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# Enhanced student perceptions of learning and performance using concept-point-recovery teaching sessions: a mixed-method approach

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## Abstract

**Background:** Active learning pedagogy has recently received a great deal of attention, and many universities have attempted to create student-centered learning environments to improve students' academic success. The purpose of this study is to explore the impact of concept-point-recovery (CPR) teaching sessions as an active learning strategy on students' perceptions of the learning environment, motivation, and academic learning outcomes in an electrical engineering course. To investigate the effectiveness of CPR sessions, students' perceptions of learning and their performance were compared to those of students in a control classroom. Finally, students' written comments on the course and instructor were explored in further analysis.

**Results:** The quantitative findings revealed that there was a significant change in students' perceptions of learning after the CPR teaching sessions, and there was an increase in students' perceptions and learning outcomes compared with those of the control group. In addition, the qualitative findings from students' written feedback demonstrated that students felt that the instructor cared about students' learning and success and that they had a positive learning environment.

**Conclusions:** CPR teaching sessions can be an alternative model for instructors to connect with students and create supportive environments to help students achieve academic success, which in turn promotes the satisfaction of students' basic psychological needs and self-determined motivation. Therefore, increasing students' engagement in their learning processes and making connections with students through CPR teaching sessions can facilitate improvements in students' motivation and academic success. How this new active learning technique can be applied to higher education is discussed.

**Keywords:** Active learning, Perceptions of learning, Motivation, Higher education

## Introduction

As active learning pedagogy has recently received a great deal of attention, many universities have attempted to create student-centered learning environments to foster higher-level thinking skills (Prince, 2004; Ritchhart et al., 2011). Along with these efforts, there has been an

increasing interest in course transformation to incorporate active teaching strategies with a traditional lecture format (Hudson et al., 2015). The current study introduces an effective active learning pedagogical teaching strategy, called concept-point-recovery (CPR), which was implemented in an electrical engineering course. The purpose of the study is to explore the impact of CPR teaching sessions in an electrical engineering undergraduate course from a self-determination theory perspective. This study examined students' perceptions of

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the learning climate, motivation, and their performance from the Fall 2016 to Spring 2018 semesters. To examine the changes in students' perceptions of learning, comparisons were made between the beginning and end of the semester. Moreover, to investigate the effectiveness of the CPR as a course intervention, students' performances and their perceptions of learning were compared with those of students in the control classroom. Finally, students' written feedback on the course and instructor was explored for additional analysis of the course transformation.

### **Active learning in course transformation programs**

Active learning can be defined as a specific instructional method that engages students in meaningful learning activities and emphasizes students' participation in activities and engagement rather than their reception of information from the instructor (Prince, 2004). Course transformation programs encourage faculty to implement active learning methods in traditional lectures. Course redesign, which is defined as the reconstruction of an academic course to enhance student participation and academic achievement (Drab-Hudson et al., 2012), has considerable effects on higher education (Chasteen et al., 2011). Extensive evidence has shown that active learning pedagogy through course transformation has a positive impact on students' learning experiences, engagement, and achievement (Boatman, 2012; Chasteen et al., 2011; Freeman et al., 2007; Hudson et al., 2014; McLaughlin et al., 2014; Russell et al., 2017).

Based on these positive effects of course transformation in higher education, a large research-oriented university recently conducted a campus-wide course redesign project called Success Through Transformative Education and Active Mentoring (STEAM), which was funded by the United States Department of Education. The STEAM project was based on a previous course transformation program, "Instruction Matters: Purdue Academic Course Transformation (IMPACT; Levesque-Bristol et al., 2019)", and used a quasi-experimental approach. The course transformation program was guided by self-determination theory (SDT; Deci & Ryan, 2002; Ryan & Deci, 2017), which suggests that an autonomy-supportive learning environment promotes the fulfillment of students' basic psychological needs and thus fosters their self-determined motivation, which in turn leads to desirable student learning outcomes and performance (Levesque-Bristol et al., 2019). The course redesign was implemented as an intervention, and the program used a quasi-experimental design to empirically investigate whether an autonomy-supportive learning environment would lead to greater learning benefits, increased performance levels, and higher

rates of student retention in the courses. Faculty members who participated in the STEAM project redesigned their courses and created a knowledge exam that was administered as a pretest and a posttest during the semester. The current study was conducted in one of the electrical engineering courses that was part of the STEAM project.

### **Instructional intervention to improve student learning in electromagnetics**

The extant literature has shown other instructors' efforts to improve students' learning in electromagnetics. For instance, Leppävirta et al., (2011) reported that complex problem exercises improved students' procedural knowledge and that students felt that these exercises were useful and relevant to their learning. Iskander (2002) introduced multimedia modules in teaching electromagnetics to enhance students' learning. Mias (2008) found that computer-assisted problem-based learning (PBL) was useful to teach fundamental electromagnetics and to assist students' learning through software development in electromagnetics. Students evaluated that this approach led to enhancement of their knowledge in the course and, thus, students were able to learn transferable skills that they could add to their skill set for their future careers (Mias, 2008). Another approach focusing on hands-on activities indicated that it helped students make the subject material relevant to them by showing the impact of electromagnetics on current technology (Bunting et al., 2006). Faculty found that this approach enriched an environment for experimentation and innovation, while students developed skills that allowed them to become more independent learners (Bunting et al., 2006). Ulaby and Hauck (2000) introduced an integrative approach including many class demonstrations, laboratory exercises, and team projects. They highlighted using undergraduate electromagnetics laboratories as a way to improve students' attitudes toward electromagnetics and in turn, students' enrollment in the follow-up course significantly increased (Ulaby & Hauck, 2000). Additionally, Beker et al., (1998) used design automation tools to assist the presentation of engineering applications and teach fundamental concepts in the course. Students expressed positive responses to this approach because they felt that it increased the degree of relevancy with respect to their assignments.

These various approaches have been used to improve students' perceptions, attitudes, and learning in electromagnetics; however, little is known about how these approaches are related to students' motivational aspects and perceptions of learning environments in electromagnetics. CPR offers a unique approach that shifts students' focus from getting a high grade to actually improving

their understanding of fundamental concepts in electromagnetics by reviewing their mistakes in the exams. Thus, our goal was to examine students' motivational beliefs, basic psychological needs, and perception of their learning environments as well as their learning achievement as they experience CPR over the semester.

## Theoretical framework

### Basic psychological needs and self-determined motivation within SDT

The course redesign program was guided by SDT (Deci & Ryan, 2002; Ryan & Deci, 2017), which proposes that there are three different basic human psychological needs, i.e., autonomy, competence, and relatedness, that must be met for optimal psychological development, growth, and well-being (Ryan & Deci, 2000b). According to SDT (Deci & Ryan, 2002; Ryan & Deci, 2017), autonomy refers to individuals' behavior that is based on a high degree of willingness and choice. Competence needs can be satisfied through individuals' confrontation of optimal challenges and development of their skills. Relatedness refers to individuals' need to feel emotionally connected to and involved in caring relationships. Basic psychological needs theory (BPNT) within SDT suggests that these three needs are likely to be positively associated with one another; further, it posits that satisfying basic psychological needs lays the groundwork for psychological wellness, which is conceptualized as full functioning, while failing to satisfy these needs is related to diminished psychological and behavioral outcomes (Ryan & Deci, 2017). Many studies have shown that satisfaction of basic needs leads to positive outcomes such as vitality, intrinsic motivation, subjective well-being, and learning outcomes including higher grades and adaptive attitudes about assessment (e.g., Faye & Sharpe, 2008; Levesque et al., 2004; Ryan & Deci, 2000b).

SDT suggests that an individual's behaviors toward a certain task can be intrinsically motivated, extrinsically motivated, or amotivated (Deci & Ryan, 2002; Ryan & Deci, 2000a, 2017). Motivational regulations can be categorized along a continuum of self-determination depending on the extent to which they are self-determined (Deci & Ryan, 2000, 2002; Ryan & Deci, 2017): from most to least self-determined, we find intrinsic regulation, integration, identification, introjection, external regulation, and amotivation. The most self-determined form of regulation is intrinsic motivation, which results in high-quality learning experiences, in which students perform a task for enjoyment or pleasure; at the opposite end of the continuum is amotivation, which refers to lack of motivation and is the least self-determined form of extrinsic motivation (Deci & Ryan, 2000, 2002; Ryan & Deci, 2000a). Four different types of extrinsic motivation exist between intrinsic motivation and amotivation:

integrated, identified, introjected, and external regulation (Deci & Ryan, 2000; Ryan & Deci, 2000a). Integrated regulation suggests that individuals choose to perform behaviors to harmonize the self (Deci & Ryan, 2002). When an individual assimilates the values and needs with the self, integration occurs (Deci & Ryan, 2002; Ryan & Deci, 2000a). Identified regulation indicates the extent to which individuals value the personal importance of behaviors and do not feel external pressure to engage in the tasks (Deci & Ryan, 2000, 2002). When they accept the regulation of a behavior as their own, identification occurs. Introjected regulation suggests that individuals perform a task to achieve social approval or to avoid negative feelings or internal pressure, such as feelings of guilt (Deci & Ryan, 2002; Ryan & Deci, 2017). This form of regulation tends to be experienced as controlling because individuals perform due to pressures even though the pressures are internal (Ryan & Deci, 2000a). Finally, when external regulation controls behaviors, individuals are regulated through external sources such as rewards or fear of punishment (Deci & Ryan, 2000, 2002). SDT proposes that intrinsic regulation, integration, and identification represent self-determined types of motivation, while introjected regulation, external regulation, and amotivation refer to nonself-determined motivation (Deci & Ryan, 2000; Ryan & Deci, 2017).

### Autonomy-supportive environment

A certain learning environment can promote the satisfaction of students' basic psychological needs and, in turn, enhance self-determined motivation and classroom engagement-related behaviors (Reeve, 2006; Ryan & Deci, 2000). An autonomy-supportive learning environment is a specific learning condition that satisfies students' basic psychological needs and supports self-determined motivation so that they feel more empowered in the learning environment (Jang et al., 2009; Reeve, 2006, 2009; Reeve & Jang, 2006). Autonomy supportive instructors tend to foster students' inner motivational resources such as their interest and basic psychological needs; use informational language; provide rationales for classroom tasks; and take students' perspectives and feelings into consideration (Reeve, 2009; Reeve & Jang, 2006; Reeve et al., 2004). These instructors strive to identify students' inner motivational resources and create learning environments that align these inner motivations with classroom tasks (Reeve & Jang, 2006). Autonomy-supportive environments have been investigated in diverse contexts and have been shown to be significantly associated with desirable learning experiences such as perceived autonomy, greater involvement, engagement, more persistence, and better self-regulation and learning outcomes (e.g.,

Cheon et al., 2012; Jang et al., 2009; Leroy et al., 2007; Reeve, 2006).

In this study, we assumed that the implementation of CPR as an active learning strategy in an electrical engineering course would create a learning environment that supports students' basic psychological needs and thereby improving self-determined motivation, which can lead to better academic performance.

### Self-regulated learning

Self-regulated learning, that is mainly defined as a proactive learning process (Pintrich, 2000; Wolters et al., 2005; Zimmerman, 2002), provides an important theoretical perspective on CPR. It involves a broad scope that encompasses cognitive, metacognitive, motivational, behavioral and emotional aspects of learning (Panadero, 2017). Students with self-regulated learning tend to be independent in their own learning and to control their motivation, learning behaviors, and emotions to achieve their learning goals in a learning situation (Boekaerts & Cascallar, 2006; Magno, 2009; Pintrich, 2000; Wolters & Pintrich, 1998; Zimmerman, 2002). They are more likely to monitor and regulate their own cognition and learning behaviors even though there are individual constraints in self-regulated learning (Pintrich, 2004). More importantly, self-regulated students evaluate the learning process after applying learning strategies and are actively engaged in reflecting on the skills and strategies needed to achieve their learning goals (Butler & Winne, 1995; Pintrich, 2004; Zimmerman, 2002). These students try to regulate their effort in tasks (Winne, 2011). Furthermore, they recognize how to approach a learning task and self-monitor their improvement during the course (Butler & Winne, 1995).

CPR teaching sessions provide an opportunity to develop learning strategies based on self-regulated learning. It requires students' willingness to monitor their learning process, review their misunderstandings and misconceptions, and even revise their learning approach to assessment to achieve learning objectives. By reviewing their understanding and learning approach through CPR, students are able to reflect on their perception and learning process and in turn self-monitor their improvement in learning outcome.

### Concept-point-recovery teaching session (CPR)

Teachers and students view exams as assessment exercises. Although the main purpose of exams is assessment, they are also learning activities. Taking an exam is a retrieval exercise that enhances memory and interrupts forgetting. Working a problem on an exam can be an elaboration exercise if the problem is structured such that the students need to connect a course concept with something they already know. When exams are returned

to students, most students spend minimal time examining the solutions and their responses, thereby missing a learning opportunity. The active learning strategy described in this paper results in additional student learning from an exam they have already taken. Through the activity, students learn a concept that they did not previously learn for the exam. The incentive for the students is the possibility of recovering points lost on the exam. Hence, this activity was referred to as "concept-point-recovery" (CPR).

After each exam, if the students attended at least 80% of the lectures, they had an opportunity to recover points on one problem. Each student has 15 min to explain, as if they were teaching a classmate, the concept behind the problem for which they are trying to improve their score. If an exam consists of 10 problems, the possible point recovery is small enough to not influence the amount of effort students dedicate to preparing for the exam. However, an opportunity to recover up to 10% of the exam points can have many positive impacts.

### Active learning by teaching

As many studies have shown, the best way to understand a concept is to determine how to explain it (Cohen et al., 1982). As part of the CPR teaching strategy, the student receives no points for only reworking the problem. The student must be able to explain the concept behind the problem of recovering lost points. This concept, which was previously a weakness for the student, now becomes a strength. In addition to students improving their learning when they try to teach it, there is a psychological drive to learn the material to regain lost points because humans exhibit greater sensitivity to losses than to equivalent gains (Kahneman & Tversky, 1979). Therefore, most students put in considerably more effort to learn material to recover lost points on an exam than they did to learn the material for the original exam. It has been observed that some students who previously had no idea how to work a problem on an exam become experts on the topic when they complete their CPR teaching session.

### Improved learning experience from exams

Accuracy-based assessment and grade curving to cause competition among students may discourage students' learning (Schinske & Tanner, 2014). However, a learning-centered teaching approach promotes student learning by increasing students' responsibility for engagement with materials, and thus, grade improvement from learning-centered teaching is a different concept from grade inflation (Mostrom & Blumberg, 2012). CPR leads to grade improvement from learning-centered teaching that may imply students' improved learning.

Most students do not spend much time reviewing a past exam, but to recover their lost points, such review is required. If students had difficulty on several problems on their exam, they likely would spend time reviewing the concepts behind all of the problems to determine which problem they should choose for their CPR teaching session. This approach provides an opportunity to learn by reviewing their misconceptions and taking responsibility for their conceptual understanding, which leads to meaningful increases in grade, not pointless grade inflation, that may not actually reflect changes in students' understanding. CPR allows students to do additional work to review their misconceptions and redeem poor grades so that they may compensate for a "bad day effect" during exams (Gordon & Fay, 2010). Implementing different grading approaches, such as CPR, may be an alternative for instructors to focus on more student-centered learning (Schinske & Tanner, 2014).

#### **Reduced exam anxiety**

Many students experience anxiety taking an exam, which affects their performance and thereby reinforcing their anxiety. During an exam, students' awareness that they will have the opportunity to recover all lost points from one problem should alleviate some of their anxiety. If students have difficulty with a problem, they can move on to finish the other problems without becoming anxious because they know they can recover the lost points later.

#### **Learning of concepts rather than just the steps to arrive at a solution**

The CPR teaching sessions in this study were incorporated into a junior-level course on electric and magnetic fields, which is a mathematically intensive course using vector calculus. All the equations can become mathematical abstractions for students who have no understanding of the concepts. It takes considerable effort on the part of students to develop mental models of what these equations actually represent, which is essential to do well in the course. For students to be able to teach the concept behind a problem, they must develop such mental models. To teach the material, the students cannot simply memorize a procedure or solution to a particular problem; rather, they must understand the concepts behind the equations.

#### **Increased class attendance**

The opportunity to recover lost points is a positive way to greatly improve class attendance. Unless a student has attended at least 80% of the lectures, they will not be eligible to recover lost points on an exam. Therefore, instead of punishing students for not attending class, the opportunity to recover lost points provides an incentive

for class attendance. This attendance policy resulted in greater than 95% attendance for all lectures.

#### **Increased utilization of office hours**

Another benefit of the CPR teaching sessions is that students who did not come to office hours before the first exam might start coming to office hours after their CPR teaching sessions. The opportunity to recover lost points is a sufficient incentive to schedule their 15-min sessions in the professor's office, after which they might feel comfortable dropping in during office hours.

#### **Early opportunity to counsel students having difficulties**

Occasionally, students might come to their teaching sessions with little understanding of the course material. This situation affords an opportunity early in the semester to counsel such students, who might otherwise never come to see the professor, begin to have poor performance, and ultimately fail the course, which is a common occurrence in large classes at large public universities.

#### **Students become comfortable presenting a technical topic one-on-one**

Some students may be clearly nervous when they come in for their first CPR teaching sessions. However, they can become much more comfortable as they gain experience from their one-on-one CPR teaching sessions. These sessions provide students with good preparation for when they are asked to explain a technical concept during a job interview.

#### **Current study**

The purpose of the present study is to examine the impact of the CPR teaching sessions on students' perceptions of learning and performance in a redesigned course. This study used a quasi-experimental design to examine the differences between a traditional course and a redesigned course. Final grades and knowledge exam scores were used as learning outcomes. Given the previous findings that course transformations seem to bolster students' learning experiences, the following research questions were investigated:

1. Is the CPR teaching session effective in improving students' perceptions of learning and performance in an electrical engineering course?
2. Compared to students in the traditional lecture class, do students in the intervention group exhibit more positive perceptions of learning and improve their performance through the CPR teaching session?
3. How do students perceive the learning environment embedded with CPR teaching sessions?

## Method

### Study context

The course in which the CPR strategy was implemented was a junior-level course entitled Electric and Magnetic Fields I. The course begins with a review of vectors and coordinate systems and then progresses from a discussion of Coulomb's law to Maxwell's equations. Vector calculus concepts, including gradient, divergence, and curl, are a significant part of the course. The course concludes with a discussion of how Maxwell's equations lead to electromagnetic waves and a study of electromagnetic waves.

As the concepts in this course build on themselves, the students are deemed unprepared to learn the material for the next exam until they have sufficiently learned the material covered on the previous exam. There are three 1-h-long exams throughout the semester that are worth 100 points each and one 2-h final exam that is worth 150 points. As the course progresses, the material in the course becomes conceptually more difficult and requires comprehensive knowledge of all previous material. Prior to the implementation of the CPR sessions in the course, the average student score on each exam was lower than that of the previous exam, typically by 3 to 5% points. Across the three exams and the final exam, significant decreases were observed in students' understandings of the material as the semester progressed. With the implementation of the CPR sessions, students had to prepare by returning to the material that they previously had not learned or had difficulty with.

### Participants

Participants were recruited from junior-level courses on electric and magnetic fields at a large midwestern university. A survey was administered as part of the STEAM project, and a subset of the course data was used for research purposes.

For the intervention group in which the CPR teaching sessions were incorporated, 73 students completed the online perception survey (Fall 2016,  $N = 18$ ; Spring 2017,  $N = 6$ ; Fall 2017,  $N = 33$ ; Spring 2018,  $N = 16$ ). The majority of the students were male (71.2%), while 28.8% were female. The majority of the students were international students (43.8%), followed by white (31.5%), Asian (12.3%), unknown ethnicity (5.5%), Hispanic/Latino (4.1%), mixed race (1.4%), and Black or African American (1.4%). For the learning outcome analysis in the intervention group, 81 students' pre- and post-knowledge exam data were used (Fall 2017,  $N = 38$  & Spring 2018,  $N = 43$ ). In addition, 126 students in the intervention group completed the course evaluation (Fall 2016,  $N = 38$ ; Spring 2017,  $N = 24$ ; Fall 2017,  $N = 36$ ; Spring 2018,

$N = 28$ ). Their written comments were used for the qualitative analysis.

Meanwhile, the control group sample consisted of 27 students who were in the same course but taught by another instructor (Fall 2017). The majority of the students were male (85.2%), and 14.8% were female. The majority of the students were international (40.7%), followed by white (37%), Asian (14.8%), unknown ethnicity (3.7%), and mixed race (3.7%).

The junior-level course in which the CPR teaching sessions were implemented was a mathematically intensive course using vector calculus. No significant difference in students' previous math achievement (e.g., Scholastic Aptitude Test) was found between the two groups.

### Measures

#### *Learning Climate Questionnaire (LCQ; Williams & Deci, 1996)*

To assess students' perceptions of an autonomy-supportive learning environment, the Learning Climate Questionnaire (LCQ; Williams & Deci, 1996) was used in this study (e.g., *My instructor conveyed confidence in my ability to do well in the course*). The scale uses a 7-point scale (1 = *strongly disagree*; 7 = *strongly agree*). The internal consistency for the current study was high (Cronbach's  $\alpha = .92$ ).

#### *Situational Motivation Scale (SIMS; Guay et al., 2000)*

A total of 18 items were adapted from the Situational Motivation Scale (SIMS; Guay et al., 2000) to measure students' self-determined motivation for this course. The scale assesses six different forms of motivation and self-regulated behaviors. All measures use a 7-point, Likert-type scale ranging from *strongly disagree* (1) to *strongly agree* (7). Sample items are "*Because I really enjoy it*" (intrinsic), "*Because acquiring all kinds of knowledge is fundamental for me*" (integration), "*Because it allows me to develop skills that are important to me*" (identification), "*Because I would feel bad if I didn't*" (introjection), "*Because I feel I have to*" (external), and "*I don't know. I have the impression I'm wasting my time*" (amotivation). The motivation subscale had strong internal consistency (Cronbach's  $\alpha$  ranged from .81 to .93).

#### *Basic Psychological Needs Scale (BPNS; Deci & Ryan, 2000; Gagné, 2003)*

This questionnaire consists of 21 items to assess students' perceptions regarding autonomy (7 items), competence (6 items), and relatedness (8 items). Sample items include "*I feel like I can make a lot of inputs in deciding how my coursework gets done*" (autonomy), "*Most days I feel a sense of accomplishment from this course*" (competence), and "*I really like the*

people in this course" (relatedness). The Cronbach's  $\alpha$  for autonomy, competence, and relatedness in the current study were .60, .78, and .75, respectively.

#### **Perceived Knowledge Transferability (PKT; Levesque-Bristol et al., 2020)**

The eight items on this scale assess students' perceived knowledge transferability. The measure uses a 7-point scale (1 = *strongly disagree*; 7 = *strongly agree*), with higher scores indicating students' greater likelihood of perceiving knowledge transferability. An example item is "I feel as if the material covered in this course is relevant to my future career". The internal consistency was very strong (Cronbach's  $\alpha = .95$ ).

#### **Performance**

To measure students' performance after experiencing the CPR teaching sessions, the students' final grades were used. The grades were determined by three 1-h-long exams throughout the semester that were worth 100 points each, a 2-h final exam that was worth 150 points, and approximately 10 homework assignments throughout the semester that were worth a total of 30 points.

#### **Knowledge exam learning outcomes**

In addition to students' final grades, to assess students' actual learning outcomes, their knowledge exam scores were used in this study. The knowledge exam was created based on the course's learning objectives. The instructor defined three learning outcomes (LOs) as follows: (a) an ability to work with electrostatic fields and to identify electric and potential fields from charge distributions including the presence of dielectric materials (LO1); (b) an ability to work with magnetostatic fields and to identify magnetic fields from current distributions including the presence of magnetic materials (LO2); and (c) an ability to work with time-varying fields, including wave propagation (LO3). The knowledge exam questions corresponded to each of these learning outcomes, so based on the scores of each learning outcome, instructors can recognize to what extent students achieve each important course learning outcome. The exam was created by the course instructor, and the same exam questions were used on the pre and posttests. For the validation of the exam question items, the course transformation project team asked three experts in this field to evaluate the questions. The three experts agreed that the knowledge exam was appropriate for measuring students' knowledge in electric and magnetic fields. Thus, the university project team administered the knowledge exam twice during the semester: at the beginning and at the end.

The knowledge exam comprised 13 multiple-choice questions to ask the fundamental knowledge in this course.

#### **Course evaluation**

In total, 126 of 193 students (65.3%) in the courses in which the CPR teaching sessions were incorporated completed the course evaluations. The data were collected through the CourseEval system by the university. A general question about the course using a 5-point scale (1 = *very poor*; 5 = *excellent*) was included. Students evaluated the course instructor in the following aspects: preparation for the lecture, clarity of the presentation, general instructional technique, availability outside of class, rapport with students, effectiveness in answering questions, and effort put forth in teaching the class. In addition, students responded to two open-ended questions: (a) comments about the course and (b) comments about the instructor.

#### **Procedure**

The current study was approved by the Institutional Review Board, and all the data collection from Fall 2016 to Spring 2018 was conducted under the IRB. Students received an online student perception survey at the beginning and end of the semester, which was administered as part of the STEAM project. Students were also encouraged to complete the course evaluation collected through the CourseEval software system at the end of the semester. Participation was voluntary and confidential.

#### **Data analysis**

To measure students' perceptions of learning before and after experiencing the CPR sessions, a paired sample *t* test was conducted. In addition, to compare the CPR class and the traditional lecture class, an independent samples *t* test was performed on perceptions of the students' learning climate, basic psychological needs, motivation, perceived knowledge transferability, and final grades. Finally, to identify common themes regarding the course redesign, students' written feedback was analyzed using content analysis (Mayring, 2000). This analysis required, first, becoming familiar with the data, then, creating the initial codes (open code), and finally, searching for common themes based on the codes.

## **Results**

#### **Preliminary analysis**

There was a significant and measurable effect on the students' exam performance and final course GPAs because of the additional learning that occurred through the CPR teaching sessions. Tables 1 and 2 show student performance before the implementation

**Table 1** Student performance before the introduction of the CPR teaching sessions

Semester	Number of students	Number of students who failed	GPA
Fall 2002	64	5	2.70
Spring 2007	93	1	2.81
Fall 2008	75	10	2.53
Fall 2009	37	3	2.72
Fall 2010	62	1	2.78

of the CPR teaching policy in fall 2011 and after. The total possible number of points from the four exams and homework was 480. The semester average student total point recovery ranged from 11.9 to 28.8 points, with a fourteen-semester average of 19.7 points. The average GPA increased from 2.71 before to 3.16 after the incorporation of the CPR teaching sessions. This is an indication that students' higher scores were not due to grade inflation, but rather to students' efforts to make up for lost points through learning opportunities.

Table 3 presents the bivariate Pearson correlation based on the post-survey after experiencing the CPR teaching sessions. The results revealed that students' perceptions of the learning environment and satisfaction of their basic needs were positively correlated with intrinsic regulation, identification, and perceived knowledge transferability. Moreover, these constructs were all negatively correlated with amotivation, which refers to a lack of motivation. In other words, when students perceived an autonomy-supportive learning environment and their basic needs were satisfied, the frequency of amotivation as their type of regulation was significantly decreased. More importantly, satisfaction with the three types of basic needs and

intrinsic regulation were all significantly correlated with students' final grades.

**Comparison between the beginning of the semester and the end of the semester**

To measure students' perceptions of learning before and after experiencing the CPR sessions, a paired sample *t* test was conducted. Cohen's *d* was used to determine the effect size when interpreting the effect of the CPR intervention. As a rule of thumb for interpreting the results, it has been suggested that 0.2 is a small effect, 0.5 is a medium effect, and 0.8 is a large effect (Cohen, 1988).

Table 4 demonstrates a summary of the results. For students in the CPR intervention group, there were significant changes over the semester in their perceptions of the learning climate, satisfaction of basic psychological needs, intrinsic motivation, and perceived knowledge transferability. Students' overall learning climate scores were significantly higher at the end of the semester than at the beginning ( $M_{pre} = 5.93$  vs.  $M_{post} = 6.38$ ,  $t(72) = -4.80$ ,  $p < .001$ ,  $d = .56$ ). Moreover, there was a significant increase in the satisfaction of students' basic psychological needs and knowledge transferability (see Fig. 1). Students in the CPR intervention group scored higher at the end of the

**Table 2** Student performance after CPR implementation

Semester	No. of students	No. of students who failed	Total average points recovered	GPA
Fall 2011	59	2	16.1	3.18
Spring 2012	56	0	28.8	3.25
Fall 2012	58	4	22.1	3.02
Spring 2013	62	2	25.8	3.03
Fall 2013	61	0	18.9	3.10
Spring 2014	57	5	15.2	3.00
Fall 2014	45	3	14.5	2.90
Spring 2015	52	1	13.9	3.30
Fall 2015	53	2	18.9	3.29
Spring 2016	57	1	20.1	3.23
Fall 2016	59	4	11.9	3.15
Spring 2017	28	0	24.6	3.28
Fall 2017	53	2	27.3	3.19
Spring 2018	51	0	17.8	3.28



**Table 3** Correlation coefficients among the variables ( $N = 73$ )

	1	2	3	4	5	6	7	8	9	10	11	12
1. Learning climate	1.00											
2. Autonomy	.46**	1.00										
3. Competence	.38**	.60**	1.00									
4. Relatedness	.29*	.37**	.58**	1.00								
5. Intrinsic	.33**	.41**	.55**	.26*	1.00							
6. Integration	.36**	.23	.48**	.43**	.60**	1.00						
7. Identification	.42**	.29*	.52**	.30*	.75**	.81**	1.00					
8. Introjection	-.10	-.34**	-.21	-.20	.16	.25*	.21	1.00				
9. External	.07	-.21	-.03	.14	.02	.13	.06	.54**	1.00			
10. Amotivation	-.36**	-.46**	-.57**	-.34**	-.31**	-.28*	-.32**	.36**	.17	1.00		
11. PKT	.45**	.34**	.53**	.36**	.62**	.54**	.64**	-.01	-.01	-.36**	1.00	
12. Final grade	.10	.28*	.47**	.25*	.25*	.11	.18	-.19	-.06	-.23	.10	1.00
Cronbach's $\alpha$	.92	.60	.78	.75	.93	.86	.85	.92	.81	.83	.95	

\* Significant at the  $\alpha = .05$  level (two-tailed), \*\* Significant at the  $\alpha = .01$  level (two-tailed)

semester than at the beginning on autonomy ( $M_{pre} = 4.55$  vs.  $M_{post} = 4.87$ ,  $t(70) = -4.73$ ,  $p < .001$ ,  $d = .55$ ), competence ( $M_{pre} = 4.69$  vs.  $M_{post} = 4.99$ ,  $t(70) = -3.49$ ,  $p = .001$ ,  $d = .41$ ), and relatedness ( $M_{pre} = 4.50$  vs.  $M_{post} = 4.79$ ,  $t(70) = -3.10$ ,  $p = .003$ ,  $d = .38$ ). Students' perceived knowledge transferability also significantly increased at the end of the semester ( $M_{pre} = 5.25$  vs.  $M_{post} = 5.65$ ,  $t(69) = -3.07$ ,  $p = .003$ ,  $d = .36$ ). Moreover, they reported increased intrinsic motivation at the end of the semester ( $M_{pre} = 4.86$  vs.  $M_{post} = 5.16$ ,  $t(71) = -2.31$ ,  $p = .024$ ,  $d = .27$ ). However, for the other types of motivational regulations, there were no significant changes over the semester (see Fig. 2).

More importantly, there was a significant improvement in students' achievement on the knowledge exam (see Table 5 & Fig. 3). The learning outcome analysis

showed significant changes between pre and posttest LO1 ( $M_{pre} = 1.23$  vs.  $M_{post} = 2.07$ ,  $t(80) = -7.91$ ,  $p < .001$ ,  $d = .88$ ), LO2 ( $M_{pre} = 1.51$  vs.  $M_{post} = 3.60$ ,  $t(80) = -9.62$ ,  $p < .001$ ,  $d = 1.07$ ), and LO3 ( $M_{pre} = 1.07$  vs.  $M_{post} = 1.89$ ,  $t(80) = -5.94$ ,  $p < .001$ ,  $d = .66$ ).

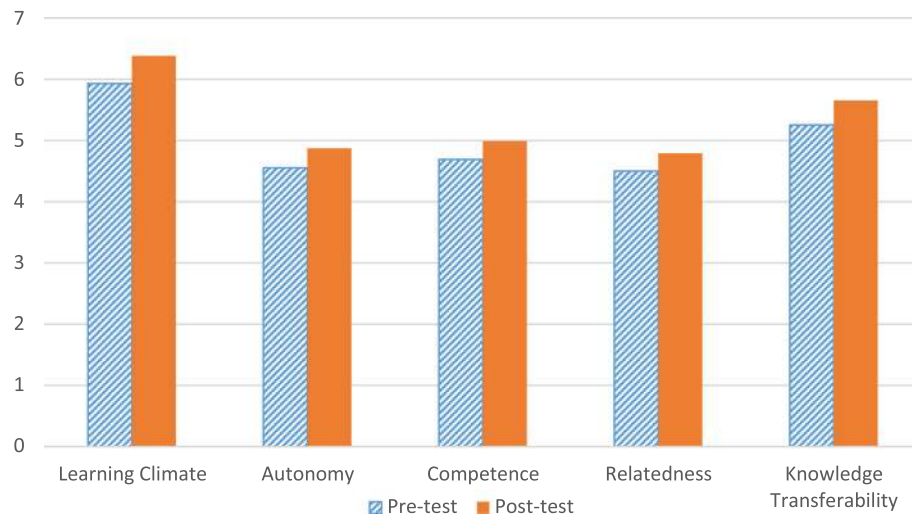
**Comparison between the intervention group and control group**

Students in the intervention group experienced the CPR sessions during the semester, while those in the control group had a traditional lecture course. To compare the CPR class and traditional lecture class, an independent sample  $t$  test was performed on perceptions of the learning climate, basic psychological needs, motivation, perceived knowledge transferability, and final grades. Table

**Table 4** Results from the paired sample  $t$  test ( $N = 73$ )

	Pretest	Posttest	Paired sample $t$ test		
			$t$	$p$	Cohen's $d$
Learning climate**	5.93 (.73)	6.38 (.70)	-4.80	< .001	.56
Autonomy**	4.55 (.71)	4.87 (.72)	-4.73	< .001	.55
Competence**	4.69 (.77)	4.99 (.95)	-3.49	.001	.41
Relatedness**	4.50 (.88)	4.79 (.78)	-3.10	.003	.38
Intrinsic regulation*	4.86 (1.16)	5.16 (1.16)	-2.31	.024	.27
Integration	5.43 (1.01)	5.51 (1.06)	-.82	.415	.09
Identification	5.44 (.91)	5.58 (.98)	-1.22	.227	.14
Introjection	3.41 (1.79)	3.55 (1.79)	-.78	.440	.09
External regulation	4.92 (1.42)	4.81 (1.44)	.67	.504	-.09
Amotivation	2.36 (1.23)	2.25 (1.25)	.85	.399	-.11
Knowledge transferability**	5.25 (.86)	5.65 (.98)	-3.07	.003	.36

Mean scores, standard deviations (in parentheses), and paired sample  $t$  test results are presented. \* $p < .05$ , \*\* $p < .01$

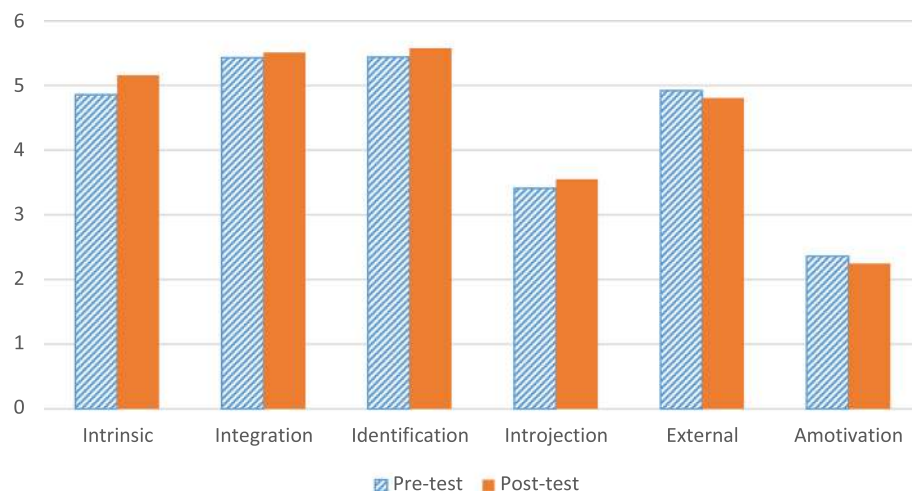


**Fig. 1** Comparison of students’ perceptions of learning between the pre and posttests. The Y-axis indicates students’ scores for each construct (max 7)

6 demonstrates the differences in students’ perceptions of learning and performance between the intervention and control groups.

When comparing these two groups, there were statistically significant differences in students’ perceptions of the learning climate, competence, relatedness, intrinsic motivation, perceived knowledge transferability and final grades between the intervention and control classes. Students in the intervention group scored higher on the learning climate ( $M_{\text{control}} = 6.02$  vs.  $M_{\text{inter}} = 6.38$ ,  $t(98) = -2.24$ ,  $p = .028$ ,  $d = .50$ ), competence ( $M_{\text{control}} = 4.43$  vs.  $M_{\text{inter}} = 5.00$ ,  $t(97) = -2.61$ ,  $p = .01$ ,  $d = .58$ ) and relatedness ( $M_{\text{control}} = 4.28$  vs.  $M_{\text{inter}} = 4.79$ ,  $t(97) = -$

$2.82$ ,  $p = .006$ ,  $d = .63$ ) measures. They also felt more intrinsically motivated ( $M_{\text{control}} = 4.57$  vs.  $M_{\text{inter}} = 5.16$ ,  $t(98) = -2.08$ ,  $p = .04$ ,  $d = .43$ ) and were also more likely to perceive that the knowledge that they learned could be transferrable to other areas and to their future careers ( $M_{\text{control}} = 4.98$  vs.  $M_{\text{inter}} = 5.65$ ,  $t(34.447) = -2.13$ ,  $p = .041$ ,  $d = .53$ ). In addition, the final grades of students in the intervention group were significantly better ( $M_{\text{control}} = 2.62$  vs.  $M_{\text{inter}} = 3.27$ ,  $t(96) = -2.54$ ,  $p = .013$ ,  $d = .58$ ). However, there were no significant differences in autonomy, integration, identification, introjection, external regulation, or amotivation between the two groups.



**Fig. 2** Comparison of students’ motivational regulation between the pre and posttests. The Y-axis indicates students’ scores for each construct (max 7)

**Table 5** Results for the Knowledge Exam Learning Outcomes (N = 81 from Fall 2017 and Spring 2018)

	Pretest	Posttest	Paired sample t test		
			t	p	Cohen's d
Learning outcome 1*	1.23 (.71)	2.07 (.86)	− .791	< .001	.88
Learning outcome 2*	1.51 (1.05)	3.60 (1.16)	− 9.62	< .001	1.07
Learning outcome 3*	1.07 (.82)	1.89 (1.06)	− 5.94	< .001	.66

Mean scores, standard deviations (in parentheses), and paired sample t test results are presented. \* p < .01

**Students’ qualitative responses**

To explore students’ opinions and learning experiences in the CPR teaching sessions, content analysis was used to analyze students’ written feedback and comments about the course and instructor. To identify common themes regarding course redesign, one of the authors first became familiar with the data, then generated initial codes, and finally searched for themes among the codes. The open-ended comments were analyzed by using N-Vivo software. The data was analyzed three times to manage internal reliability and avoid researcher biases in terms of interpreting the qualitative data. Table 7 shows the summary of the analysis. Based on the students’ comments, three themes were identified in the students’ written feedback on the course evaluations.

**Theme 1: students felt that the instructor cared about their learning and academic success (# of comments = 51)**

The first theme was that students thought that the instructor cared about their learning and academic success, which was mentioned 51 times. The students expressed that they felt that the instructor cared about their learning because the instructor was willing

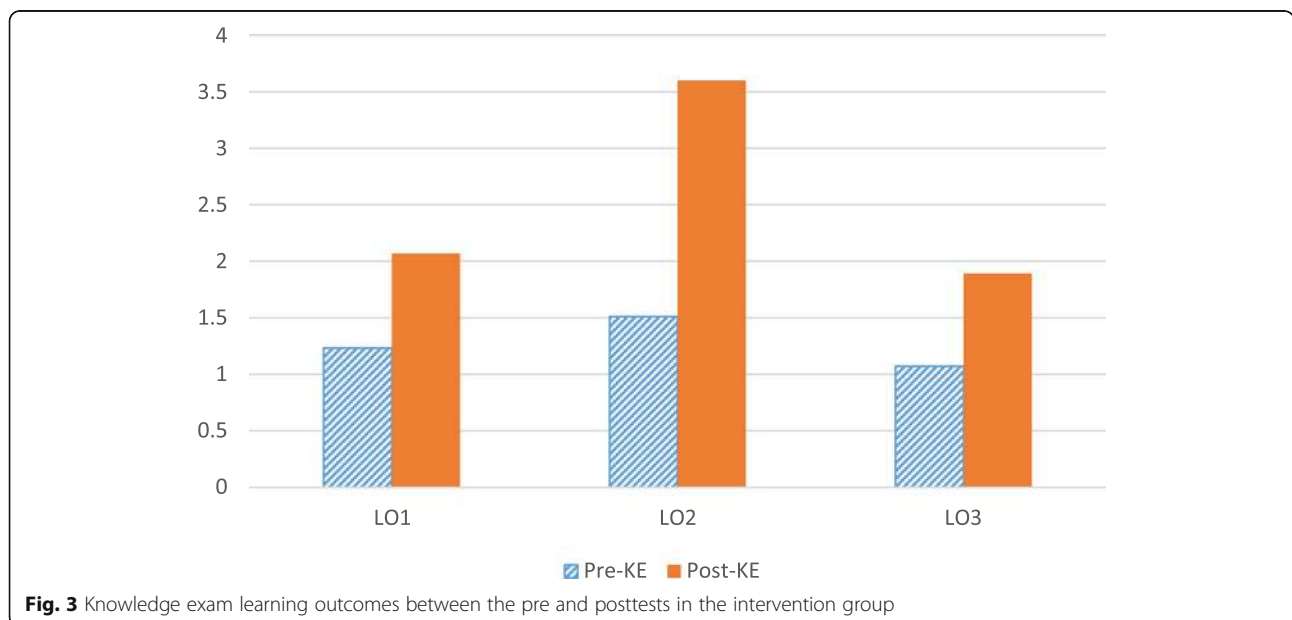
to take any questions, put effort into helping students understand, and even allowed them to make mistakes and learn through them. One student (2016F) mentioned,

*He welcomes questions of all kinds and (extremely importantly) pauses between concepts to ensure there are no lingering questions before advancing. He also provides ample opportunities for help outside of class, with six hours of office hours each week (including TA’s) as well as exam remediation sessions. He genuinely cares about his students’ learning.*

Another student (2018SP) stated,

*He encouraged learning concepts instead of pure memorization. For example, he allows students to make up on question by giving a presentation to him on the related topics. This ensures we learn from our mistakes while also rewarding us for doing so. I have truly enjoyed being in his class this semester.*

Another student (2017F) added,



**Fig. 3** Knowledge exam learning outcomes between the pre and posttests in the intervention group

**Table 6** Results from the independent sample *t* test

	Control	Intervention	Independent sample <i>t</i> test		
			<i>t</i>	<i>p</i>	Cohen's <i>d</i>
Learning climate*	6.02 (.75)	6.38 (.70)	- 2.24	.028	.50
Autonomy	4.54 (.81)	4.87 (.71)	- 1.91	.059	.43
Competence*	4.43 (1.04)	5.00 (.94)	- 2.61	.010	.58
Relatedness**	4.28 (.85)	4.79 (.77)	- 2.82	.006	.63
Intrinsic regulation*	4.57 (1.55)	5.16 (1.15)	- 2.08	.040	.43
Integration	5.19 (1.32)	5.49 (1.07)	- 1.20	.234	.25
Identification	5.21 (1.44)	5.58 (.98)	- 1.45	.150	.30
Introjection	3.44 (1.66)	3.53 (1.79)	- .22	.830	.05
External regulation	5.05 (1.28)	4.80 (1.43)	.80	.427	.18
Amotivation	2.54 (1.37)	2.24 (1.25)	1.06	.293	.23
Knowledge transferability*	4.98 (1.52)	5.65 (.97)	- 2.13	.041	.53
Final grade*	2.62 (1.19)	3.27 (1.06)	- 2.54	.013	.58

Mean scores, standard deviations (in parentheses), and independent sample *t* test results are presented. \**p* < .05, \*\* *p* < .01

*His availability outside of class for help is also astonishing, as he is always welcoming students into his office for extra help even when it is not during his official office hours. I felt very encouraged when I asked questions during office hours because even if it was a very simple question, he never made me feel that I was incompetent for asking an easy question.*

One student (2017F) mentioned the CPR teaching session,

*The instructor is actually my favorite professor that I have had. His teaching style allows you to make mistakes and then forces you to learn from them, all while receiving remediation points in the process. It makes his class seem actually manageable and feel*

*like you are truly learning something instead of the usual cram the information in and then lose it by next semester. I think that if all teachers could take a note from his book on teaching that would be very helpful.*

Students felt that the instructor encouraged them to learn through their mistakes, and the CPR sessions gave them the opportunity to review the concepts that they had missed on the exam. In addition, they appreciated that the instructor wanted the students to understand the material and provided as much help as possible. After they went through the course, they found that it was a genuine learning experience. They acknowledged that the instructor made himself readily available to help with any problems or answer any questions the students might have during the class.

**Table 7** Coding and main themes (*N* = 126)

Codes	Number of references	Themes
Cared about students' learning and success	11	1. Students felt that the instructor cared about their learning and academic success (total # of references = 51).
Willing to take questions	9	
Helped during or outside office hours	10	
Put effort into helping students understand	14	
Good grading system and make-up points	7	
Excellent or good course	9	2. Students had positive learning experiences (total # of references = 40).
Easy, fun, and interesting; pure enjoyment	11	
Good or enthusiastic teaching	20	
Cared about students	15	3. Students felt that the instructor cared about them as individuals (total # of references = 24).
Built rapport	3	
Tried to become acquainted with students and remember their names	6	

**Theme 2: students had positive learning experiences (# of comments = 40)**

Almost 40 comments were related to students’ positive learning experiences in the course. They mentioned that the class was fun, interesting, and enjoyable. Although concepts were challenging to understand for some students, they expressed that they enjoyed taking the course.

One participant (2017F) stated,

*The professor is very good at explaining difficult concepts and was always happy to help during office hours. The lesson plans went at a good pace, and I truly enjoyed all of the interesting demonstrations!*

Another (2018SP) stated,

*I have thoroughly enjoyed this course. It builds well off previous electricity and magnetism courses I have taken. Overall, the course is well organized, and exams do a great job of testing the material.*

**Theme 3: students felt that the instructor cared about them as individuals (# of comments = 24)**

The last theme was that students felt that the instructor cared about them as individuals. In the students’ written feedback, this theme was mentioned 24 times. One participant (2017F) stated,

*The professor really cares about his students, as he made an effort to get to know every single one of us, and as students, we are able to feel that connection and work harder in the class because of this encouragement.*

Another (2018SP) said,

*The instructor is extremely motivated to help the students learn all about electromagnetics as well as the history of electromagnetics. I looked forward to every single class with the professor. The professor also went through the effort of learning every single student’s name, and he made sure to take weekly input from every student to ensure their success in the class. The instructor has taught me how to be thorough with my understanding of the subjects taught.*

Notably, the students appreciated the fact that the instructor tried to learn their names and interact with students outside office hours so that they could develop rapport or connections with him. Students appreciated that he took the time to learn their names and be friendly and caring to them. Students felt comfortable

asking questions when they did not understand the material.

In addition to students’ written comments on their learning experiences, the course evaluation supported these three themes. Table 8 shows the summary of the course evaluation scores (max 5) in the following seven categories for the four semesters: preparation for the lecture, clarity of the presentation, general instructional technique, availability outside of class, rapport with students, effectiveness in answering questions, and effort put forth in teaching class. It can be assumed that the CPR as a course redesign strategy was able to promote students’ desirable learning experiences over the semester.

**Discussion**

This study explored the impact of CPR teaching sessions in an electrical engineering undergraduate course. To examine the effectiveness of the CPR strategy, students’ perceptions of learning and their academic achievement were compared in within-subject and between-subject conditions. The quantitative findings revealed that after students experienced the CPR teaching sessions, there was a significant change in their perceptions of learning, degree of motivation, and perceived knowledge transferability (RQ1). Moreover, there was an increase in students’ perceptions and learning outcomes compared with those of the control group (RQ2). The qualitative findings from students’ written feedback on the course and on the instructor demonstrated that students felt that the instructor cared about students’ learning and success and that they had a positive learning experience (RQ3).

First, the CPR teaching sessions seemed to help the instructor produce an environment that supported students’ basic psychological needs and self-determined motivation. That is, the CPR sessions created an autonomy-supportive learning environment in which students felt competence for course tasks and connectedness with the instructor in the learning process. Students’ intrinsic motivation significantly increased after they participated in the CPR sessions. In particular, students’ written comments about the course supported this quantitative finding. Many students thought that the

**Table 8** Course evaluation scores (max 5)

Students’ evaluation	2016F	2017SP	2017F	2018SP
Preparation for lecture	4.9	5.0	4.9	5.0
Clarity of presentation	4.9	4.9	4.9	4.9
General instructional technique	4.9	5.0	4.9	4.9
Availability outside of class	4.9	5.0	4.9	4.9
Rapport with students	4.9	4.9	4.9	5.0
Effectiveness in answering questions	4.8	4.9	4.8	4.9
Effort put forth in teaching class	4.9	5.0	4.9	5.0

instructor wanted his students to learn the course materials and succeed. The students' comments regarding the CPR learning environments exactly describe how autonomy-supportive instruction should be. Reeve (2006, 2009) proposed that autonomy-supportive instructors use informational and noncontrolling language, strive to communicate the meaning of tasks and offer explanatory rationales for coursework. They tend to support students' inner motivation by creating environments that satisfy students' basic needs to promote the internalization process and bolster intrinsic motivation (Reeve, 2009; Reeve et al., 2004; Reeve & Jang, 2006). Such instructors provide informative feedback to support students' learning progress and mastery of learning rather than focusing on the students achieving higher scores on the exam, which then allows the instructors to show empathy by identifying potential learning difficulties for students (Reeve, 2009). Students' qualitative responses to the CPR instruction are consistent with the tenets of autonomy-supportive instruction. The students felt that the instructor cared about their learning and was always willing to help them understand the concepts and achieve success in the course. In addition, the three 15-min CPR sessions during the semester (because the course had three exams) resulted in the instructor knowing the students well. Therefore, the students felt that the instructor cared about them as individuals. A recent study showed the importance of active engagement with a faculty member for students' lives after college (Ray & Marken, 2014). Other studies regarding autonomy-supportive learning environments also found that such active engagement is significantly associated with perceived competence and better learning outcomes (Cheon et al., 2012; Dincer et al., 2012). Students in autonomy-supportive learning environments seem to tend to feel more competent and related (Adie et al., 2008; Jang et al., 2009). The CRP teaching sessions enable instructors to create an autonomy-supportive learning environment and thus to foster such engagement.

In addition, the current findings support the research that demonstrates how feelings of relatedness and connection with an instructor can be essential in increasing students' perceptions of learning and engagement. According to the tenets of SDT, individuals are more likely to engage in the behaviors that they believe are valued by people to whom they feel connected, and thus, feeling a sense of relatedness is the foundation for facilitating the internalization process (Ryan & Deci, 2000). The independent *t* test showed that the students in the intervention group had higher levels of the satisfaction of their need for relatedness. Students' written feedback also supported this finding. The students acknowledged that the instructor cared about them as individuals. Notably, the students

appreciated the instructor's effort to learn all of the students' names, to take weekly input from students to ensure that students succeeded in the course and to try to connect with the electrical engineering students. It is imperative that students feel respected and cared for by instructors for them to be willing to accept the value of classroom activities (Ryan & Deci, 2000). The current findings support this hypothesis drawn from SDT.

However, there have been inconsistent findings regarding the basic need for *relatedness*. Some literature has found that relatedness did not predict students' learning outcomes relative to the other two types of needs, i.e., autonomy and competence (e.g., Wang et al., 2020). Competence has been shown to be the most salient predictor of students' performance (e.g., Wang et al., 2020; Yu & Levesque-Bristol, 2020). However, the current qualitative findings provide a different perspective regarding the sense of relatedness in the learning process. The results reveal how powerful the satisfaction of the need for relatedness can be in students' learning experience, especially when students feel they are connected with the instructor. This finding is aligned with a recent study that showed that relatedness with the instructor had a more powerful impact on students' motivation and performance than relatedness with peer groups (Fedesco et al., 2019). When students felt more connected to their instructors than to their peer classmates, they were more likely to enjoy the course and apply greater efforts in the course (Fedesco et al., 2019). How instructors treat students can affect students' attitudes toward a course and even their academic performance (Ryan & Deci, 2000b). Our study sheds light on the role of the need for relatedness and the importance of the connection with the instructor in students' learning and engagement.

More importantly, the CPR teaching session has many potential educational implications in higher education. For example, the CPR strategy can help students shift their attitudes and perspectives about assessment from a score on an exam to a genuine learning experience. When an assessment relies on too much memorization, it can trigger anxiety, which can negatively affect students' actual learning (Amrein & Berliner, 2002; Ryan & Weinstein, 2009). However, if students are given an opportunity to reflect on their errors on an exam, they are more inclined to reexamine their misconceptions and mistakes, which is needed to advance to the next steps of the course. The CPR strategy can provide an alternative solution to help students shift their perspectives and attitudes about testing that might be associated with maladaptive learning outcomes. To provide evidence to further examine this relationship, we might need to investigate students' perception of assessment with a large dataset in the future. Additionally, the CPR teaching

sessions provide supportive feedback to help students develop self-regulated learning strategies. The instructional model of providing supportive feedback can enhance students' self-regulation of problem-solving skills (Zimmerman & Campillo, 2003). CPR sessions require students to review their misunderstandings and misconceptions, reflect on their learning approach, and, if necessary, revise their strategies. By reviewing their mistakes and misunderstanding through CPR, students are more likely to self-regulate and self-monitor their improvement in the course. Finally, given that students experienced greater educational benefits through CPR teaching sessions than they did in traditional lectures, this new active learning strategy can be effectively applied in higher education. Any instructor wishing to incorporate this technique into his or class can do so immediately. For a class with 60 students and three exams during the semester, the instructor time investment is approximately 40 h during the semester. For larger classes or for instructors who cannot invest this time, teaching assistants could take on this role. By providing CPR to students with teaching assistants, students have opportunities to interact with them and review their misconceptions in a more friendly environment.

#### Limitations and future directions

This study has certain limitations. First, although this study was conducted across multiple semesters, the sample sizes were relatively small. The sample size of the control group was smaller than that of the intervention group. This study was conducted as an exploratory study to show how the CPR teaching sessions affect engineering undergraduate students' perceptions of learning, motivation, and performance. Future research should be conducted with a larger sample size to replicate the study.

Another limitation is that since the two different courses were taught by different instructors, we cannot exclude the possibility of teacher impact. There is a possibility that the effect may be potentially due to the teacher rather than the method. To further study the effects of CPR teaching, future investigations should include comparisons between a CPR section and a non-CPR section by the same instructor or controlling for a teacher effect.

In addition, considering the beneficial aspects of CPR, our interest is in a follow-up study to examine the perceptions that international students have regarding CPR. Additionally, it would be interesting if we follow up on students who have completed an electromagnetics course as a prerequisite and took advanced courses where they can apply what they have learned in this course. Another future study should investigate the relationship between CPR and self-regulated learning strategies with larger quantitative data.

Finally, students' written feedback provided short and concise snapshots of their learning experiences. To further explore students' learning experience in the CPR sessions, in-depth interviews or classroom observations may be used to supplement the current findings. Such qualitative work would vividly represent students' voices and responses to the effect of the CPR on their motivation and academic performance.

#### Conclusion

The recent findings concerning active learning techniques suggest that faculty should take into consideration a non-conventional model for enhancing academic achievement and adaptive attitudes toward learning (Prince, 2004). Putting effort into increasing students' engagement in their learning processes and making connections with students through the CPR teaching sessions improved students' perceptions of learning, their degree of motivation, and their level of academic achievement. Despite some limitations of the current study, the results are very encouraging for further research in creating autonomy-supportive learning environments through the CPR strategy. Faculty who have a desire to create a supportive learning environment for students should consider teaching strategies that integrate CPR into lecture-based courses to transform traditional learning climates. CPR teaching sessions can be an alternative model for instructors to connect with students and to create supportive environments to help students achieve academic success.

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#### Authors' contributions

All authors contributed to the paper. *Hyun Jin Cho*: conceptualization, data curation, formal analysis, writing—original, draft preparation, writing—review & editing, *Michael R. Melloch*: conceptualization, data curation, formal analysis, writing—original, draft preparation, writing—review & editing, *Chantal Levesque-Bristol*: supervision, funding acquisition, writing—review & editing. The authors read and approved the final manuscript.

#### Availability of data and materials

Data will not be shared in public due to the characteristics of the data.

#### Competing interests

There is no conflict of interest regarding the publication of this article.

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