Journal of Education and Learning; Vol. 14, No. 1; 2025
ISSN 1927-5250 E-ISSN 1927-5269
Published by Canadian Center of Science and Education

The Effects of Context-Rich Problems on Motivation and Learning in Mechanical Physics

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Received: June 14, 2024 Accepted: August 15, 2024 Online Published: September 12, 2024

doi:10.5539/jel.v14n1p15 URL: https://doi.org/10.5539/jel.v14n1p15

Abstract

This study examines the effects of the pedagogical use of context-rich problems on motivation and learning, as compared to traditional problems, in mechanical physics courses at the college level. The results indicate that the treatment has appreciable outcomes on conceptual learning gain, on the perception of task value and on a perceived sense of competence. Moreover, the affected motivational variables exhibit a considerable positive correlation with learning gain. A linear regression analysis shows that the best predictors of learning gain are perceived sense of competence and interest. The former acts as the main learning gain predictor when the theme of the problem is imposed by the teacher, whereas the latter becomes the best predictor when students can choose the theme among different possibilities, situations that seem to be more conducive to learning gain. Therefore, offering a choice of themes, while using context-rich problems, appears to increase the students' emotional reactions, making this pedagogical device a promising tool for achieving learning gains.

Keywords: authentic situation, context-rich problems, interest, learning gain, motivation, sense of competence, task value

1. Introduction

1.1 Research Question

Cooperative Group Problem Solving (CGPS) is an active learning approach that has been developed by the University of Minnesota for the introductory physics course at the college level, with the aim of allowing student to better "integrate the conceptual and mathematical aspects of problem solving" (Heller, Keith, & Anderson, 1992). This approach has since then been widely exploited in a variety of educational fields worldwide (Maries & Singh, 2023; Burkholder, Salehi, Sackeyfio, Mohamed-Hinds, & Wieman, 2022; Reinhard, Felleson, Turner, & Green, 2022; Major, Harris, & Zakrajsek, 2021; Price, Kim, Burkholder, Fritz, & Wieman, 2021; Burkholder, Blackmon, & Wieman, 2020; Burkholder et al., 2020; Gunawan, Harjono, Nisyah, Kusdiastuti, & Herayanti, 2020; Pulgar, Candia, & Leonardi, 2020; Ince, 2018; Nilson, 2016; Docktor & Mestre, 2014; Docktor & Mestre, 2015; National Research Council, 2012; Schweingruber, Nielsen & Singer, 2012; Nussbaum, 2008; Michael, 2006; Felder, Woods, Stice, & Rugarcia, 2000; Crouch & Mazur, 2001; Hake, 1998), and has drawn attention at the college level in Quebec (Jang, Lasry, Miller, & Mazur, 2017; Lasry & Aulls, 2007). CGPS is a pedagogical approach that uses Context-Rich Problems (CRPs) that students solve in small groups and that integrates the preliminary use of explicit problem-solving teaching (Heller et al., 1992; Heller & Hollabaugh, 1992).

The literature shows that this type of pedagogical approach improves learning (Heller et al., 1992). However, when it comes to understanding why this approach is effective or what specific elements make this approach effective, there is a scientific gap. Indeed, research findings indicate the positive effects of this strategy, but only partially explain, by means of the beneficial impacts of cooperative learning, the processes that lead to these positive effects (Heller et al., 1992; Brundage, Malespina, & Singh, 2023; Guo, She, Chen, & Tsai, 2023). The effects of CRPs' contextualization on motivational dynamics have not been examined and the aim of this study is to focus precisely on these effects. Does contextualization of CRPs influence motivational dynamics and learning? The pedagogical use of CRP permits the selection of problems that are in line with students' interests, for example by giving students choices among a variety of themes. Does the possibility of choosing the theme influence motivational dynamics and learning?

1.2 Conceptual Framework

In Quebec, the college level is the first level of postsecondary education. Quebec colleges offer technical and pre-university programs that prepare students for university or the job market. The pre-university program in Science is composed of compulsory courses in mathematics, chemistry, biology, and physics, among others. These courses do not necessarily align with the vocational choices of all students. For example, only 19% of students enrolled in Science choose university programs related to the mechanical physics course (Cormier & Pronovost, 2016) and enjoy this subject. The others expressed negative emotions about physics.

It is well known that motivation has a positive effect on learning and that learning activities have a very strong influence on motivation (Viau, 2000). Cormier and Provonost (2016) studied interest and motivation for science among college students in Quebec and found that physics is the scientific discipline with the lowest success rate, that is the least appreciated, and that is the most anxiety-provoking. One might then wonder if the learning gain observed with the CGPS approach can be attributed to positive effects of this pedagogical practice on the motivational dynamics. Curiously, to our knowledge, no study on CGPS has examined motivational variables in relation to CRP contextualization, which suggests that by promoting a greater use of activities set in the real world, has a good chance of increasing learning value in the students' minds (Duval & Pagé, 2013).

To define the motivational variables to be analyzed, Viau's (2009) model of motivational dynamics was chosen. This model is not the only one used in the field of education, however, "It is particularly popular in Quebec and Europe and is widely cited in French language literature" (Tremblay-Wragg, Ménard, & Raby, 2018). In addition, it was designed to study motivation in specific learning activity contexts (Cabot, 2016). According to this model, learning activities influence student motivation based on three types of perceptions: activity value, which is judged by the two criteria of interest and utility, controllability, with respect to the activities, and sense of competence in performing the activities (Viau, 2009).

It seems reasonable that the CRPs' contextualization, achieved by setting the activity more closely in reality, has a good chance of increasing the value placed on learning in the students' minds. Moreover, it has been suggested that teaching by themes, "brings personal meaning and direction to the learning process" (Handal & Bobis, 2004). However, when we closely examine the two criteria, which, according to Viau, are the basis of students' perception of the value of learning, we realize that the fact that the activity is realistic and linked to a particular theme could make it more meaningful, thus increasing the perceived utility. However, it is not at all clear that this characteristic would make it more interesting from the student's point of view, especially if the student is enrolled in a generalist pre-university program, as in the present case. Indeed, if this pedagogical approach is used in a professional technical program, a CRP's theme related to the student vocational choice will be in line with his or her interests, if the student has chosen the program according to such interests. However, this reasoning is not at all obvious for students enrolled in pre-university programs. Indeed, Laveault (2004) points out that authentic situations are not sufficient to motivate students to learn: "because authentic situations are closely associated with individual life experiences, they can give rise to very different emotional reactions from one individual to another." Offering a choice of themes in physics problems therefore appears to have the potential of increasing students' interest and of further contributing to increasing their perception of the value of learning. Indeed, according to (Cabot, 2017), "interest is a motivational concept that stands out for its strong emotional component. It is plausible to believe that this characteristic makes interest a unique entry to motivational dynamics…" (p. 1). Research shows that allowing students to express their interests by making choices is effective (Viau, 2009). Indeed, studies indicate that interest and controllability by means of exercise choice are interrelated variables (Patall & Hooper, 2019; Bradette & Cabot, 2022).

To sum up, although it is well known that learning activities exert a very large influence on motivation, which, in turn has a positive effect on learning, research on the pedagogical use of context-rich problems is not exhaustive regarding the analysis of the motivational mechanism in relation to the independent variables of problem contextualization and theme choice. This is a gap in scientific research that should be bridged.

This study has a dual objective. First, it is to examine the effects on motivational dynamics and on learning of the pedagogical use of context-rich problems vs. traditional problems, in two different situations: when students can choose the problem's theme among different possibilities, and when the theme is imposed by the teacher. Secondly, to examine the links between motivation and learning and to determine if motivation variables can act as predictors of learning gain.

2. Method

This study is part of a quasi-experimental design in a real-world context with pretest/post-test measurements and control conditions as well as a mixed analysis design.

2.1 Description of Treatment Conditions

The sample consists of 4 class groups and 2 teachers. Each teacher oversaw 2 classes in mechanical physics during the winter 2023 semester. In one of the two classes, the teachers used their usual pedagogical strategies (control group—CG), which included cooperative group problem-solving activities with traditional problems. In the other class, they replaced the traditional problems with CRPs (experimental group—EG) for three cooperative group sessions and for three individual activities. One of the two teachers (henceforth called Teacher B) offered the opportunity of choosing the themes of the problems when it was given as an individual activity. These crossed-conditions treatment allowed to disentangle the cooperative independent variable (present in all groups) from those related to contextualization (present in both experimental groups—EG-A and EG-B), and from those offering the choice of themes (present in the experimental group of Teacher B only—EG-B). Table 1 presents the 4 conditions to be compared.

Table 1. Treatment conditions

	CG-A	EG-A	CG-B	EG-B
Registrants	35	30	38	37
Participants	32	26	14	21
CRP	No	Yes	No	Yes
Choice of theme	No	No	No	Yes

The pedagogical strategies were applied in two phases: a planning phase and pedagogical follow-up in the fall 2022 session and an experimentation phase in the winter 2023 session. The first phase allowed the teachers to familiarize themselves with the CRP pedagogical approach by means of workshops organized by the research team and by the implementation of this approach in the classroom. Follow-up meetings were held throughout the fall 2022 session. Qualitative data were collected, from 57 students with a questionnaire to assess pedagogical strategies, and from the two teachers with focused interviews, to evaluate implementation before the experimentation phase. The required adjustments were then made for the winter 2023 experimentation phase. Concurrent to the two participating teachers learning and assimilating CRPs pedagogical strategies, the principal investigator selected 11 CRPs from the archive of the Physical Sciences Resource Center (PSRC) of the University of Minnesota (PSRC, 2014) and from the realistic activity website of the College Center for the Development of Didactic Materials (Lasry, 2008). The CRPs were organized according to different themes, which included, sports activities, forensic science, biomechanics, mechanical engineering, travel, astronautics, and astronomy. The selected PSRC problems were translated and then adapted to a Quebec college level. Two new CRPs were created by the research team for the final individual activity. In the second phase, three cooperative problem-solving sessions were facilitated by the two teachers in their groups and three problems were given to be solved individually as homework to be completed within a few days. In the experimental groups, the six activities were performed using CRPs, whereas in the control groups, traditional problems were always used. The students received feedback from the teacher for all the activities. In group sessions, an emphasis was placed on cooperative learning, following the CGPS approach, while in individual activities, both teachers worked on teacher-learner interactions and applied the concept of scaffolding according to Bruner (1983). In all the groups, the problem-solving procedure teaching method was conducted by gradually guiding the student towards autonomy in accordance with the framework of explicit instruction. Other pedagogical strategies adopted in these courses, all classes combined, were lectures, accompanied by videos and demonstrations, problem-solving examples, and traditional laboratories. All the groups had a study guide, which included a list of textbook problems to be solved autonomously outside of class time.

2.2 Data Collection Instruments

As previously mentioned, qualitative data were collected from the students and the two teachers in the fall 2022 semester to assess the implementation phase. The following instruments were then administered during the experimental phase to conduct the formal evaluation of the various pedagogical conditions.

A general information questionnaire (QRG) was administered at the beginning of the semester to examine the participants' socio-demographic characteristics and to verify their homogeneity within the four groups with their different pedagogical conditions. For example, gender, age, and high school GPA were obtained.

The gain (g) of conceptual learning was obtained from the FCI test of Hestenes and Wells (1992). The g_{FCI} considers the learner's starting level and is normalized by the maximum gain that the learner can achieve given his or her starting result. This score is obtained as follows:

$$g_{FCI} = \frac{score_{FCIpost} - score_{FCIpre}}{score_{FCImax} - score_{FCIpre}} \quad (1)$$

Motivation for the physics course was measured using a scale representing 4 motivation subscales (interest, utility, controllability, and sense of competence), adapted from Cabot & Bradette (2022) and Losier et al. (1993). It is composed of 14 items, with pretest formulations measuring motivational expectations and post-test formulations measuring motivational perceptions (e.g.: During this physics course, I expect to have a choice among different activities offered [pretest]; During this physics course, I had the choice among different activities offered [posttest]). Likert-like, they are five-point subscales, ranging from 1 (strongly disagree) to 5 (strongly agree). A new measure of normalized motivation, in the likeness of conceptual learning gain, has been defined. This measure, named normalized variation in motivation, v_{MOT}, is obtained as follows:

- $v_{MOT} = \frac{score_{MOTpost} - score_{MOTpre}}{score_{MOTmax} - score_{MOTpre}}$, if $score_{MOTpost} - score_{MOTpre} \geq 0$ (2)

- $v_{MOT} = \frac{score_{MOTpost} - score_{MOTpre}}{|score_{MOTmin} - score_{MOTpre}|}$, if $score_{MOTpost} - score_{MOTpre} < 0$ (3)

Where $score_{MOTpost}$ and $score_{MOTpre}$ represent post-test and pretest measures of motivation, respectively; $score_{MOTmax}$ and $score_{MOTmin}$ represent the maximum and minimum measurements that can be obtained (i.e. 5 and 1 respectively). The numerator represents the difference between the post-test and pretest measures of motivation and therefore it is positive if the student has experienced a gain in motivation and it is negative if the student has experienced a loss of motivation. The denominator, on the other hand, represents the greatest gain (or the absolute value of the greatest loss) of motivation that the person can obtained based on his or her initial score. Similarly, four normalized scores were calculated for each of the four motivational measured variables, v_{INT}, v_{UTIL}, $v_{CONTROL}$, v_{COMP}, referring respectively to the variation in interest, in perception of usefulness value, in perception of controllability and in perceived sense of competence.

The qualitative content on students' appreciation of the pedagogical strategies to which they were exposed during the semester, obtained by questionnaire, and on the pedagogical experience of teachers, obtained by interviews, was collected at the end of the semester. Two types of performance data were also collected: the final grade for the course, as a measure of overall performance, and the score on a final exam problem, which incorporated several notions covered throughout the course, as a measure of performance in problem solving.

2.3 Participants

QRG data and pretest FCI and motivation scores were used to create a portrait of participants at baseline and to compare them according to their treatment conditions groups, thus reducing the risk of sample bias. To make these comparisons, *t*-tests were performed on the continuous data and Chi-squares were conducted on the categorical data. Descriptive data for each group and the test results are presented in Appendix A. Overall, the four subgroups are similar at baseline, except for general interest in studying. Indeed, the participants of EG-B seem to be less interested in studying at the beginning of the semester.

2.4 Analysis

A quantitative data analysis was performed using JASP for Ubuntu (JASP Team, 2023). When parametric tests were used to compare the groups, the prescribed assumptions were verified beforehand. When the equality of variance condition was not met, the Welch correction was applied. As for the analysis of qualitative data from questionnaires and interviews, it was carried out by coding the contents by fragmentation of units of meaning and categorizing them manually, following part of the procedure proposed by Paillé and Muchielli (2021). According to Viau (2009), the student's appreciation of the teacher is one of the four factors that influence motivational dynamics. This factor could thus be a confounding variable in the study proposed here. To circumvent this potential bias, the experimental group was always compared to the control group of the same teacher.

3. Results

3.1 Treatment Effects on Learning

First, a MANOVA was performed to compare the groups with respect to overall learning (combined effect of the three continuous numerical variables). The MANOVA result for Teacher A's groups (F = 3.58 (1, 56), p = .020) indicates a significant difference between the groups, as does the MANOVA result for Teacher B's groups

(F = 4.05 (1, 33), p = .015).

To establish which variable contributes the most to the synergistic effect observed for the three learning variables, ANOVAs were run on each of them. The results, showing the comparison between the two groups for each teacher, are presented in Table 2.

Table 2. Averages (*standard deviations*), and results to comparative tests for learning variables after the pedagogical interventions

Posttest variables	CG-A (n = 32)	EG-A (n = 26)	F χ^2	CG-B (n = 14)	EG-B (n = 21)	F χ^2
g_{FCI} (Out of 1)	0.20 (*0.25*)	0.41 (*0.25*)	9.688**	0.15 (*0.14*)	0.40 (*0.23*)	12.876**
Problem score (Out of 18)	12.0 (*6.2*)	14.4 (*3.8*)	2.954	10.0 (*5.9*)	12.1 (*5.8*)	1.067
Final grade (%)	77 (*17*)	82 (*13*)	1.451	65 (*16*)	74 (*15*)	2.923

Note. **p < .01.

The learning-related results indicate that the conceptual learning gain exhibits a statistically significant difference between the two groups (experimental vs. control) for both teachers. Although the p-value is under 0.01 for both teachers, statistical significance appears to be slightly better for Teacher B, when the theme's choice was applied in the EG (p = 0.003 for Teacher A vs. p = 0.001 for Teacher B). The difference in the conceptual learning gain between the experimental and the control group also appears to be slightly higher for Teacher B. Concerning the two other performance variables, namely the score to the final integrative problem and the final grade, although the differences favor the GEs, these are not sufficient to be statistically significant.

3.2 Treatment Effects on Motivation

For motivational variables, gains and losses in motivation were calculated as explained in the previous section and t-tests were performed on these data. In addition, the number of gains and losses of motivation per group was counted. Chi-square tests were performed on these data. The results are presented in Table 3.

Table 3. Average changes in motivation (*standard deviations*), number of gains and losses of motivation, and test scores

	CG-A (n = 32)	EG-A (n = 26)	t χ^2	CG-B (n = 14)	EG-B (n = 21)	t χ^2
v_{INT}	-0.09 (*0.50*)	+0.23 (*0.45*)	2.60*	-0.23 (*0.31*)	+0.20 (*0.36*)	3.64***
N gains	15	21	7.00**	5	15	4.38*
N losses	17	5		9	6	
v_{UTIL}	-0.16 (0.52)	+0.17 (0.43)	2.58*	-0.24 (0.25)	+0.12 (0.32)	3.60**
N gains	11	18	6.97**	4	15	6.22*
N losses	21	8		10	6	
$v_{CONTROL}$	-0.11 (0.45)	+0.07 (0.24)	1.92^{tw}	-0.02 (0.38)	+0.06 (0.28)	.74
N gains	20	17	.05	7	16	2.56
N losses	12	9		7	5	
v_{COMP}	-0.17 (0.50)	+0.11 (0.37)	2.39*	-0.14 (0.37)	+0.18 (0.39)	2.39*
N gains	14	19	5.03*	9	15	.20
N losses	18	7		5	6	
v_{MOT}	-0.15 (0.39)	+0.12 (0.28)	2.96**	-0.16 (0.25)	+0.13 (0.19)	3.82***
N gains	12	17	4.46*	5	17	7.36**
N losses	20	9		9	4	

Note. *p < .05; **p < .01; ***p < .001. t: .05 < p < .07. w: Welch correction applied.

These results show that the use of contextualized problems instead of traditional problems positively influences motivational dynamics. Indeed, the experimental groups showed a gain in motivation, (the sign of the mean of the changes is positive) while the control groups showed a loss of motivation (the sign of the mean of the changes is negative). In addition, the number of people who experienced increased motivation in the experimental groups was higher than in the control groups. The motivational variables associated with the task value (interest and utility) appear to have undergone the most notable statistically significant change. The gain of perceived sense of competence is also statistically significant. The treatment appears to have had very different effects from one individual to another on the controllability variable in the CG-A vs. EG-A comparison, as both groups, initially homoscedastic with respect to this variable, became non-homoscedastic after treatment.

3.3 Correlation Between Motivation and Learning

We then assessed the correlation between motivation and learning in the overall sample using Pearson correlations, summarized below.

Table 4. Correlation matrix between motivational and learning variables

	1	2	3	4	5	6	7	8
1. g_{FCI}	-							
2. Final grade	.43***	-						
3. Problem score	.36***	.81***	-					
4. v_{INT}	.44***	.20	.21*	-				
5. nv_{UTIL}	.31**	.17	.16	.74***	-			
6. $n_{CONTROL}$	.19	.14	.08	.35***	.38***	-		
7. n_{COMP}	.51***	.42***	.32**	.50***	.56***	.23*	-	
8. n_{MOT}	.47***	.29**	.25*	.84***	.87***	.60***	.74***	-

Note. *$p < .05$; **$p < .01$; ***$p < .001$.

The learning variable most correlated with overall variation in motivation is conceptual learning gain, which is the variable on which treatment had statistically significant positive effects. The level of correlation is particularly strong. The variation in motivation is also positively correlated with the other two learning variables, although the level of correlation is lower. On the entire sample, the variations in the perceived sense of competence and in interest appear to be the motivational variables most correlated with learning, followed by the variation in the perception of the usefulness of the activities. It is worthwhile to note that the hierarchical order of the three affected motivational variables when considering solely the treatment effect is somehow different from the ones in the correlation analysis: treatment effects on motivation appears to be more significant for the variables associated with task value, whereas the correlation to learning gain is stronger for the variation in the perceived sense of competence and in interest. Since this study is also focused on examining whether the independent theme variable modifies the effects of treatment, it thus becomes intriguing to move from an overall correlation insight to a predictive analysis for Teacher A (imposed themes) and Teacher B (choice of themes applied during the individual learning situations of the EG).

3.4 Prediction of Learning Gain Through Motivational Variables

A look at distinctive correlations for Teacher A and Teacher B revealed that the hierarchical order for the affected motivational variables, regarding their correlation to conceptual learning gain, is different in the two situations. For Teacher A, the motivational variable that correlated more with conceptual learning gain is the variation in perceived sense of competence ($r = 0.56$, $p < 0.001$), followed by the variation in interest ($r = 0.42$, $p = 0.001$) and in perceived utility of the activity ($r = 0.30$, $p = 0.023$). For Teacher B, the motivational variable that correlated more with conceptual learning gain is the variation in interest ($r = 0.50$, $p = 0.002$), followed by variation in perceived sense of competence ($r = 0.39$, $p = 0.020$) and utility ($r = 0.36$, $p = 0.034$). For these reasons, the most correlated motivational variables (v_{COMP} for Teacher A and v_{INT} for Teacher B) were used for the first step of a hierarchical multiple regression analysis. For the second step, v_{INT} was added for Teacher A, and v_{COMP} was added for Teacher B. The results of these two steps are shown in Table 6.

Table 5. Linear models of predictors of learning gain, with 95% bias corrected and confidence intervals in parentheses

	Teacher A (no choice)				Teacher B (choice)			
	B	***SE B***	***β***	***p***	***B***	***SE B***	***β***	***P***
Step 1								
Constant	.29 (.22, .36)	.04		< .001	.30 (.22, .38)	.04	.50	.002
v_{COMP}	.33 (.20, .46)	.06	.56	< .001	-	-	-	-
v_{INT}	-	-	-	-	.29 (.12, .47)	.09	.50	.002
Step 2								
Constant	.29 (.22, .36)	.04		< .001	.30 (.22, .37)	.04		< .001
v_{COMP}	.29 (.12, .45)	.08	.49	< .001	.16 (-.01, .34)	.08	.16	.061
v_{INT}	.06 (-.09, .21)	.08	.11	.44	.25 (.08, .43)	.09	.44	.006

Note. Teacher A: R^2 = .315 for Step 1 ($p < .001$); ΔR^2 = .007 for step 2 ($p < .001$); Teacher B: R^2 = .254 for Step 1 ($p < .01$); ΔR^2 = .079 for step 2 ($p < .01$).

For Teacher A (imposed themes), v_{COMP} explains 33% of the variance in learning gain and its contribution is statistically significant ($p < 0.05$). When v_{INT} is added to the model in step 2, v_{COMP} explains 29 % and v_{INT} explains 6 % of the variance in learning gain. However, the contribution of the latter does not appear to be statistically significant ($p > 0.05$). Moreover, no improvement is obtained in the significance of the ANOVA model at this step ($p < 0.001$ in both cases). On the other side, when students can choose the theme (teacher B condition), v_{INT} explain 29 % of the variance in learning gain. When v_{COMP} is added to the model in step 2, v_{INT} explains 25 % of the variance in learning gain and v_{COMP} explains 16 % of the variance in learning gain. The p-value is significant for v_{INT} only, but it appears to be quite close to the significant threshold even for v_{COMP} ($p = 0.061$). No improvement is obtained in the significance of the ANOVA model at this step ($p = 0.002$ in both cases).

When the variation in perceived utility of the activity, v_{UTIL}, is added, its contribution is not statistically significant for both teachers (the p-value is significantly higher than the threshold value) and the significance of the ANOVA does not improve. Moreover, the utility's contribution turns out to be negative for both teachers, whereas, when used alone as a predictor of conceptual learning gain, it is positive, and it explains 16% of the variance in learning gain for Teacher A and 24% of the variance in learning gain for Teacher B. Its contribution is significant in both cases ($p = 0.023$ for Teacher A and $p = 0.034$ for Teacher B). This apparent inconsistency is most likely due to the strong correlation between interest and utility, which makes the latter redundant when the former is already present.

3.5 Qualitative Results

In all four groups, students claim, almost unanimously, that the problem-solving activities were useful. However, when considering the arguments provided to support such usefulness, there are clear differences between the control groups and the experimental groups: whereas in both cases, and in all four groups, students mentioned that these activities allowed them to test their comprehension and sharpen their sense of understanding, when students had solved context rich problems, they frequently mentioned that they could apply the course notions in practical situations and make connections with reality. In addition, the contextual problems allowed them to better perceive the utility of the course contents and to understand certain concepts more in depth. In the case of students who solved traditional problems on the other hand, these problems were used mainly as models for the exams. Most students liked the themes because they were realistic, interesting, varied, concrete, easy to visualize, thus permitting a better understanding of the problem as well as the usefulness of physics. The teachers' responses to the interviews are consistent with these findings.

4. Discussion

4.1 Main Findings

The results suggest that the contextualization of problems affects conceptual learning gain in an appreciable way. The statistical significance is high for both experimental groups but appears to be slightly better for the experimental group with the choice of themes. The use of contextualized problems instead of traditional problems positively influences motivational dynamics by acting on the two variables associated with the task value and on the perceived sense of competence. All learning variables are positively correlated with motivational variation, which is consistent with the literature on academic motivation. The correlation between motivation variation and conceptual learning gain over the entire sample is strong, indicating that motivational variables can indeed be good predictors of conceptual learning gain. An examination of each motivational component indicates that the link between motivation and learning is mediated mainly by the perceived sense of competence and interest. When focusing solely on the two components of the task value according to Viau, it emerges that the contextualization of problems, independently from the choice of theme, increases the students' perception of activity utility nearly as strongly as interest, although interest appears to be a better learning predictor than utility. These findings suggest that contextualization acts on the overall task value, because of the strong link between interest and utility, but when it affects the emotional variable, induced motivational gain is the most likely to influence learning gain. This indicates that it is wise to treat interest and utility separately in the motivational dynamics of the individual. Each of these two components of task value seems to require and react to different pedagogical interventions (Cabot, 2017; Hulleman et al., 2017). When considering the process leading to learning gain even in more details (Table 6), as mentioned in the introduction, we observe that, when the theme of the problems is imposed (teacher A), a learning gain seems to occur mainly caused by experiencing an accrued sense of competence. In contrast, when students are allowed to choose the theme of context-rich problems according to their personal interests (teacher B), the interest gain generated by this situation becomes the main lever by which the learning gain is achieved. As the effect on learning seems to be greater under teacher B's teaching conditions, we could deduce that this represents the optimal solution.

4.2 Limits

The main limitation of this study is the size of the sample. Only two teachers agreed to change their teaching practices to participate in the study, without being able to anticipate the benefits that students could derive from it. This makes the results more difficult to generalize. It should be noted, however, that descriptive statistics consistently show better results for the experimental groups, and it is not excluded that by replicating the experiment with a larger number of participants, a statistically significant effect could appear. Moreover, after having experienced the training (the training that the teachers underwent to be able to teach in the appropriate way for the GEs), and the experimentation, the two teachers expressed the intention of continuing to teach with interesting, from the student's point of view, and context rich problems. They also express the wish to initiate colleagues who want to follow this path. All in all, the sample is appropriate for the exploratory context of the study.

Another limitation is the modest variety of CRP theme choices aimed at meeting students' interests, as well as the fact that the choice of a theme does not apply to cooperative group sessions. Students' personal interests could be collected using a short questionnaire that would inspire physics teachers to develop CRPs on a wider variety of themes that affect a larger range of young adult interests. In addition, a pedagogical strategy that allowed students to choose the themes of the problems could be set up, including during cooperative learning. For example, groups could be formed according to students' vocational choices or broad categories of interests to facilitate the homogeneity of intra-group interests, thus simplifying the attribution of an interest soliciting theme for each of the cooperative groups. This strategy could be tested at a future opportunity to evaluate the effectiveness of the pedagogical use of CRP with a choice of themes in post-secondary physics.

4.3 Conclusion

Physics courses in general pre-university programs are known to be the least appreciated and the least successful by students. The results of the present study indicate that the contextualization of problems produces a learning gain, which is mediated to a good extent by a motivational stimulation, mainly through a perceived sense of competence and interest. The activation of the affective domain becomes prevalent when students are allowed to choose the problem's theme, a situation wherein learning gain seems to be favored. This finding suggests that the use of context rich problems with choice of theme is a promising pedagogical device, the use of which could be extended to other scientific and non-scientific disciplines.

Acknowledgments

We greatly appreciate the valuable contributions of the Cégep Édouard-Montpetit research service team and Ethics Committee. We would also like to thank the teachers and the students who took the time to participate in this study and Guy-Olivier Pellettier for the proofreading service.

Authors' contributions

Dr. Lisa Giachini was responsible for study design and Dr Isabelle Cabot revised it. Dr Lisa Giachini was responsible for data collection. Lisa Giachini was responsible for data analysis and Dr. Isabelle Cabot provided guidance. Dr. Lisa Giachini drafted the manuscript and Dr. Isabelle Cabot revised it. All authors read and approved the final manuscript.

Funding

The authors disclosed receipt of the following financial supports for the research, authorship, and/or publication of this article: This research has been funded by the Ministère de l'Enseignement supérieur under the Program d'Aide à la Recherche sur l'Enseignement et l'Apprentissage (PAREA) [project number 12122]. The preparation of this article has benefited from a financial contribution from the Ministère de l'Emnseignement supérieur under the Program d'Aide à la Diffusion des Résultats de Recherche (PADRRC) [project number 13168].

Competing interests

Sample: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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Appendix A. Portrait of participants at baseline

Table 6. Frequencies[1] and averages (*standard deviations*), and results to pretest comparative examinations

Pretest variables	CG-A (*n* = 32)	EG-A (*n* = 26)	CG-B (*n* = 14)	EG-B (*n* = 21)	F/χ^2
Age	17.66 (*0.70*)	17.50 (*0.91*)	17.71 (*0.99*)	17.38 (*0.67*)	0.72
Gender	M = 15	M = 14	M = 9	M = 7	5.12
	F = 16	F = 10	F = 5	F = 13	
High school GPA	84.81 (*6.29*)	85.46 (*6.78*)	83.50 (*5.86*)	84.19 (*5.86*)	0.35
Mother's schooling	Pri. = 1	Pri. = 0	Pri. = 0	Pri. = 0	7.18
	Sec. = 3	Sec. = 1	Sec. = 0	Sec. = 2	
	College = 4	College = 6	College = 3	College = 2	
	Uni. = 23	Uni. = 18	Uni. = 11	Uni. = 17	
	Other = 1	Other = 1	Other = 0	Other = 0	
Father schooling	Prim. = 1	Prim. = 0	Prim. = 0	Prim. = 0	9.88
	Sec. = 3	Sec. = 2	Sec. = 1	Sec. = 2	
	College = 3	College = 8	College = 1	College = 3	
	Uni. = 23	Uni. = 14	Uni. = 11	Uni. = 16	
	Other = 1	Other = 2	Other = 1	Other = 0	
Targeted diploma	Uni.Certif. = 0	Uni.Certif. = 1	Uni.Certif. = 0	Uni.Certif. = 1	20.14
	B. = 1	B. = 5	B. = 5	B. = 4	
	M. = 7	M. = 5	M. = 2	M. = 4	
	PhD. = 15	PhD. = 4	PhD. = 4	PhD. = 8	
	Other = 0	Other = 2	Other = 0	Other = 0	
	Undecided = 9	Undecided = 9	Undecided = 3	Undecided = 4	
Vocational choice	Ing = 3	Ing = 1	Ing = 3	Ing = 2	16.98
	HealthSc = 14	HealthSc = 8	HealthSc = 2	HealthSc = 13	
	PureSc = 5	PureSc = 3	PureSc = 2	PureSc = 3	
	Undecided = 4	Undecided = 6	Undecided = 4	Undecided = 1	
	Other = 2	Other = 3	Other = 1	Other = 2	
Time reserved for out-of-class study. (number of hrs/week)	15.98 (*8.42*)	17.82 (*8.10*)	14.57 (*11.22*)	18.36 (*8.85*)	0.71
General interest in studies	A lot = 6	A lot = 5	A lot = 2	A lot = 1	13.60*
	Enough = 23	Enough = 21	Enough = 7	Enough = 15	
	Little = 3	Little = 0	Little = 5	Little = 5	
First time in this course?	Y = 27	Y = 25	Y = 11	Y = 19	3.38
	N = 5	N = 1	N = 3	N = 2	
Semester	1st = 1	1st = 1	1st = 0	1st = 0	3.17
	2nd = 24	2nd = 19	2nd = 11	2nd = 18	
	3rd/4th = 6	3rd/4th = 5	3rd/4th 2	3rd/4th = 3	
	Other = 1	Other = 1	Other = 1	Other = 0	
FCI pretest	12.19 (*4.86*)	9.73 (*5.47*)	11.00 (*4.13*)	9.33 (*3.83*)	2.02
Motivational expectations:	3.26 (*0.59*)	3.47 (*0.73*)	3.23 (*0.86*)	3.20 (*0.70*)	0.74
(From top to bottom: interest,	3.94 (*0.47*)	4.04 (*0.49*)	4.05 (*0.57*)	3.79 (*0.60*)	1.04
utility, controllability, and	2.77 (*0.66*)	2.96 (*0.47*)	3.00 (*0.65*)	3.10 (*0.58*)	1.40
sense of competence)	3.15 (*0.88*)	3.30 (*0.65*)	2.93 (*0.87*)	3.13 (*0.57*)	0.73

Note. [1] When the sum of the frequencies does not equal the sample's *n*, some students did not answer that *$p < .05$