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The Struggle is Real: An Intervention to Regulate and Resolve Confusion During Complex Statistics Problem Solving

Martina C. Kohatsu[1], Krista R. Muis[1], Reinhard Pekrun[2, 3, 4], Gale M. Sinatra[5], Panayiota Kendeou[6], Kristy Robinson[1], Alana Kennedy[7], and Sanheeta Potola[1]

[1]McGill University

[2]University of Essex

[3]Australian Catholic University

[4]Ludwig Maximilian University of Munich

[5]University of Southern California, Rossier School of Education

[6]University of Minnesota

[7]Northern Arizona University

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Correspondence concerning this article can be addressed to Krista R. Muis, Department of Educational and Counselling Psychology, Faculty of Education, McGill University, 3700 McTavish Street, Montreal, QC, H3A 1Y2. Email: krista.muis@mcgill.ca.

Abstract

The purpose of this study was to develop a cognitive-emotive strategy training intervention (CEST) to help university students regulate and resolve confusion during complex statistics problem solving. One hundred sixty-eight university students from Canada, the United States, and England participated. Measures of academic control, epistemic emotions, and confusion regulation strategies were collected. Audio-recordings of the sessions were transcribed and coded to investigate learning and confusion regulation strategies used. Results revealed that the intervention was not effective in helping students better regulate their confusion during problem solving. Students in the intervention group did not increase their perception of control after problem solving, did not increase their learning or confusion regulation strategy use, and did not experience more positive and less negative emotions. Although the intervention had no positive effect, this was the first study to consider emotion regulation skills that are particular to the self-regulated learning processes students must engage in to regulate and resolve confusion. To develop more effective interventions, future research should provide more opportunities for students to practice confusion regulation skills over longer periods of time, and ideally to conduct research in natural learning environments.

Keywords: emotions, emotion regulation, confusion, self-regulated learning, intervention, statistics problem-solving

Imagine it was 2021 and you have been in a Zoom meeting with ten other academic colleagues. Once the meeting started, the group's Ph.D. student shared the news: the efficacy of the Pfizer COVID-19 vaccine is 80%; that is, 80% of those receiving the vaccine will not contract the virus when exposed. Unfortunately, she just tested positive for Covid, and since everyone was working in the lab yesterday, everyone was exposed. Of your ten colleagues, six of them are vaccinated. What is the probability that at least one exposed person in your group will get COVID if all ten people are exposed? Do you have an answer off the top of your head? Perhaps you would like to read it again? If you are trying to solve the problem, maybe something does not add up and you feel stuck. The confusion you might feel if you attempt to solve the problem is a common experience for students trying to solve complex problems (Di Leo et al., 2019, Di Leo & Muis, 2020; D'Mello & Graesser, 2012; Newman et al., 2017).

In education research, confusion is defined as an emotion that arises when incoming information is incongruent with current knowledge (Piaget, 1952) or when there is an impasse in the learning flow (D'Mello & Graesser, 2012; D'Mello et al., 2014). Impasses are caused by appraisals stemming from novelty, complexity, conflict, or unfamiliarity (Ellsworth & Scherer, 2003), coupled with an appraisal that the resolution will be difficult (Di Leo et al., 2019, Di Leo & Muis, 2020; D'Mello & Graesser, 2012; Pekrun, 2021). The intensity of confusion can vary from slight, like uncertainty about the words someone has just said in a conversation, to severe, like working through problems that are so complicated, one may feel like giving up. These experiences share a few common features such as cognitive incongruity – or not knowing how to proceed; the feeling of being stuck (D'Mello et al., 2014), or, in other words, to struggle.

To succeed in the struggle to solve complex problems, students must be able to coordinate important information, activate prior knowledge, and engage in self-regulatory processes (Greene et al., 2024). Self-regulated learning (SRL) is the process students engage in to achieve their learning goals via cognitive, metacognitive, and resource-oriented skills to evaluate, monitor, and apply strategies accordingly (Greene et al., 2024). To achieve a learning goal, students may use multiple cognitive, metacognitive, social, or affective processes. For example, to solve a statistics problem, a student may recollect information from a prior lesson on statistics (cognitive), break down the problem into smaller parts (metacognitive), ask questions (social), feel joy when getting through a difficult step in the problem, or feel frustration and disengage from it (affective). Affective experiences during SRL are likely to occur (Muis et al., 2018) and are particularly significant given that positive affective states may facilitate SRL by indicating that “all is well” and thus encouraging students to use more flexible and holistic learning strategies, such as elaboration, organization, and critical thinking (Pekrun et al., 2017). In contrast, negative emotional experiences may hinder SRL as they may propel students to adopt more rigid approaches, such as rehearsal, to process information superficially, or give up (Munzar et al., 2021; Pekrun et al., 2017).

In Schoenfeld’s (2016) review of mathematical thinking, problem solving has been defined as the experience of confronting a problem in which the solver does not have a ready answer but whom nonetheless has the appropriate requisite tools to find one. Problem solving has also been conceived as a means to achieve other ends (i.e., serving as a motivator to learn subject topics), as a skill consisting of the ability to obtain solutions to problems assigned, or as “the heart of mathematics itself” (p. 339). As a skill, problem solving is critical during statistics courses given that students are required to understand the relationship between abstract concepts, properly adopt theoretical assumptions, and decide on a method of analysis for descriptive and inferential purposes.

In the current curriculum landscape of college majors, statistics courses are often required, making them a gate-way course (American Statistical Association, n.d.). As students' problem-solving skills in mathematics decline as they progress through higher levels of education (OECD, 2023), it directly affects their choice of majors. The avoidance of majors that require complex problem solving in statistics creates labor shortages (Deming & Noray, 2018) and reinforces stereotypical gendered professions aspirations (Makarova et al., 2019) among other issues. Therefore, it is critical that students be well equipped to solve complex problems with the necessary cognitive and metacognitive skills coupled with effective emotion regulation.

Current State of Research on Confusion Regulation

Of particular concern, research conducted with elementary and university students has reported that during complex problem solving, confusion and frustration are the most frequently expressed emotions (Di Leo & Muis, 2020; Lehman et al., 2012, 2013). If not resolved, persistent confusion can be detrimental to learning as this affective state may transition into frustration, which in turn transitions into boredom and subsequent disengagement from the task (Di Leo et al., 2019; Munzar et al., 2021). However, research has also demonstrated that if confusion can be resolved, students' learning and performance are superior compared to when it is not successfully resolved, or not experienced (D'Mello et al., 2014; Lehman et al., 2012). Accordingly, it is critical to teach students how to regulate and resolve confusion when it arises during learning. This requires that students develop effective SRL skills (Di Leo & Muis, 2020).

Several interventions with university students exist in the literature that have been effective in fostering skills in emotion regulation (see Frenzel et al., 2024; Harley et al., 2019; Järvela et al., 2019) and SRL (see Hadwin et al., 2018; Greene et al., 2024). However, even though emotions and cognitive processes are interconnected and dynamically linked (Barrett, 2009; Blair, 2002; Pekrun, 2006, 2018; Scherer, 2009), there is currently only one intervention that considered links between cognition and emotions to improve mathematics problem solving skills (see Di Leo & Muis, 2020). To address this research gap, the current intervention was adapted from Montreuil and Tiley's (2017) intervention developed specifically for elementary students. To our knowledge, no intervention has been developed to improve statistics problem solving among university students from both a cognitive and affective perspective. Given that statistics is a required course for most undergraduate and graduate programs, it is critical to foster the skills necessary for students to succeed. As such, the goal of this research was to evaluate an intervention designed to help university students resolve confusion during statistics problem solving by promoting emotional awareness and SRL strategies. Prior to delineating the specific intervention, relevant theoretical and empirical work is reviewed.

Control-Value Theory of Achievement Emotions

Emotions are conceptualized as multi-componential and include cognitive (e.g., fear of failing an exam), motivational (e.g., urge to flee the exam), physiological (e.g., sweaty palms while writing down the answers), expressive (e.g., darted eyes and swiveled head in anxiety) and affective (e.g., feelings of nervousness) processes. One prominent theoretical framework is Pekrun's (2016, 2021) control-value theory of achievement emotions. Relevant to educational settings, Pekrun (2016, 2021) proposed that achievement emotions are those tied directly with achievement-related *activities* (e.g., boredom while attending a lecture, or joy when understanding a difficult subject) or achievement-related *outcomes* (e.g., shame for getting a bad exam grade, or hope for a good one).

Further, Pekrun (2006) proposed that students experience achievement-related activity emotions based on their appraisals of *control* (e.g. "persistence at studying can be enacted, and that it will lead to success” p. 3) and achievement-related outcome emotions based on their appraisals of *value* (e.g., “the perceived importance of success” p. 3) they feel towards the achievement activity. Therefore, if a student realizes that she is in control of her learning task, and she values the task, it is theorized that the student will experience positive activating emotions such as joy during the learning task. In contrast, a student who believes she has control of her learning task, but is not interested in the task, will experience negative deactivating emotions such as boredom. The achievement emotions students experience during learning tasks affect cognitive, motivational, and regulatory processes, and as such, emotions may hinder or facilitate learning (Pekrun et al., 2002; Pekrun, 2006).

Dynamic Affective States

D’Mello and Graesser (2012) developed the theory of dynamics of affective states during learning of complex content to describe how students transition between emotions following an impasse. They theorized that when students’ goals are blocked, meaning they reach an impasse or a cognitive incongruity, they are bound to experience emotions such as surprise, curiosity, and confusion. Surprise is likely to be the first reaction when there is a discrepancy between new incoming information and prior beliefs/knowledge (D’Mello et al., 2014). Curiosity may occur when new information is apprehensible and thus fosters a desire to continue engaging in the task (D’Mello & Graesser, 2012; Muis et al., 2018). Confusion is hypothesized to occur when consistent incongruity occurs and it is appraised to be difficult to resolve or when new information cannot be integrated into existing mental models (D’Mello & Graesser, 2012; Pekrun, 2021; Piaget, 1952). Both these situations cause cognitive disequilibrium and pose an obstacle to goals, and create impasses and contradictions (Piaget, 1952; VanLehn et al., 2003). Cognitive disequilibrium occurs during difficult learning tasks, so the experience of confusion is expected to occur during complex problem-solving activities (D'Mello et al., 2014). Further, D'Mello and Graesser (2012) hypothesized that cognitive disequilibrium first causes confusion; if the impasse is resolved, delight, curiosity, and improved understanding follow; if the impasse persists, frustration, and eventually boredom follow.

Current State of Research for Confusion Resolution

D'Mello and Graesser's (2012) model has been empirically supported. Studies revealed that persistent confusion that is not resolved transitions into frustration, which in turn can transition into boredom and disengagement from the task or oscillate between confusion and frustration (Munzar et al., 2021). However, if confusion is resolved, students return to a state of "flow" (Csikszentmihalyi et al., 2005*)* or cognitive engagement. D'Mello and colleagues (2012, 2014) argued that this process enhances learning as students must engage more deeply with the content to identify what is the source of confusion and correct any misconception. Graesser et al. (2014) also tested this model by inducing confusion in a complex learning task wherein they hypothesized that if students had the appropriate skill levels to resolve confusion and were provided sufficient scaffolds to resolve that confusion (if they cannot resolve it on their own), then students who experienced confusion would demonstrate deeper learning compared to students who did not experience confusion or were not able to resolve that confusion. This is because confusion that is caused by cognitive disequilibrium leads to a restructuring of the cognitive system (Piaget, 1952), and therefore makes the system more attuned to receive information, critically evaluate it, and process it more deeply (D'Mello et al., 2014). Indeed, results found that contradictions induced confusion, and learners who were confused by the contradictions were more likely to perform better on the learning tasks when confusion was resolved.

Confusion is theorized to be potentially beneficial for learning as it can inspire more effortful cognitive activities such as reflection and deliberation to resolve the cognitive disequilibrium. Once students experience cognitive disequilibrium, they must apply cognitive and metacognitive strategies to overcome that incongruity (D'Mello & Graesser, 2012; Muis et al., 2018). However, if students are not provided with appropriate scaffolding or lack motivation, ability, or prior knowledge that would allow resolution of confusion, then confusion will be unproductive (D'Mello & Graesser, 2012; Lehman et al., 2015).

In another study, Lehman and Graesser (2015) found that confusion resolution via explanatory texts were not enough to help students resolve their confusion. They suggested that further research investigate the confusion resolution processes (e.g., monitoring confusion intensity, what kinds of strategies are used to resolve confusion) rather than simply confusion resolution outcomes. Their results suggest that students who do not have emotion regulation skills may be at a higher risk of having an unproductive experience of confusion since they may direct their cognitive resources to the object of their confusion and rely on a single strategy to overcome it such as rereading or memorization (Berger & Karabenick, 2011; Pekrun et al., 2017; Pekrun, 2006). At other times, students who are not able to deal with persistent or intense confusion may choose to disengage from the learning task to avoid further negative experiences (Munzar et al., 2021; D'Mello et al., 2014). In contrast, students who can recognize confusion and shift their strategies to resolve the impasse are more likely to have a productive experience of confusion (Arguel & Lane, 2015; Munzar et al., 2021; D'Mello et al., 2014). Such cognitive flexibility and wider use of learning strategies is a quality expected from students who can successfully regulate their learning. Therefore, to resolve confusion, students must be able to apply SRL strategies.

Current State of Research for SRL, Control and Confusion

To self-regulate, students must have high self-efficacy, or perceptions of control, meaning the belief that they can succeed in carrying out a task (Berger & Karabenick, 2011; Zimmerman, 2000). Indeed, perceptions of control are correlated with the use of more SRL strategies (Zimmerman, 2000) and with the kinds of learning strategies students engage in (Arguel et al., 2017). For example, students who believe they have the skills necessary to solve a problem may take the time to plan, break the problem down into parts, and elaborate on what aspects of the problem confuses them – at least more so than students who give importance to solving the problem but are not confident in their abilities to do so, and hence tend to use more strategies like rehearsal, which requires less time and effort (Berger & Karabenick, 2011). However, it is likely that students first develop SRL skills which then affords higher perceptions of control. Otherwise, it would be unlikely to expect students to have high perceptions of control without ever having successfully solved problems in which SRL skills were needed (Muis et al., 2018).

For example, Dowd et al. (2015) found that lower perceptions of control predicted higher levels of confusion during learning and problem solving. Others have reported that higher perceptions of value predict higher levels of curiosity, and lower levels of confusion and frustration during problem solving (Muis, 2015; Di Leo et al., 2019). Given the link between perception of control, confusion, and learning strategies, it is crucial to target perceptions of control in interventions designed to teach students cognitive and metacognitive strategies to resolve confusion when it occurs (Muis et al., 2018). This underlies the importance of acquiring a foundation of self-regulatory skills to increase awareness of their cognitive and metacognitive processes, as well as emotional states, and to implement SRL strategies accordingly to resolve confusion when it occurs during problem-solving activities. As such, calls have been made for the development of an intervention for students that facilitates SRL while also considering emotion regulation processes (Arguel et al., 2017; Muis et al., 2018).

Self-regulated Learning (SRL)

Self-regulated learning (SRL) is defined as the process in which students use cognitive, metacognitive, and resource-oriented skills to evaluate, monitor, and apply strategies to achieve a learning goal. Through metacognitive skills, students can enact and respond to other cognitive, motivational, affective, or social components to achieve their goals (Greene et al., 2024). Several models have been developed to delineate how students engage in SRL. Muis's (2007; Muis et al., 2018) model of SRL includes four phases of learning, namely, task definition, planning and goal setting, enactment, and evaluation, and five areas for regulation, including cognition, motivation, affect, behavior, and context. To progress toward a learning goal during problem solving, students' engagement in SRL is often cyclical and nonlinear (Muis et al., 2018).

In the first phase, students define their task, which can be influenced by the five areas for regulation. This phase relates to Schoenfeld's (1991) argument of mathematics as sense making, in which the student can assign adequate meaning to the elements of math problems, rather than simply memorizing facts and procedures and applying them to a set of problems. For example, a student about to engage in a statistics problem may define their task as finding the correct percentage for the problem. To find such a percentage, prior knowledge about finding percentages may be activated (cognitive), as well as the feeling of excitement to complete the task (affective), and a desire to get the correct answer (motivational). During the second phase, students set goals and plans for achieving the task. For example, students may plan that they must a) find important information from the problem statement, b) convert values into decimal form, c) assign values to an equation and, d) solve for the equation.

In the third phase, enactment, students implement their strategies to fulfill the task. During mathematics/statistics problem-solving, to carry out each strategy, students may hypothesize, summarize important information, re-read the problem, recalculate, self-question or ask for help (Muis, 2015). In the fourth phase, students evaluate each strategy's successes and failures and their own progress and perceptions of self. Metacognition is the main activity involved in this phase since it enables reflective thinking through judgement, monitoring, self-questioning and self-correcting of their own learning processes. Metacognition has been construed as what enables a student who has been taught a learning strategy in a particular problem context to retrieve and deploy that strategy in a similar but new context (Lai, 2011). Importantly, metacognition is composed of general, rather than domain specific, skills (Schraw, 1998). These skills can be improved upon and even help compensate prior knowledge on a subject during problem solving. Muis (2007; Muis et al., 2018) proposed that metacognitive processes can occur within all phases of SRL and reoccur throughout learning and problem-solving. Therefore, metacognitive monitoring is a critical skill for students to successfully self-regulate during problem-solving (Ben-Eliyahu & Linnenbrink-Garcia, 2015; Greene et al., 2024; Kuhn, 2009; Winne & Hadwin, 2008) and, as such, it is crucial to teach students the cognitive and metacognitive skills needed to self-regulate specifically during complex problem-solving.

Promoting Self-regulated Learning for Confusion Resolution

Students can be instructed on how to master complex strategies to self-regulate during learning (MacArthur, 2012). There is substantial evidence that supports cognitive instruction as an effective way to facilitate complex tasks (Rosenshine, 1997), to promote metacognitive monitoring as they engage in problem-solving (Mevarech & Kramarski, 2003; Verschaffel et al., 1999), and to promote mathematics literacy and problem-solving skills (Carnine, 1997; Kroesbergen & Van Luit, 2003; Maccini & Hughes, 2000; Montague et al., 2011).

Cognitive strategy instruction has been successful in promoting SRL to support achievement in students with various learning profiles (Di Leo & Muis, 2020). Previous studies on the role of confusion during learning have examined cognitive strategies to promote confusion resolution to aid learning (Lehman et al., 2012; 2013; Lehman & Graesser, 2015). However, such training programs have focused solely on strategies that emphasize cognitive, metacognitive, and motivational processes without consideration of the role of emotions in learning and problem-solving. Given that emotions experienced during learning and problem-solving can facilitate or constrain SRL and learning outcomes (Muis, 2015; Di Leo et al., 2019; Pekrun, 2006, 2018), there is a critical need to incorporate emotional components into training programs that aim to improve statistics problem solving through strategy instruction. Furthermore, emotions are bound to occur when students encounter information that is incongruent with prior/current knowledge (D'Mello & Graesser, 2012; Muis et al., 2018), so successful SRL must also include regulation of affective states. Therefore, it would be highly relevant and important to train students on emotion regulation strategies and to monitor their emotional states and engage such strategies to effectively manage their confusion.

Emotion Awareness and Emotion Regulation

Emotion regulation is the process that allows individuals to elicit and/or suppress emotions according to their situational needs, and to manage the intensity and expression of those emotions (Gross, 2002). As a multi-component process unfolding over time, emotion regulation involves the attempt to increase or decrease the magnitude or duration of one's emotions (Gross et al., 2006; Gross & Thompson, 2007; Gross, 2002). Within the academic context, the goal of emotion regulation is to maintain engagement with the task at hand (Fried, 2010). Successful emotion regulation presupposes students' awareness of their emotions as they happen (Boden & Thompson, 2015), which requires students to pay attention to their bodily sensations and have a clear understanding of how subjective sensations distinguish one emotion from another (Coffey et al., 2016). Upon discerning what emotion one experiences, one can then apply appropriate strategies to regulate that emotion through expressive suppression, acceptance, or cognitive reappraisal of the emotion (Boden & Thompson, 2015; Harley et al., 2019). Specifically, emotion identification tends to be the predictor of implementing emotion regulation strategies (Boden & Thompson, 2015).

Combining Findings to Build a Cognitive-Emotive Strategy Training Intervention (CEST)

Of particular importance to our study, the normalization of confusion is a precursor to being able to regulate this affective state by first recognizing that experiencing confusion while problem-solving is normal, can be beneficial to learning, and understanding the possible causes that give rise to confusion during learning (Arguel et al., 2017; Di Leo & Muis, 2020; D'Mello et al., 2014). Teaching students to develop awareness about states of confusion and to implement regulatory strategies can be done through modelling strategies, which the student can then use (Pincus & Friedman, 2004; Schunk & Zimmerman, 2007). Direct instruction can help bring students' strategy use into conscious awareness as they reflect on becoming aware of the emotions they experience and understand their strategy use (Frenzel et al., 2024; Gross, 2014; Harley et al., 2019; Järvelä et al., 2019; Zepeda et al., 2015). Furthermore, it is possible that prompting students to talk about previous experiences of confusion can further develop students' awareness of them (Weare, 2004), as this may increase students' knowledge of emotional expression (Denham et al., 2002). Additionally, students who receive feedback during the learning activity have shown significantly higher levels of perceived control which helps them to regulate confusion (Arguel et al., 2019; Wang & Wu, 2008). Hence, providing feedback during problem-solving is another way to foster students' confusion regulation.

To incorporate confusion normalization and regulation during learning, we developed a cognitive-emotive strategy training intervention (CEST) by integrating cognitive strategy instruction with emotion regulation strategies designed specifically for the normalization and regulation of confusion. Montreuil and Tiley's (2017) *Healthy Minds, Healthy Schools* program that targets anxiety was adapted for confusion as part of the emotive component of the CEST intervention. The program focuses on helping students (1) recognize feelings and bodily sensations in reaction to emotions, (2) clarify thoughts about confusing situations, (3) develop coping skills, and (4) evaluate the outcomes. Behavioral training strategies include modeling, role playing, and relaxation training, and cognitive strategies include self-control, self-observation, self-modification, and self-evaluation (Di Leo & Muis, 2020).

The current CEST intervention was based on Di Leo and Muis' (2020) cognitive-emotive strategy training intervention that targeted the regulation of confusion in elementary students through training of cognitive and metacognitive strategies over the four phases of SRL (see Di Leo & Muis, 2020) during mathematics problem-solving. They aimed to evaluate if students who received the intervention would perform better on the mathematics problems, apply more SRL strategies during problem-solving, experience overall more positive emotions and less negative emotions, report greater levels of perceived control while solving the problems, and regulate their confusion more effectively.

Di Leo and Muis' (2020) intervention targeted increasing students' awareness of their emotive states during learning activities through cognitive-behavioral therapy strategies and used cognitive strategy instruction and modeling techniques to teach students a repertoire of cognitive and metacognitive strategies that can be implemented to overcome confusion when it occurs during mathematics problem-solving. Results revealed that students in the intervention scored higher on the mathematics problems, engaged in more cognitive and metacognitive strategies, experienced more positive and fewer negative emotions, and better regulated their confusion compared to students in the control condition. However, Di Leo and Muis' (2020) intervention did not consider emotion regulation strategies that can be implemented to resolve confusion during mathematics problem-solving.

In response to research calls made to address emotion regulation strategies during problem-solving (see Di Leo & Muis, 2020; Arguel et al., 2017), the current CEST intervention addressed this gap in the literature and included emotion regulation strategies designed specifically for confusion resolution. In addition to cognitive instruction, the CEST intervention focused on fostering students' awareness of confusion as a normal affective state that occurs during complex problem-solving, why it occurs; how confusion can lead to both positive or negative emotions, and once confusion is identified, what strategies can be implemented to resolve it, such as taking a deep breath and finding the exact source of confusion. Students were also taught strategies that focused on cognitive and metacognitive strategies they could apply to resolve confusion. Further, as part of this study, we developed a confusion regulation questionnaire to capture the strategies students used when feeling confused prior to and post intervention.

The Current Study

Adapting Di Leo and Muis’ (2020) cognitive-emotive strategy training (CEST; see Di Leo & Muis, 2020) intervention, this CEST intervention was developed for university students and targeted training of cognitive and metacognitive strategies as well as regulation of confusion during statistics problem-solving. The objective of this study was to evaluate the efficacy of the CEST intervention with a sample of university students who had taken or were currently enrolled in a statistics course. Cognitive strategy instruction and modeling techniques were applied to provide students with a repertoire of strategies that could be implemented to overcome confusion when it occurred during complex statistics problem-solving.

Based on Di Leo and Muis’ (2020) intervention for elementary students, the current CEST intervention draws from their results to address the following questions: compared to students in the control condition, will students in the intervention condition (1) express more confusion, (2) use more metacognitive strategies to resolve confusion, (3) report greater levels of perceived of control, (4) better regulate their confusion, (5) experience more positive emotions and less negative emotions, and (6) perform better on a complex statistics problem? Accordingly, the hypotheses are that university students in the intervention will (1) experience confusion equally compared to students in the control condition, as this intervention was targeted to help students identify and overcome confusion when it occurs during learning activities and not to specifically reduce its occurrence; (2) use more cognitive and metacognitive strategies during statistics problem solving; (3) report higher levels of perceived control, (4) better regulate their confusion during problem-solving, (5) experience more positive and fewer negative emotions, and (6) perform better than students in the control condition. To capture self-regulatory processes and emotions, we used a think-emote-aloud protocol (see Muis et al., 2015, 2018).

Methodology

Participants

One hundred sixty-eight students (n = 117 female) across Canada (n = 78), USA (n = 57), and England (n = 33), who were taking or had taken statistics courses at the undergraduate or graduate level were recruited to participate. Students were recruited via online advertisements or campus flyers and were compensated with $30 (CAD), a $20-$30 Amazon gift card ($10 for every 30 minutes of participation) or earned course credit depending on the research location. The mean age of the sample was 22.3 years (SD = 5.01), ranging between 17 and 39 years of age. The study was conducted from April 2022 to July 2023 through Zoom and in person. Students' educational levels ranged from undergraduate (n = 129), masters (n = 26), PhD (n = 8), other (n = 3), and 1 missing. Ninety-two participants were pursuing or had an academic major in social sciences, 52 in STEM, seven from business, and 11 from other fields or were undecided.

Materials

Perceived Control

To measure students' perceptions of control before carrying out statistics problems, students completed the Perceived Academic Control Scale (Perry et al., 2001), which was modified to focus specifically on solving statistics problems. Students were told that they were about to be presented with a lesson on the binomial distribution and would be given statistics problems to solve based on that lesson. They were then asked to rate four statements on a scale of 1 ("not confident at all") to 7 ("very confident"), such as "I will be able to perform well on statistics problems." Cronbach's alpha reliability for the four items before solving the statistics problems was .91. After finishing the statistics problems, students completed another four items designed to measure their perceptions of control on the same scale using similar items, "I am convinced that I was able to perform well on the statistics problems." Cronbach's alpha reliability on the four items after solving the problems was .92.

Epistemic Emotions

The Epistemic Emotions Scales (EES; Pekrun et al., 2017) was used to capture the intensity of the emotions that students experienced while solving the statistics problems. This instrument consists of 21 items designed to measure seven emotions: surprise, curiosity, enjoyment, confusion, anxiety, frustration, and boredom. Each item consists of a single adjective that describes one emotion with three synonyms for each emotion (e.g., confusion is measured using "muddled" and "puzzled"). Students were instructed to report the emotions they experienced while solving the problems by choosing the number that best described the level of intensity of that emotional response, which ranged from 1 ("Not at all") to 5 ("Very strong"). Scores for each emotion were calculated by taking the average of the three items. Cronbach's alpha reliability for each emotion was as follows: surprise, $\alpha = 0.71$; curiosity, $\alpha = 0.73$; enjoyment, $\alpha = 0.85$; confusion, $\alpha = 0.79$; anxiety, $\alpha = 0.88$; frustration, $\alpha = 0.82$; and boredom, $\alpha = 0.71$.

Confusion Regulation Questionnaire

Drawing from Gross' (2015) process model of emotion regulation, the Emotion Regulation in Achievement Situation (ERAS) model (Harley et al., 2019), and Pekrun's (2006) conception of emotion regulation, the Confusion Regulation Questionnaire (CRQ) was developed in two parts specifically for this study. The first part measured what students typically do when they are confused while studying for statistics, attending class, or taking a statistics test, and included 34 items across five categories of emotion regulation strategies. The second part measured the strategies students used to reduce confusion as they solved the statistics problems and included 28 items across four different categories of confusion regulation strategies. Items in the second part resembled the items from the first part but were written in past tense and focused on the specific context of problem solving.

For the first part, the five categories included competence development (eight items, e.g., “To feel less puzzled by statistics, I identify my weaknesses and practice related materials”), cognitive reappraisal (nine items, e.g., “When I am confused, I remind myself that I have successfully mastered previous tasks in math and statistics”), expression (six items, e.g., “To reduce my confusion in class, I openly talk about it”), expressive suppression (six items, e.g., “To reduce my confusion, I don’t let my feelings show”), and other strategies (e.g., relaxation techniques, exercise, taking drugs) (five items, e.g., “When I feel confused about statistics, I calm myself down with food”). For the first part, students were instructed to remember a few situations where they experienced confusion while studying, attending class, or taking a test in statistics and were asked to report how they dealt with that confusion using a five-point Likert scale ranging from 1 “Not true at all” to 5 “Completely true.” Cronbach’s alpha reliability estimates were .74 for competence development, .76 for cognitive reappraisal, .86 for expression, and .84 for expressive suppression. Alpha for “other” strategies was not calculated as it was not a cumulative scale.

For the second part, the items were altered to reflect the current context – solving statistics problems individually. Given that students were not attending class or studying, the items in the expression category were not relevant. The four categories included competence development (nine items, e.g., “To reduce confusion during problem solving, I broke the problem down into smaller parts”), cognitive reappraisal (eight items, e.g., “When I was confused about a problem, I tried to see the situation as a positive challenge), suppression (six items, e.g., “During problem solving, I tried not to show my confusion to not make it any worse), and other strategies (five items, e.g., “When I got confused, I took a deep breath”). Students were instructed to indicate the frequency with which they used each of the strategies to reduce confusion using a five-point Likert scale that ranged from 1 “Never” to 5 “Always.” Cronbach’s alpha reliability estimates were .73 for competence development, .81 for cognitive reappraisal, .88 for expressive suppression, and .74 for other strategies.

Binomial Distribution Lesson

The binomial distribution lesson was written by the primary investigator. The lesson began with an example of flipping a coin followed by guessing a card that is drawn from a deck.

> When a coin is flipped, the outcome is either a head or a tail; when a person guesses the card selected from a deck, the person can either be correct or incorrect; when a baby is born, the baby is either born in the month of March or is not. In each of these examples, an event has only two possible outcomes. If one outcome occurs, the other did not occur. For convenience, one of the outcomes can be labeled a "hit" and the other outcome a "miss."

The mathematical formulas for each of the probabilities of a hit (p) or miss (q) were presented followed by an example. Each component of the full equation was defined, and two sample problems were then presented, “What is the probability of getting exactly 2 heads in 6 tosses of a fair coin?” and “A multiple-choice exam has 10 questions with five possible responses to each question. A student takes the test whereby each question is answered independently. The student gets 6 questions correct and claims that she guessed the answer to each question. Do you believe her? Justify your answer." Each sample question was followed by a step-by-step solution.

Statistics Problems

Students were given two statistics problems to solve and were required to enter their final answer. Because many of the students participated online via Zoom, capturing students' step-by-step solutions was impossible. Once students entered their solution, they could obtain feedback regarding whether their answer was correct. If the answer was incorrect, they were given a second chance to complete the problem. This option was included to provide an opportunity for students to experience confusion (when getting an answer wrong that they thought was correct). Moreover, the problems were progressively more difficult to induce students' confusion. The problems were developed by the primary investigator for university-level students who had taken or were taking statistics courses.

The first statistics problem was a simple binomial problem with two parts for students to solve: "An intensive care unit (ICU) is currently occupied by 12 COVID-19 patients. Of these patients, 10 are unvaccinated and 2 are fully vaccinated. Given this sample, what is the probability of being vaccinated and in the ICU?" The second part of the problem then asked: "Given this sample, what is the probability of being unvaccinated and in the ICU?" The second problem was as follows: "The efficacy of the Pfizer COVID-19 vaccine is about 80%; that is, 80% of those receiving the COVID-19 vaccine will not contract the virus when exposed. Assume that each person's response to COVID is independent of another person's response. Find the probability that at least one exposed person will get COVID if 10 people are exposed."

Intervention

The overall objective of the CEST intervention was to provide university students with learning strategies to resolve the confusion they experienced while solving complex statistics problems. By explicitly modeling learning strategies for students to apply during states of confusion, there is a greater likelihood that the experience of confusion is productive rather than unproductive. Moreover, when students experience confusion, their perceptions of control over learning decrease (Munzar et al., 2021), which may be a contributing factor to the reduction of learning strategies and therefore of learning and achievement. To help students become aware of their state of confusion when it occurs and to successfully apply learning strategies to regulate confusion, students were told this emotion is expected during complex problem-solving tasks and that there are strategies they can use to resolve that confusion. This message may help to normalize the state of confusion and may enhance perceptions of control over the task.

The intervention was as follows. First, students were told to pay attention to the video as they would be asked to summarize the information at the end of the presentation. Students then watched a 15-minute Prezi presentation in which the presenter described the state of confusion in a variety of different learning settings and normalized that state, i.e. "When you experience confusion, this tells you that something is not right. It may mean that you have a mental roadblock or don't understand something…" Next, in accordance with treatment fidelity assessment (Sanetti et al., 2021), the video was paused to allow for the student to answer if they had ever experienced something similar and how they described confusion in their own words. Students were then asked to summarize what they had understood so far. Next, the presenter described a variety of emotion regulation strategies to adopt once they experienced confusion, i.e. "Stop for a moment and take a deep breath. Then think about the problem. Ask yourself, 'what exactly is confusing me?' Identify the source of your confusion. Write it down."

After watching the presentation, students were once again asked to summarize the information from the presentation. They were then given a list of cognitive learning strategies and emotion regulation strategies and were encouraged to refer to the list if they experienced confusion during problem solving. The items in the strategy list were divided into three sub-groups. If students were confused because they did not understand the structure of problem, they were given competence development strategies such as “reread the problem,” “summarize important information,” “ask if you have successfully solved a similar problem in the past” or “identify what information from the problem you know that might help you solve it.” If students were confused because they did not know how to solve the problem, they were given cognitive strategies to help them increase control over the situation such as “identify what is your end goal,” “what might be the first step to solve this problem?,” “break down the problem into smaller parts,” “identify what calculations you need to do,” “once you have made a plan, carry out the calculations” and “check your work.” If students were confused because their plan did not work, they were given metacognitive strategies such as “recalculate to make sure you did not make any mistakes,” “reread the problem” or “refer to previous strategies.”

Specifically, through explicit instruction, the intervention was designed to: (1) describe and normalize the state of confusion; (2) provide cognitive and physiological cues to help students recognize that state and reflect on the cause of confusion; (3) instruct students on cognitive and metacognitive learning strategies they can use to regulate their confusion during problem solving, and, (4) instruct how and when to implement such learning strategies. The intervention titled “*Overcoming Confusion*” was designed for university students, wherein the language of the intervention and context of the problems to solve was adapted from a larger training intervention for fifth-grade students which was comprised of two 90-minute lessons. The images used for elementary students were also removed (i.e., images of emotions, images of a cartoon feeling confused) and the strategy list was updated to include more sophisticated strategies for problem-solving.

Confusion Regulation and Emotions During Problem Solving

To capture students' confusion regulation processes and emotions as they occurred during problem solving, a think-aloud protocol (see Ericsson & Simon, 1998) was combined with an emote-aloud protocol (Craig et al., 2004; D'Mello et al., 2014; Eva-Wood, 2004). This type of protocol provides a more accurate measure of students' regulatory processes, compared to post hoc self-reports of strategies (see Winne & Jamieson-Noel, 2002), and emotions (Craig et al., 2004) as they spontaneously occur in real time. To train students how to think and emote out loud prior to problem solving, students were given instructions on how to think and emote out loud followed by an audio example modeling another student thinking and emoting out loud while solving a short, unrelated, statistics problem. Students were instructed to say everything they were thinking and feeling as they experienced it while solving the statistics problems. If students remained silent for more than three seconds, the research assistant would remind them to continue thinking and emoting out loud. During the think-and-emote aloud session, each student's think-emote-aloud was audio recorded using Zoom audio (for online students) or Camtasia (for in-person students).

Coding

The think-emote-aloud audio recordings were transcribed verbatim, then segmented and coded for confusion regulation processes and confusion. A definition for each code used along with examples are reported in Table 1. Think-emote-aloud protocols ranged from 3 minutes to one hour. The nine items on the competence development subscale of the CRQ were used as a guide to code the same emotion regulation strategies that occurred during problem solving (see Table 1). The other subscale items were not coded as it was not possible to capture those processes using the think-aloud (e.g., suppression, “To reduce my confusion during problem solving, I didn’t let my feelings show”). The nine confusion regulation strategies were coded when students: made a plan, tried to identify what confused them, reread the problem, summarized important information from the problem statement, asked themselves if there was a similar problem they successfully completed in the past that could help them with this problem, checked their work, recalculated, broke the problem down into smaller parts, identified what calculations were needed to solve the problem, and coordinated important information from the lesson. These strategies were explicitly taught as part of the intervention via Prezi and handed out as they solved the problems. Confusion was the only emotion that was coded when students explicitly said that they were confused or that something was confusing (see Table 1). Based on this coding scheme, the primary investigator and five other research assistants independently coded 6 transcripts. Inter-rater agreement was established at 87% and two research assistants coded another 30 transcripts for an inter-rater of 93%. One research assistant coded the remaining transcripts.

Statistics Problem Solving Outcome

Students’ answers to a problem were graded as correct (1) or incorrect (0) with no partial marks since students only submitted final responses (given that some students completed the session online due to COVID research protocols in place at that time). The total score for each student’s response consisted of the sum of the correct answers for each of the two problems. The first problem was worth 33% for the first part and another 33% for the second part. The second problem was worth the remaining 33%. For an answer to be considered correct, students were required to find the correct probability for each question, that being the probability of a hit; 0.16, 17% or 1/6 for the first part of the first problem, the probability of a hit; 0.83, 83% or 10/12 for the second part of the first problem, and 89% or 1-(10^0.8) for the second problem. Students were allowed to take notes and work through the problems using a pen, pencil, and/or computer calculator that was provided to them.

Table 1

Coding scheme for learning strategies in the think-emote-aloud protocol.

Competence Development	Definition	Examples
Made a plan.	State what approach will be taken, what strategy will be used to solve the problem, or what part of the problem will be solved in some sequence. This includes restating plans.	"Oh, actually, let's make a note of how I'm going to check my question. So, don't forget to check. Sum and what that means is I'm going to sum up PP of X = 1, P of X = 2 P of X = 3 for the first couple terms and see if like the limit kind of approaches. My answer is that it's quite a bit of time to mess around with, so let's get to calculating."
Tried to identify what confused me.	Followed by an explicit statement about what confused them.	"Okay, I'm just going to type. 0.027889 equals... [laughs] It's the exact same number! How did that happen?"
Reread the problem.	Re-reading a section of the problem, word for word. Important that it is word for word, otherwise it is summarizing.	"The efficacy of the Pfizer COVID-19 vaccine is about 80%."
Summarized important information from the problem statement.	Summarizing what was just read in the problem statement.	"Receiving the vaccine will not contract the virus, so there's a 20% chance then that they do get the virus if they have the vaccine."
Asked myself if there was a similar problem that I successfully completed that could help me with this problem.	Searching for or explicitly recalling relevant prior knowledge.	"Now I'm actually recalling that previous stats experience. Previous problems I have solved where I needed to do... You don't do P of big X = X, you do P of big X is greater

		than, zero, actually in this case.”
Checked my work.	Monitoring something relative to goals. “Check/review my work/answer” as part of the intervention. Judging whether goals have been met, whether a particular strategy is working, whether the answer is correct, whether the work is neat, etc. Judgment of all facets that fall under monitoring.	“Okay, it is giving me the same number, so, either this is the right answer, or I misunderstood something. This seems very low to me.”
Recalculated to ensure I did not make any mistakes.	Correcting one’s mistakes by going back to redo the same calculations.	“Let me just, I guess, do this again and see if I went wrong somewhere in the calculations... 12 minus 2... Wait, what?”
Broke the problem down into smaller parts.	Assigning values to the equation, performing separate calculations prior to tackling the main problem.	“OK, we have Q, n - X. Of course, X is 0 and n is 10, so we're going to have 0.8 to the power of 10. Excellent.”
Identified what calculations I needed to do to solve the problem.	Making decisions based on the information read about which calculations or set of calculations to perform.	“Alright, so for the next one, except well, changing the value depending on what we are looking for. So, we just take 10 / 12 which will leave you with .83.”
Coordinating important information.	Recognizing the usefulness of information. “Summarizing important information” as part of the intervention.	“So, x, X, oh so X is number of hits, in this case it would be 1. Ah… that’s equal to number of trials, with an ! / a hit, it seems like, which would be 1, and then parenthesis next to it, and 10-1.”

Procedure

The Research Ethics Board (REB) approved the study at each respective university from which students were recruited. Students were randomly assigned to the intervention (n =87) or control (n =79) condition. Participation in the study was completed in one session that lasted up to 90 minutes. After consenting to participate, all students were directed to Qualtrics to begin the study. Upon completion of the perceptions of control, epistemic emotions, and confusion regulation measures, students responded to open-ended questions (e.g., "What is confusion to you?", "What is the experience of confusion like?"). Students in the intervention condition then watched the Prezi video, after which they were prompted to summarize what they understood from the video. Additionally, they listened to the example of someone referring to the strategy list to resolve their confusion before proceeding to the next stage. Students in the control condition skipped this stage. Next, all students were trained on how to think and emote out loud and practiced it with a text and unrelated statistics problem.

Subsequently, all students worked through a lesson on the binomial distribution while thinking and emoting out loud. Finally, students were asked to solve three statistics problems that increased in complexity to induce confusion. Students entered their final answer to each question and had a chance to ask the research assistant for feedback about the correctness of their answer. If their answer was incorrect, they were given a second chance to complete the problem. This was done to ensure there were opportunities for students to experience confusion (i.e., getting an answer wrong can induce confusion; see Di Leo et al., 2019). Once done, students were instructed to complete the same measures at post-test followed by a demographics questionnaire. Students in the control condition were then provided the opportunity to see the Prezi intervention and the strategy list to resolve confusion.

Results

Preliminary Analysis

Normality was first assessed for all variables. Normality was not expected for emotions expressed in the think-emote-aloud (see Di Leo & Muis, 2020). Data were non-normal for all individual learning strategies across countries, combined learning strategies for Canada, S-W (75) = .861, p <.001 and USA, S-W (52) = .886, p < .001, and statistics problem-solving outcomes for Canada, S-W (75) = .711, p < .001, USA, S-W (52) = .673, p < .001, and England, S-W (33) = .611, p < .001. However, skewness and kurtosis values were also examined for normality for emotions, learning strategies to resolve confusion, perceptions of control, and statistics problem-solving outcomes. All variables were within an acceptable range using Tabachnick and Fidell's (2013]) criteria of <|3| for skewness and <|8| for kurtosis.

Levene's test was performed to assess equality of variances for learning strategies and emotions among the participating countries. All tests were statistically non-significant for emotions, indicating that the assumption was met for emotions. For learning strategies, making a plan (F(2, 162) = 25.178, p <.001), and recalculating (F(2, 162) = 4.209, p <.001) were statistically significant and thus violated the assumption for homogeneity of variance.

Emotions at pretest. Students' emotions were measured prior to commencing the problem-solving session to determine whether there were group differences. Analyses revealed no significant differences in self-reported confusion t(164) = −.031, p = .46, Cohen's d = 0, between the control condition (M = 3.08, SD = .971) and the intervention condition (M = 3.08, SD = .905). There were also no significant differences in self-reported anxiety, t(78) = −.301, p = .09 ($M_{control}$ = 2.68, SD = 0.88, $M_{intervention}$ = 2.74, SD = 1.11), d = .06, self-reported boredom, t(78) = −.829, p = .06 ($M_{control}$ = 2.30, SD = 0.15, $M_{intervention}$ = 2.49, SD = 0.91), d = .29, self-reported curiosity, $t(78) = -.720$, p = .773 ($M_{control} = 3.27$, SD = .88, $M_{intervention} = 3.42$, SD = 0.88), $d = .17$, self-reported joy, $t(78) = 0.12$, $p = .14$ ($M_{control} = 2.35$, SD = 1.06, $M_{intervention} = 2.35$, SD = 0.81), $d = 0$, self-reported surprise, $t(78) = -.492$, $p = .98$ ($M_{control} = 2.16$, SD = 1.07, $M_{intervention} = 2.28$, SD = 1.05), $d = .11$, or self-reported frustration, $t(78) = -.320$, $p = .94$ ($M_{control} = 2.59$, SD = 1.14, $M_{intervention} = 2.67$, SD = 1.08), $d = .07$. These results indicate that students in both groups had equal levels of confusion and emotional experiences prior to beginning the study.

Confusion regulation at pretest. Prior to assessing whether students' confusion regulation strategies were equivalent at pretest, we first assessed the factorial structure of the CRQ using Mplus 8.11. Results revealed a good fit of the data to the model, $\chi^2 = 724.34$, $df = 373$, $p < .001$, CFI = .96, RMSEA = .06. Analyses revealed no significant differences in the four subscales of the confusion regulation questionnaire of competence development, $t(164) = -.418$, $p = .40$ ($M_{control} = 3.27$, SD = 1.18, $M_{intervention} = 3.33$, SD = 1.15), Cohen's $d = .05$, reappraisal, $t(164) = -.056$, $p = .60$ ($M_{control} = 2.94$, SD = 1.22, $M_{intervention} = 2.94$, SD = 1.87), $d = 0$, expression, $t(164) = -.298$, $p = .65$ ($M_{control} = 2.86$, SD = 1.20, $M_{intervention} = 2.92$, SD = 1.18), $d = .05$, suppression, $t(164) = .567$, $p = .48$ ($M_{control} = 2.10$, SD = 1.14, $M_{intervention} = 2.00$, SD = 1.12), $d = .08$, and other strategies $t(164) = -.211$, $p = .55$ ($M_{control} = 2.44$, SD = 1.15, $M_{intervention} = 2.48$, SD = 1.11), $d = .03$. These results indicate groups were equivalent in confusion regulation strategies prior to the intervention.

Main Analysis

Table 2 presents a zero-order correlation matrix between all emotions and means and standard deviations for the process and outcome measures are reported in Table 3. To assess the first research question regarding whether students in the intervention condition expressed more confusion as a function of verbal frequency in the think aloud data than students in the control condition, ANOVA results revealed no significant difference between groups. As predicted, there was no significant difference in the frequency of confusion expressed between groups, $F(1, 161) = .057$, $p = .812$, partial $\eta^2 = .000$. To answer the second research question regarding whether students in the intervention condition used more overall cognitive and metacognitive learning strategies to resolve confusion compared to students in the control condition, the frequency of students' verbally expressed learning strategies were summed into one variable. ANOVA results revealed no significant differences between groups, $F(1, 161) = 2.60$, $p = .109$, partial $\eta^2 = .016$. To address the third research question regarding whether students in the intervention condition experienced higher perceptions of control after statistics problem solving than students in the control condition, ANCOVA results revealed no significant difference between groups after controlling for perceptions of control at pretest, $F(1, 162) = .882$, $p = .349$, partial $\eta^2 = .005$.

Next, multiple ANCOVAS were conducted to assess the fourth research question regarding whether students in the intervention condition would better regulate their confusion during problem solving. Results revealed no significant difference between groups in confusion regulation using competence development strategies, $F(1, 161) = 1.083$, $p = .43$, partial $\eta^2 = .007$, reappraisal strategies, $F(1, 162) = 1.697$, $p = .32$, partial $\eta^2 = .010$, suppression strategies, $F(1, 163) = .630$, $p = .54$, partial $\eta^2 = .004$, and other strategies, $F(1, 161) = .848$, $p = .53$, partial $\eta^2 = .005$, after controlling for confusion regulation strategies at pretest. Expression was not included given the laboratory setting which did not allow students to adopt expressive strategies to regulate confusion (e.g., talking to another student or asking for help). To address the fifth research question regarding whether students in the intervention condition experienced more positive and fewer negative emotions, each of the seven epistemic emotions were averaged together with three synonyms that referred to that emotion (e.g., anxiety with nervous and worried). ANOVA results revealed no significant difference between groups in the intensity of confusion, $F(1, 164) = .83$, $p = .449$, partial $\eta^2 = .005$, anxiety, $F(1, 164) = .31$, $p = .668$, partial $\eta^2 = .002$, boredom, $F(1, 164) = .60$, $p = .546$, partial $\eta^2 = .004$, curiosity, $F(1, 163) = 1.19$, $p = .520$, partial $\eta^2 = .007$, joy, $F(1, 163) = .59$, $p = .590$, partial $\eta^2 = .004$, surprise, $F(1, 163) = .73$, $p = .503$, partial $\eta^2 = .004$, and frustration, $F(1, 164) = .75$, $p = .465$, partial $\eta^2 = .005$. Therefore, students in the intervention condition did not experience more positive emotions and less negative emotions than students in the control condition. Finally, an ANOVA was conducted to address the final research question regarding whether students in the intervention condition performed better on the statistics problems than students in the control condition. Results revealed no significant difference between groups on statistics problem solving, $F(1, 164) = .228$, $p = .634$, partial $\eta^2 = .001$.

Supplemental analysis. For further analysis, we examined the correlations between variables (see Table 2). Consistent with Muis et al.'s (2018) hypothesis regarding the role of emotions during complex learning, confusion and surprise were positively related as were confusion and anxiety. As Muis et al. (2018) noted, when an impasse occurs, individuals are likely to experience surprise first, followed by confusion if they perceive that the impasse may be difficult to resolve. Confusion may then transition into anxiety if perceptions of value are high, but control is low. Moreover, confusion was positively correlated with frustration. As Muis et al. (2018) noted, if confusion is not resolved, it transitions into frustration and eventually disengagement. Lastly, consistent with Munzar et al. (2021), confusion was negatively related to perceived control wherein the less control students perceive they have for complex statistics problem solving, the more confusion they experience as they attempt to solve those problems.

Table 2
Zero-order correlations between all variables

	2	3	4	5	6	7	8	9	10
1. Confusion	.064	.182*	.268**	.570**	.631**	-.216**	.222**	-.559**	-.264**
2. Curiosity		-.298**	.387**	.006	-.093	.528**	.193*	.128	-.096
3. Boredom			.092	.194*	.398**	-.128	.007	-.162*	-.129
4. Surprise				.332**	.280**	.431**	.107	.018	-.149
5. Anxiety					.498**	.570**	.109	-.413**	-.183*
6. Frustration						-.187*	.223**	-.511**	-.221**
7. Joy							.081	.314**	.159*
8. Learning Strategies								.085	.078
9. Control									.373**
10. % Correct									

* $p < 0.05$
** $p < 0.01$

Table 3
Means and Standard Deviations for each variable by condition.

	Intervention Condition Mean (SD)	Control Condition Mean (SD)
Statistics Achievement	61.30 (30.01)	59.07 (30.17)
Learning Strategies	26.39 (18.53)	22.08 (15.23)
Perceived Control	3.69 (1.44)	3.52 (1.57)
Confusion (think-aloud)	1.07 (1.65)	1.01 (1.48)
Confusion (self-report)	3.32 (.91)	3.47 (.92)
Curiosity	3.20 (.85)	3.11 (.87)
Boredom	1.99 (.80)	2.03 (.91)
Surprise	2.27 (.87)	2.23 (.96)
Anxiety	2.73 (1.14)	2.83 (1.22)
Frustration	2.63 (1.10)	2.67 (1.18)
Joy	2.09 (.90)	2.12 (1.01)

Discussion

Confusion, or the affect learners experience after cognitive incongruity, can be related to optimal learning outcomes when students appropriately implement learning strategies to resolve it (D’Mello et al., 2014). However, confusion can have detrimental effects on student learning (e.g., Muis et al., 2015, 2018; Lehman & Graesser, 2015; Lehman et al., 2013; Lodge et al., 2018). Recently, researchers have looked at the benefits of confusion resolution on learning outcomes through cognitive strategies (see Arguel & Lane, 2015, Arguel et al., 2017). Although confusion resolution had positive effects on learning outcomes, no research has considered both SRL strategies and emotion regulation skills to resolve confusion during learning. Given this, research calls have been made to teach students at all educational levels appropriate cognitive and emotion regulation skills to resolve confusion (Arguel et al., 2019; Muis, 2015; Di Leo & Muis, 2020).

In response to these research calls, the purpose of this study was to evaluate the efficacy of a cognitive-emotive strategy training intervention (CEST) developed to make university students more aware of their confusion during statistics problem solving, and to equip them with emotion regulation and SRL strategies they can use to recognize, regulate, and resolve confusion during statistics problem solving through explicit instruction. Pekrun’s (2006) control-value theory of achievement emotions, D’Mello and Graesser’s (2012, 2014) affective dynamics framework, cognitive strategy instruction methods (e.g., Montague, 2008; Rosenshine, 1997), cognitive behavioral therapy (Montreuil & Tilley, 2017), and Di Leo and Muis’ (2020) cognitive-emotive strategy training intervention for elementary students served as the foundations from which to develop this intervention. Overall, results were inconsistent with hypotheses: indeed, students’ experience of confusion did not vary as a function of condition, however, students in the intervention condition did not use significantly more metacognitive strategies while solving the problems; did not report higher perceptions of control; did not experience more positive and less negative emotions; did not better regulate their confusion during problem solving, and did not perform better compared to students in the control condition. Each of these results is discussed in relation to the literature followed by a discussion of broader educational implications. Subsequently, limitations and future directions are addressed.

Experience of Confusion

The first research question addressed whether students in the intervention condition would experience more confusion compared to students in the control condition. Given that confusion arises out of cognitive incongruity, cognitive disequilibrium, or impasses during learning (see D’Mello & Graesser, 2012; D’Mello et al., 2014) and students were exposed to the same statistics problems, we did not expect their confusion levels to differ between the intervention and control groups. Rather, students in the intervention condition were expected to respond differently to confusion after being equipped with self-regulatory strategies to regulate and resolve confusion both at the cognitive and emotive level. In line with our hypothesis, students in the intervention and control conditions reported no significant differences in their experience of confusion while solving the statistics problems. Research findings attest to confusion's positive effects on learning when resolved (Arguel & Lane, 2015, Munzar et al., 2021). Accordingly, the aim of this intervention was not to reduce students' experience of confusion, as confusion is a normal cognitive and affective process that occurs during complex learning tasks and other circumstances of daily life. Instead, the goal of this intervention was to normalize the experience of confusion during complex learning tasks and equip them to successfully resolve it.

Self-Regulated Learning Strategies

The second research question addressed whether students in the intervention condition would apply more cognitive and metacognitive strategies to resolve confusion during problem solving. Previous research has shown the effectiveness of cognitive strategy instruction for improving students' repertoire of self-regulatory strategies, strategic knowledge, application of strategies, and problem-solving performance and accuracy (see Di Leo & Muis, 2020; MacArthur, 2012; Montague et al., 2011). Consistent with this literature, the intervention modelled cognitive strategies and instructed students to apply metacognitive strategies when confused during problem solving. It was expected that students in the intervention would retain and apply these strategies during problem solving. However, students in the intervention condition did not use significantly more overall cognitive and metacognitive strategies than students in the control condition during problem solving. Besides modeling new learning strategies for students, a crucial aspect of promoting SRL is to provide students the opportunity to practice the newly acquired skill with scaffolding and feedback repeatedly in a "low stakes" environment. Unfortunately, the laboratory nature of the intervention did not allow students the opportunity to practice their recently acquired knowledge like they were in Di Leo and Muis' (2020) successful intervention with elementary students, which was implemented directly in students' classrooms with authentic learning tasks.

Perception of Control

The third research question addressed whether students in the intervention condition would report higher levels of perceived control after solving the statistics problems. Students in the intervention condition watched a 15-minute Prezi video that normalized and explained why confusion arises during learning and were modelled cognitive strategies to adopt when confused. The intervention messaging included having control when confused. This message should have helped increase students' perceptions of control coupled with training of the various strategies they could employ when confusion occurred.

Following Munzar and colleagues' (2021) findings, we expected that the successful regulation and resolution of confusion would increase students' perception of control after completing the statistics problems. Aligned with Pekrun's (2006) control-value theory of achievement emotions and results from Di Leo and Muis' (2020) study, we also expected students with higher perceptions of control to experience more positive and less negative emotions. Because students' emotions during the learning process are also said to predict the learning strategies they use, we also expected students with higher perceptions of control to use more appropriate learning strategies to regulate (emotive) and resolve (cognitive and metacognitive) confusion during problem solving. However, contrary to our hypothesis, students in the intervention condition did not report higher levels of perceived control compared to students in the control condition.

One of the possible reasons students' perceptions of control did not increase after the intervention is that for perceptions of control to increase students must acquire the new self-regulatory skills through scaffolding and have ample opportunity to practice those skills. Upon successful implementation of their new skills into regular practice, it is expected that students' perception of control over a learning task will increase. However, given the constraints of the laboratory settings in which this intervention was conducted, students were not provided with opportunities to practice these new skills. As a result, students who participated in the intervention did not demonstrate higher perceptions of control during problem solving compared to students who did not receive the intervention.

Additionally, it is important to mention that this intervention was adapted from Di Leo and Muis' (2020) intervention with elementary students in which the researchers worked with students for three days over training sessions of 90 minutes. The current intervention was composed of a 15-minute Prezi video that modelled confusion regulation strategies. While Di Leo and Muis' (2020) intervention provided scaffolding opportunities through extended periods of training where students could ask questions, it was also targeted at elementary students, many of which were learning emotive and cognitive learning strategies for the first time. In the current study, aside from the shortened time of the intervention without opportunity for scaffolding or asking questions, students were adults, many of whom had already established learning habits and attitudes about statistics problem solving. It may be that the intervention did not provide enough time for students to integrate the new information into existing mental models (Piaget, 1952). As a result, students' perception of control over statistics problem-solving remained relatively the same after solving the problems.

Confusion Regulation

The fourth research question addressed whether students in the intervention would better regulate their confusion during problem solving, but no differences between groups in confusion regulation strategies occurred. From Gross' (2015) process model of emotion regulation and the ERAS model (Harley et al., 2019), we created a Confusion Regulation Questionnaire to measure students' use of emotion regulation and SRL strategies to regulate and resolve confusion. The items in the questionnaire represented students' use of competence development, cognitive reappraisal, suppression, and other strategies. The intervention targeted *competence development* as students were given strategies to make a plan for resolving the confusion (e.g., 1. "Identify the end goal. What are you trying to figure out? 2. Ask yourself, what is the first step you have to take to figure out the problem?); *cognitive reappraisal* through the Prezi video explaining that confusion is the emotion people most experience when solving complex problems and that it is normal to experience confusion and confusion can be beneficial; and *other strategies* through the Prezi video explaining to students that when confused, they can take a deep breath and remind themselves that they have control over their learning. However, the suppression element of the Confusion Regulation Questionnaire was not included in the intervention, as students were not instructed to suppress their confusion during problem solving.

It is possible that some components of the questionnaire did not reflect the strategies students used for solving the problems, therefore not reflecting the intervention's efficacy on student strategies. For example, some students did regulate their confusion at the emotional level and attempted to follow the steps to resolve confusion using cognitive strategies, perhaps just not enough. Indeed, our sample size was small, and power was lower than the expected .80. Moreover, some students did not have the appropriate mental representation of statistics problems, or the problem perception that was needed to solve the problems, which made confusion resolution impossible despite having the lesson provided to them. Recall that Schoenfeld's (2016) definition of problem-solving includes having the requisite tools to solve a problem in which the solution is not obvious at first.

Schoenfeld (2014) distinguished mental representation as influencing how students perceive problems, and that the quality of mental representation of problems improves problem perception, which in turn is a "tool" that supports mathematical problem solving. That is why students who have problem representations can "see" how to solve a problem, whereas students who do not have such representations are left wandering. Problem perception improves as students solve more problems (Schoenfeld, 2014), so if students did not already possess a problem representation that was sufficient to solve the statistics problems they were given, it is unlikely that they would be able to develop it within the single lesson of our intervention. Indeed, students might have lacked the appropriate problem representation required to solve the exceptionally challenging statistics problems they were given, reflected in the low average score. We needed to elicit confusion from students, but maybe confusion was simply too high, or the complexity of the problems was too great.

Emotions

The fifth research question addressed whether students in the intervention would experience more positive and less negative emotions. Contrary to our hypothesis, students in the intervention condition did not experience more positive emotions and less negative emotions compared to students in the control condition. Based on Pekrun's (2006) control-value theory of achievement emotions, we expected students who perceived to be more in control over statistics problem solving to experience more positive and less negative emotions. As previously discussed, the intervention was not effective in increasing students' perception of control and, as a result, there were no differences in students' experience of emotions nor on their use of SRL strategies. Additionally, based on Gross' (2014, 2015) model of emotion regulation, it is possible that students who experienced confusion were not able to successfully regulate that state, thereby causing them to fall into the negative loop of confusion-to-frustration-to-boredom and disengagement from the task. In Di Leo and Muis' (2020) intervention, students experienced more positive emotions and less negative emotions, but they also used SRL strategies. The successful application of those strategies to resolve confusion may have caused more positive emotions and less negative emotions, indicating that students in their intervention likely fell into the positive confusion-to-engagement loop. Since students in the current intervention did not resolve confusion more than students in the control condition, the indirect effects of experiencing more positive emotions and less negative emotions were also not present.

Statistics Problem Solving Outcomes

The sixth question addressed whether students in the intervention would score better on the statistics problems. Contrary to our hypothesis, students in the intervention did not perform better than students in the control condition. The combined intervention targeting normalization and awareness of confusion with cognitive and metacognitive strategies that student could use while confused during problem solving were expected to increase students' regulation and resolution of confusion. The resolution of confusion was expected to increase students' perception of control and the experience of positive emotions. While unresolved confusion is found to be detrimental to learning (D'Mello et al., 2014), we expected that successful regulation and resolution of this state would result in better performance during problem solving (see Arguel et al., 2019; Munzar et al., 2021). However, as we have seen, the intervention was not successful in increasing students' confusion resolution and therefore perception of control and use of more cognitive or metacognitive strategies, which resulted in no effects on students' performance. Additionally, given the complexity of the problems, we may have a floor effect.

Importantly, Executive Function (EF) also called cognitive control, is "the deliberate, top-down neurocognitive processes involved in the conscious, goal-directed control of thought, action, and emotion–processes that include cognitive flexibility, inhibitory control, and working memory" (Miyake et al., 2000). Given its overlap with the skills needed to engage in self-regulated learning, it is likely that EF serves as the underlying cognitive process that allows students to engage in self-regulation during learning. Zelazo and Carlson (2012) distinguished "hot EF," which occurs in situations where people are motivated or emotionally involved, and "cold EF," which occurs in more neutral, abstract contexts. This distinction is important because they suggest that motivationally significant contexts also demand different cognitive control processes. It is beyond the scope of this study to mitigate how "hot/cold" EF development might have impacted students' performance, but it suffices to note that "hot EF," associated with motivated and emotionally relevant contexts develops later than "cold EF." Relevant to this study, adult learners might not have been motivated or sufficiently involved with the task conducted in a decontextualized environment and relied on "cooler" EF, which is also harder to change since human cognition has "sensitive periods" in which the brain is more plastic and susceptible to environmental influences (Zelazo & Carlson, 2012). This may also explain why the original intervention with elementary students was successful. First, younger students would get bonus points towards their final grades if they performed well on the problem-solving tasks (stimulating use of both "hot" and "cold" EF) and secondly, they were also at the ideal age to be instructed on "cold EF" measures such as competence development, cognitive reappraisal, metacognition, and other such skills important for successful self-regulated learning.

Educational Implications

There are a few educational implications of this research. First, there are numerous initiatives to teach students emotion regulation and emotional awareness in and out of classrooms (Broderick & Frank, 2014; Metz et al., 2013; Montreuil & Tiley, 2017). However, this intervention is unique in that it aimed to teach university-level students emotion regulation skills that are particular to the SRL process. In fact, although the laboratory setting provided opportunities for individual training and to capture students' thought processes in real time, each student's level of emotion regulation, use of learning strategies, motivation to understand and complete the problems, and attitude towards the intervention may vary and impact the result of the intervention. Nonetheless, it is important for researchers interested in the effects of confusion resolution to learning outcomes to also consider emotion regulation and emotional awareness during learning processes. Additionally, teaching students how to regulate their confusion through emotional awareness remains an important element of the confusion resolution process.

Second, knowledge of statistics and statistics problem solving is complex and can be challenging for university students (Muis & Duffy, 2013). As such, it is important that students can work through statistics problems by breaking them down and identifying what elements of the problem they do not understand. In our data, we saw a significant number of students who began the problem-solving section with phrases such as "I am not a statistics person, so we will see" or "I've always been bad at stats" which demonstrates the negative attitude towards statistics. Since statistics is a challenging topic for most students (Muis & Duffy, 2013), future research that aims to improve statistics problem solving outcomes must consider how each student comes in with a different perception of their capabilities, motivation, and attitude. Interventions designed in laboratory settings might benefit from providing more opportunities for students to practice their knowledge and ask questions so that the intervention is beneficial for students to learn new skills.

Limitations and Future Directions

The results of the current study contribute to the literature on understanding the complex relations between emotion regulation and SRL applied to confusion to improve students learning outcomes. Some limitations of this study might help clarify what future research may address differently to develop more effective interventions for confusion regulation and resolution with university students solving complex statistics problems. One limitation to this intervention is that students worked through a lesson and then solved statistics problems in a laboratory setting that did not fully reflect their learning dispositions and habits. For example, in a classroom environment, students would have the opportunity to ask questions to clarify their doubts or socially regulate their emotions, and if studying at home they would be able to consult the internet for information or to share their questions in online platforms. The fact that students did not have ample opportunity to scaffold the new information they acquired nor were able to ask questions they had may have created a “test-like” atmosphere that could have negatively impacted students by creating anxiety and frustration in the face of unresolved confusion. Future research may benefit from authentic learning environments that allow students to work with meaningful content using the full extension of their abilities and learning dispositions, thus creating more ecological validity for interventions.

Additionally, students’ scores were graded with correct (100%) or incorrect (0). This may not have fully captured the effect of the intervention on students’ progress through the problems. For example, some students did follow the given strategy list and diligently tried to resolve their confusion. However, they still did not get the answer correct, and their progress did not translate to better learning outcomes. Future research might benefit from considering students' engagement in the process of confusion resolution instead of only looking at their final answer. In this intervention, it became clear that prior knowledge of statistics' facts and rules were a determinant in students' performance outcomes. Because students could not use external resources to resolve their impasses, there were cases in which they successfully regulated their confusion at the emotional level and correctly followed the steps to resolve it cognitively, but missing important information prevented them from resolving confusion. Although emotion regulation skills and self-regulated strategies are important for confusion resolution, having access to scaffolding opportunities and accurate information is equally important, as we saw from students who succeeded in regulating confusion with the information available but still got the wrong answer.

Moreover, the intervention time was a major limitation. Recall that the current intervention was based on Di Leo and Muis' (2020) cognitive-emotive strategy training intervention designed for elementary students (10-12 years old), in which the students attended two 90-minute lessons that incorporated interactive activities such as brainstorming, modelling of each learning strategy by the primary investigator, and opportunities for students to practice the strategies while solving short and simpler problems. The current intervention was designed for a lab environment, so students from different statistics courses participated individually, and had no practice opportunities to develop the learning strategies they were taught. Additionally, the current intervention was comprised of a single 90-minute session, which may have had too much information (binomial distribution lesson, emotion regulation modelling and strategies, think aloud training, cognitive learning strategies modelling, and problem solving) and too little time to practice these skills before testing their performance. Especially given that adult learners' plastic phase of cognitive development has passed, they may need more time and opportunities to practice in a meaningful context to improve their cognitive control abilities such as metacognition and regulation, which reflect on self-regulated learning skills. In the future, it will be crucial to design interventions with ample practice opportunity and at different time points to assess meaningful change.

Conclusion

The aim of this study was to evaluate an intervention designed to help university students regulate and resolve confusion using emotion regulation and SRL strategies during complex statistics problems. Previous research on confusion in academic settings has looked at the benefits of confusion resolution to learning outcomes using cognitive strategies (Arguel et al., 2017) but to date, no intervention has examined the influence of emotion regulation in SRL processes during experiences of confusion. Therefore, this research broadens the literature by incorporating considerations of emotion regulation in cognitive instruction for students in a state of confusion during problem solving. We explored whether the intervention helped students better regulate and resolve their confusion by increasing emotional awareness, using more cognitive and metacognitive strategies and by increasing students' perception of control during problem solving. Results from the study showed that the intervention was not effective in helping students regulate their confusion through emotive or cognitive strategies. However, much remains to be done to better understand the process of being confused.

This research responded to a call by Lehman and Graesser (2015) and Muis and colleagues (2015) concerning the need to investigate the confusion resolution processes of students as they solved complex problems, along with emotion regulation and SRL strategies that accompany these processes. Perceptions of confusion vary from student to student, so naturally, awareness and resolution of this state will also consist of different elements and strategies. Different than previous studies on confusion resolution that induced confusion by providing students with contradictory or false information (see D'Mello et al., 2014; Lehman et al., 2012), this study induced "organic" confusion as they solved statistics problems, meaning that each student could be confused about a different element of the problem that was not foreseen by the researchers. In this way, the process of confusion resolution also varied widely from student to student. Nonetheless, a first step to promoting constructive confusion is to continue efforts to normalize this state and provide students with opportunities to be organically confused and work through that confusion with adequate support (scaffolding opportunities and immediate feedback) in an environment where they feel safe (can ask questions and share their emotions). Additionally, given the complexity of confusion, it is important that future research continues to look at the emotive and cognitive aspects of this phenomena as we saw in our study that solving only one of its aspects was not translated to a learning benefit. This study was the first to include emotions and target confusion within an intervention for statistics problem solving among university students. However, given that there were only two conditions, (i.e., intervention and control), more work is needed to assess whether the emotive or cognitive aspects of the intervention worked better. As such, it is recommended that future research include three experimental conditions, i.e., cognitive-emotive strategy instruction, cognitive strategy instruction only, and emotional awareness/regulation training only. Future research must address these considerations.

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