008).

Researchers have distinguished between PBL and PjBL, although no single distinction is universally accepted. Indeed, it can be argued that the two share much more similarities than

differences. Barron et al. (1998) suggest that PBL is the scaffold to PjBL. PjBL approaches often start with a 'driving question' where the task has authenticity because it is based in real-world problems. Collaboration among students, between students and teachers and between students, teachers and sometimes members of the community is a feature of such approaches. Blumenfeld et al. (1991) define PjBL as

> a comprehensive perspective focused on teaching by engaging students in investigation ... There are two essential components of projects: They require a question or problem that serves to organize or drive activities; and these activities result in a series of artifacts or products, that culminate in a final product that addresses the driving question. (p. 37)

The distinction between PBL and PjBLs adopted in this article is according to the definition of Prince and Felder (2006): The emphasis in PjBL is on applying or integrating knowledge while in PBL it is on acquiring it.

Research points to some beneficial effects of the use of PBL-like student-centered pedagogies with regard to the development of self-directed learning (Loyens et al., 2008), and a small body of work suggests that PBL approaches can facilitate the adoption of several abilities specifically associated with self-regulated learners. Sungur and Tekkaya (2006) found that in comparison to traditional lecture-based instruction in biology, high school–aged students in a PBL approach to the same biology topic reported being more intrinsically motivated at the end of the 6-week experiment than students in the traditional approach and reported higher valuation of the importance of the task. In terms of use of learning strategies, students in the PBL condition reported greater use of elaboration, metacognitive self-regulation strategies, critical thinking, effort regulation and peer learning than their counterparts in the traditional instructional setting. Evenson et al. (2001) found that medical students in a PBL environment developed over time the tendency to use deeper level study and learning strategies, plan, set goals and reflect. Langendyk (2006) found that high achieving students in PBL environments were able to assess themselves and their peers accurately, as compared to teacher assessments.

The extent to which students engage in learning is determined by numerous individual, social and environmental factors, such as interest in the task, the value a student places on the task, how competent students feel, instructor feedback on task performance or the way the learning environment is structured. Despite the extensive research base on the interaction between learners and their contexts, there are many things we have yet to understand clearly, particularly with regard to the relationships between student SRL and non-traditional classroom environments. Articulating the classroom conditions that are related to different student self-regulated behaviours, dispositions and attitudes can help deepen our understanding of the ways in which the learning environment might influence students' learning choices. This understanding may, in turn, inform educational practices and help instructors foster adaptive outcomes such as self-efficacy, metacognition, effort regulation and collaboration. The purpose of this study was to examine whether there are measurable differences in SRL for students in PBL and PjBL environments – two pedagogies gaining increasing attention in higher education.

In summary, a considerable amount of research has been done on contextual factors and their influence on student learning. Research on the effects of instructional environments using less traditional formats, such as PBL and PjBL, on student SRL is less abundant. Research that compares outcomes between these environments is particularly lacking. This article therefore studies the relationship between these two types of student-centered instructional environments and students' SRL outcomes.

Method

Methodology

This study utilized a design-based research approach: a design for studying innovative learning environments in classroom settings that is theoretically driven and empirical without controlling variables of interest to the degree that is necessary in laboratory studies of learning (Brown, 1992; Sandoval and Bell, 2004). Such designs offer a means of addressing the need for sound research designs that produce consumable, contextually intensive outcomes. Because this study was done in situ with an interest in naturally occurring student outcomes, this design was considered most appropriate. Design-based research (a) is situated in real educational settings, (b) utilizes an intervention (i.e. a learning activity, use of technology and a particular pedagogical design), (c) can include multiple methodologies (i.e. quantitative, qualitative and case study), (d) can involve multiple iterations and (e) involves collaboration between practitioners and researchers (Anderson and Shattuck, 2012). This study involved the collaboration of two instructors in applied disciplines and one educational psychologist. Quantitative data of student self-reports of SRL and experience of autonomy support were collected over a 2-year time period in six courses at two private universities. The pedagogy employed in the courses represented the intervention: two courses used PBL, while the other four used PjBL. We emphasize again that our distinction between the two pedagogies (Prince and Felder, 2006) hinges on whether the course's main goal is on student acquisition of new content knowledge (PBL) or on integration and application of prior content knowledge (PjBL).

Participants

Seventy-seven undergraduate students and two instructors from two private universities in the northeastern United States agreed to participate in the study, carried out in the academic years 2009/2010 and 2010/2011. Over the course of the 2-year period of data collection, some participants enrolled sequentially in a PBL and a PjBL course in different semesters and chose to participate in the study for both (n = 11). Others participated in the study in only one course (n = 66). Some students experienced the problem-based course first, while others experienced the project-based course first. Both instructors taught one problem-based course, and one instructor taught one project-based course, while the second instructor taught three project-based courses. Specifics of the courses are described below.

In the two PBL courses, there were 10 females and 17 males: 3 first-year students, 20 juniors and 4 seniors. In the four PjBL courses, there were 28 females and 22 males: 16 sophomores, 10 juniors and 24 seniors. Both instructors were male. Table 1 provides information on the total enrolment in each course, the gender of students in the course and the distribution of students by their year of study in the course, with the number who participated in the study in parentheses.

Context

Both student-centered pedagogy formats are team based and student driven. Although both formats emphasized team-based problem solving and offered significant opportunities for student–student and instructor–student interactions, the types of problems, constraints and learning goals were different in the PBL and PjBL courses. In the PBL courses, the instructors presented students with a set of common problems that were designed to help students develop deep conceptual understanding in specific technical areas. Students were expected to decide

Table 1. Student participants' (in parentheses) and non-participants' gender and year of study in each course.

Course type and enrolment	Male	Female	First year	Sophomore	Junior	Senior
PBL (n = 28)	19 (12)	9 (4)	0	0	28 (16)	0
PBL (n = 21)	10 (6)	11 (5)	6 (3)	0	8 (4)	7 (4)
PjBL (n = 28)	19 (12)	9 (4)	0	0	0	28 (16)
PjBL (n = 16)	4 (1)	12 (9)	0	3 (3)	11 (5)	2 (2)
PjBL (n = 18)	5 (3)	13 (6)	0	7 (3)	4 (1)	7 (5)
PjBL (n = 18)	9 (9)	9 (6)	0	10 (10)	7 (4)	1 (1)

PBL: problem-based learning; PjBL: project-based learning.

Table 2. Titles of courses, design and data collection timeframe.

Year	Problem-based course	Project-based course
Year 1	Heat Transfer (fall semester)	Failure Analysis and Prevention (fall semester) Metals and Alloys (spring semester)
Year 2	Materials Science (spring semester)	Failure Analysis and Prevention (fall semester) Senior Design (spring semester)

what they should know and what they would need to learn in order to solve the problems. The PjBL courses emphasized analytical process over specific technical content. The attainment of common knowledge was not a primary goal in these courses. Because student teams either chose a project to work on or worked on a project that was commissioned by a client, as in the senior design course, each team acquired different technical content depending on their project topics. Student teams designed experiments to test their ideas, identified information resources and established their own goals, timelines and strategies specific to the projects they selected. Table 2 provides the course names, course design and the year and semester in the study during which data were collected.

Procedure

Permission to approach students to invite participation in the study was obtained through formal Institutional Review Board (IRB) processes at both universities. Once the IRB proposals were reviewed and approved, students were provided an explanation of the study in class by their instructor and an opportunity to choose to participate. Students were also provided contact information for the educational researcher in the study if they had unanswered questions or concerns. Students were informed that participation was voluntary, without compensation, and all information collected through the surveys would be kept anonymous. They were also informed that they could discontinue participation at any time. Students who agreed to participate were provided with a code to use to complete the online surveys to ensure anonymity. During the study, the courses took place as they would normally. The only difference was that students who agreed to participate completed the Motivated Strategies for Learning Questionnaire (MSLQ) at the beginning and end of the course and the Learning Climate Questionnaire (LCQ) at the end of the course.

Instrumentation

MSLQ. The MSLQ is an 81-item self-report questionnaire designed to measure motivational orientations and the use of learning strategies in college students. This instrument was specifically designed to measure aspects of SRL among college students. Students respond to the items using a 7-point Likert format, with 1 indicating that the statement is 'not at all true of me' and 7 indicating that the statement is 'very true of me'. The MSLQ provides subscale scores in 15 areas. Six are motivation subscales of intrinsic motivation, extrinsic motivation, task value, control of learning beliefs, self-efficacy and test anxiety. Nine are learning strategy subscales of rehearsal, elaboration, organization, critical thinking, self-regulation, time and study environment, effort regulation, peer learning and help seeking. Subscale scores are averages for each subscale. The MSLQ manual reports 'robust Cronbach alphas ranging from .52 to .93' and confirmatory factor analysis that shows 'reasonable factor validity' (Pintrich et al., 1991: 4–5). Reliability estimates based on the data set from this study are consistent with those in the manual (ranging from 0.62 to 0.91). The MSLQ is designed to be used in whole or in part. For this study, the subscale of Test Anxiety was eliminated because it was irrelevant to one of the courses where no tests were given. Furthermore, the wording in several items was modified to better reflect the learning environments. Specifically, references to 'study' or 'studying for the course' were replaced with 'prepare' or 'preparing for the course', and a reference to 'lecture' was replaced with 'class discussion'. Thus, for this study, students completed a 76-item modified MSLQ.

LCQ. The LCQ is one of the Perceived Autonomy-Supportive Climate Questionnaires developed by Deci and Ryan (n.d.) (www.psych.rochester.edu/SDT/measures/paslearning/php). The LCQ is a 15-item self-report questionnaire that asks students to respond to questions regarding their perception of the degree to which they find the educational environment supportive or controlling. It is part of a collection of questionnaires measuring perceptions of autonomy-supportive climates, specifically an educational autonomy supporting climate. Students respond to the items using a 7-point Likert format, with 1 indicating strong disagreement with the statement and 7 indicating strong agreement. One total score results as the average of the item scores. Williams and Deci (1996) report good internal consistency and construct validity for the LCQ. Internal consistency using the data from this study is consistent with that reported by Williams and Deci (1996).

Analyses

MSLQ. Data were analyzed for pre- to post-test differences within pedagogy type on students' MSLQ subscale scores using paired samples *t*-tests. Post-test differences on the MSLQ occurring as a result of the two pedagogies were examined using analysis of covariance (ANCOVA) on subtests where there were differences at pre-test, and one-way analysis of variance (ANOVA) for all others. One-tailed hypotheses were tested, where gains were expected in intrinsic goal orientation, task value, control of learning beliefs, self-efficacy, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, peer learning, effort regulation and help seeking, and no gains were expected in extrinsic goal orientation and rehearsal. Effects sizes for ANOVA are reported as $\acute{\eta}^2$ and are interpreted as the percent of variance explained by the variable.

LCQ. Post-test differences on the LCQ as a result of the two pedagogies were examined using an independent sample *t*-test, with effect size reported as Cohen's *d*, with small effects noted by 0.0–0.2, medium effects by 0.3–0.5 and large effects by 0.6 and above.

Results

MSLQ

Paired sample t-tests. Quantitative analyses showed significant differences on several subscales of the MSLQ from the beginning of the semester to the end for students in PBL versus PjBL courses. Means (M) and standard deviations (SDs) of these significant differences are found in Table 3. Students in the PjBL courses showed significant differences from pre- to post-test in elaboration ($t(49) = 2.243$, $p = 0.015$, $d = 0.32$), critical thinking ($t(49) = 1.909$, $p = 0.031$, $d = 0.27$), metacognitive self-regulation ($t(49) = 2.393$, $p = 0.011$, $d = 0.34$) and time and study environment ($t(49) = 2.427$, $p = 0.001$, $d = 0.34$). Students had higher mean scores at post-test in elaboration, in critical thinking and metacognitive self-regulation but lower scores at post-test in time and study environment. Students in the PBL courses showed significant increases from pre- to post-test only in peer learning ($t(26) = 1.994$, $p = 0.029$, $d = 0.38$).

Analysis of variance and covariance. Where no pre-test differences existed, a one-way ANOVA was conducted, with pedagogy type (PBL and PjBL) as the factor, to determine post-test differences on the subscales of the MSLQ between students in the PBL and PjBL learning environments. Pre-test differences were found in the areas of intrinsic and extrinsic goal orientations, task value, control of learning beliefs and self-efficacy, and thus, ANCOVA was used to control for these pre-existing differences by using the pre-test scores in these areas as the covariate. ANCOVA resulted in no significant post-test differences for any of these variables. No pre-test differences were found in the areas of rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, effort regulation, peer learning and help seeking therefore ANOVA was used to test for post-test differences. The ANOVA resulted in significant post-test differences between the groups on elaboration ($F(1, 75) = 10.441$, $p = .001$, $\acute{\eta}^2 = 0.12$), critical thinking ($F(1, 75) = 10.433$, $p = 0.001$, $\acute{\eta}^2 = 0.12$) and metacognitive self-regulation ($F(1, 75) = 5.441$, $p = 0.011$, $\acute{\eta}^2 = 0.068$). In all cases, students in the PjBL courses reported higher mean scores at post-test than students in the PBL courses. Table 4 contains M and SDs for these variables.

LCQ

Independent sample t-test. Mean scores on the LCQ were compared between the groups using an independent sample *t*-test. Results indicate a significant difference between the two groups ($t(28.703) = 3.022$, $p = 0.005$, $d = 0.91$) with students in the PjBL courses reporting higher perceptions of autonomy support ($M = 6.37$, SD = 0.47) than students in the PBL courses ($M = 5.55$, SD = 1.34).

Table 3. *M* and SD for subtests with significant pre–post test differences.

	Elaboration		Critical thinking		Metacognitive self-regulation		Time/study environment		Peer learning	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
	M (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)
PjBL	4.95 (0.77)	5.21 (0.68)	4.63 (0.97)	4.88 (0.83)	4.46 (0.70)	4.69 (0.66)	5.33 (0.78)	5.11 (0.81)		
PBL									4.05 (0.87)	4.44 (1.4)

M: mean; SD: standard deviation; PBL: Problem-based learning; PjBL: project-based learning.

Table 4. *M* and SD for subtests with significant post-test differences.

Elaboration		Critical thinking		Metacognitive self-regulation	
M (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)
PBL	PjBL	PBL	PjBL	PBL	PjBL
4.59 (0.98)	5.21 (0.68)	4.16 (1.09)	4.88 (0.83)	4.26 (0.96)	4.70 (0.66)

M: means; SD: standard deviations; PBL: problem-based learning; PjBL: project-based learning.

Discussion

These course designs are intended to promote high levels of student autonomy and the engagement of deeper level learning strategies. Both autonomy and deep-level engagement have been associated with adaptive motivational orientations and efficacy. The use of problem-driven contexts, authentic contexts, team-based work scenarios and the provision of multiple opportunities for collaboration with ample time to complete assignments are elements that theory suggests should encourage students to exercise independence in problem solving (e.g. Paris and Paris, 2001; Prince and Felder, 2006, 2007). Students in neither pedagogical condition reported increases in using surface-level learning strategies or in being driven to learn for reasons external to the task itself. This was as we had expected because these pedagogies are intended to require students to engage in deeper level learning strategies. However, students in the project-based courses reported increases in key areas relative to their own start point and relative to that of their peers in the problem-based courses, suggesting that project-based designs may have more effect on student SRL than problem-based designs. Both designs appeared to have successfully resulted in creating environments that facilitated student engagement of self-regulated behaviours and attitudes, especially with regard to deeper level strategies but did so differentially in terms of elaboration, critical thinking and metacognitive self-regulation.

Below, we provide an analysis of these results using Pintrich's (2004) model that includes four areas for regulation: (a) regulation of cognition, (b) regulation of motivation/affect, (c) regulation of behaviour and (d) regulation of context.

Regulation of cognition

Deep-level learning strategies and critical appraisal of one's efforts and knowledge appeared to be encouraged in the PjBL environment, which, in our study, is associated with more student autonomy, authenticity in problems to solve and focus on applying knowledge in contrast to gaining specific new knowledge that is associated with the PBL environment. Evidence of the capability of this instructional environment to foster the adaptive behaviours of elaboration, critical thinking and metacognitive self-regulation is seen in the results for the PjBL students both relative to themselves from beginning to end of the semester and relative to their peers in the PBL environment. Perhaps, as Barron et al. (1998) suggest, PBL is the scaffold to PjBL, and when comparing the two approaches, the strongest effects may be found with the pedagogy that pushes students farther. The more real-world, ill-defined, complex, open-ended projects in the PjBL courses appear to have sparked increased higher-level cognitive strategy use among students.

Regulation of motivation

Self-determination theory links high-intrinsic motivation, feelings of control over one's own learning and high valuation of autonomous learning tasks with self-reports suggesting engagement in

learning. It is widely acknowledged that the more student-centered the learning environment, the greater the opportunity for developing a goal orientation consistent with intrinsic drives (e.g. Blumenfeld et al., 2006; Evenson et al., 2001; Loyens et al., 2008; Sungur and Tekkaya, 2006). The learning contexts in this study did not appear to be related to a positive shift in motivational orientation, as would be expected given previous research on such open instructional designs. In both the PBL and PjBL settings, students adopted motivational orientations that persisted throughout the term. One explanation may be that the effect of student-centered learning environments on student motivation is cumulative, and the students in this study may not have had enough exposure to these less didactic classrooms to fully experience a noticeable change in motivational orientation. Future work in the area of motivation might provide important information on the motivational orientations of students who experience these student-centered environments over time.

Regulation of behaviour

The only area where significant differences were found with regard to regulation of behaviour was in the management of one's time and arrangement of one's study environment. Interestingly, the students in the project-based group reported less effort given to managing their time and arranging their study environment to support learning. This might be best understood by referring to the reality of such pedagogical designs and the specific questions on our instrument, the MSLQ. Studying in the 'traditional' sense would not seem to be a highly valued activity when you are faced with the types of authentic tasks that faced the students in the PjBL courses. How does one study to complete a project for a client or to explain why a product has failed? Just-in-time learning for new information may be the more typical way new knowledge is accrued in this type of learning environment. In that sense, arranging for a quiet study place and making time during the day to study, which are the types of questions asked in the MSLQ, are not critical features that would lead to success for these students given their circumstances.

Regulation of context

Surprisingly, only students in the problem-based courses reported higher use of peers in the aid of learning at the end of the semester. Both courses were team based, and all work was completed in teams. Students in the problem-based courses relied on each other as experts in the field, able to step in and explain what was needed or how to approach a problem. Students in the project-based courses were drawn to projects based on interest with team composition having a high probability of being heterogeneous in terms of field of expertise. Perhaps that reliance on peers in this scenario is for complementary expertise rather than corroborative expertise is one way to interpret this result.

Perceptions of autonomy-supportive environments

Both courses were structured to provide students with autonomy, and the LCQ scores for both the PBL and PjBL environments indicate that students experienced autonomy-supportive learning. While students in both courses reported perceptions of high autonomy support, a significant difference was found in students' perceptions between those in PjBL and PBL classrooms. Students in the project-based courses reported a greater sense of autonomy support than students in the problem-based courses. One aspect that might help to explain this difference was in the perception of authenticity of the problems provided with regard to solution paths. While all problems were realistic, students in the problem-based course may have felt that there was a correct solution, and they

needed to find that solution. The problem contexts in both courses were authentic, but the problems themselves varied in how well versus ill-defined they were perceived by the students. For the students in the problem-based course, the problems were ill defined because they did not necessarily know the solution path. Their instructor knew what needed to be done, and they needed to figure out what he knew. Yet, these students were not given solutions or equations but were helped to find them on their own, suggesting that there was support for their autonomy. Such an arrangement suggests that students were required to be independent problem solvers. However, the fact that there was *one* solution, although with multiple paths to arrive at the solution, could have affected the students' perceptions of the degree to which their instructors supported their autonomy.

For students in the project-based course designs, the authenticity of the tasks before them might have suggested to them that their instructor did not have the answer and that they truly needed to be independent thinkers. The support of the instructors in both types of courses for students developing a sense of authority and autonomy was a critical pedagogical factor. Perhaps the use of truly ill-defined problems in the PjBL environments enhanced students' perceptions of support their instructors provided. As Blumenfeld et al. (2006) explain, the use of authentic problems has many challenges, including determining what students will find meaningful, finding problems that can be feasibly completed given constraints such as time and material availability and using problems where the novelty of the driving question does not overpower student's engagement in learning itself. It appears that instructor support for student autonomy was a more salient feature in the more authentic environment provided by the project-based course designs.

Conclusion

This study explored the relationship between different student-centered instructional contexts and student ownership and self-regulation of the learning process. Two types of student-centered courses designed to facilitate students' engagement in SRL provided the context from which data were gathered. Students' self-reports are consistent with theoretical expectations of the effects of student-centered learning environments. However, there is evidence that the two environments, problem-based and project-based, although similar in structure, supported students' self-regulatory behaviours differently. No statistically significant differences were seen in students' motivation or regulation of behaviour between the two environments. However, the context mattered in terms of the cognitive learning strategies students adopted with students in the PjBL environment reporting higher use of elaboration, critical thinking and metacognitive self-regulation. These students also reported higher autonomy support.

This research project utilized a design-based methodology. Such methodologies have the promise of bridging the gap between research and practice by providing a realistic analysis of authentic praxis. However, such designs do not control as much of the environment as experimental research methodologies and therefore are susceptible to questions of internal validity and generalizable results. As noted earlier, approximately 14% of the students who provided data were students enrolled sequentially in a PBL and a PjBL course. This degree of exposure to these intensive student-centered learning environments could have implications for the strength of the effects on self-regulation. A further confound may lie in the learning environment differences students experience at their university. One university relies more on a traditional, didactic learning environment with students' first exposure to PBL occurring in the course that was part of this study. Students in the other university experience a less traditional learning environment with more opportunities earlier in their studies to experience the more student-centered pedagogies that were the subject of this study. Future studies may consider using an experimental methodology with balanced and

controlled samples to determine whether the same pattern of student response holds under more standardized conditions. Furthermore, a broader sample that includes students from large public universities and from the range of disciplines would provide a more robust understanding of the effects of these pedagogies on student SRL.

Overall, PBL and PjBL contexts appear to provide a rich playground for students to exercise autonomy and cognitive behaviours associated with SRL. The fact that such environments encourage these behaviours and attitudes is not surprising. However, the fact that they seem to do this differently is interesting, as it implies that the problem-based and project-based contexts provide for different forms of constructive friction in the cognitive domain. The findings from this study have important implications for instructors and curriculum designers who wish to promote students' use of self-regulatory strategies. First, although both PBL and PjBL approaches appear to lead to constructive cognitive friction leading to increased self-regulatory strategy use in a given course, the PBL and PjBL courses examined in this study did not lead to increased motivational and behavioural self-regulatory strategy use among students. In fact, the PjBL courses appear to have discouraged students' adoption of certain behavioural self-regulatory strategies related to managing study time and environment.

Open-ended, project-based courses such as those examined in this study may not be the best place for students to develop their study skills, as these courses do not typically include traditional assessments, such as examinations, that prompt students to set aside time and find a good location to study. Second, given the different cognitive outcomes associated with different active learning approaches, it appears that PBL and PjBL pedagogies may better support some areas of cognitive development over others. As such, PBL and PjBL course facilitators should carefully consider the particular cognitive outcomes they wish to emphasize in their classrooms in order to make strategic course design decisions to support these outcomes. If peer learning is a desired outcome, for example, the more commonly structured activities in PBL may offer a better opportunity for this. Finally, the fact that students perceive PjBL settings as more autonomy-supportive than the PBL settings may imply that projects are a more suitable approach for building students' sense of control and ownership in learning. In summary, since no single course or activity can support all learning outcomes, instructors should be intentional in their choice of an active learning approach that is best aligned with the desired learning outcomes.

Declaration of conflicting interests

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