How ”What Might Have Been” can Shape What’s Yet to Come: Preliminary Evidence for Counterfactual Thoughts as an Intervention in Early Engineering Courses

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Abstract

Students often struggle in first-year courses required for engineering majors, with up to 30% of students in some of these courses earning lower than a C. Previous research suggests students may develop study skills too late in the semester to get on track in these courses. The goal of our project, funded by NSF's Engineering Education program in the Division of Engineering Education and Centers, is to leverage research in cognitive science to develop an intervention to increase rates of successful completion in these early courses. Specifically, previous research suggests that counterfactual thoughts, which identify how things "might have been" different than they really were, can increase intentions for future behavior and improve future outcomes. Generating counterfactuals after an early course setback may thus be a useful strategy for overcoming these challenges and getting back on track in the major. We therefore examined whether students generated counterfactuals about exam performance, and the conditions under which these thoughts were associated with improved course performance.

Literature Review

After negative events, individuals frequently wonder how things might have turned out differently. *Counterfactual thoughts* are a form of mental simulation that compares reality to an imagined alternative. Although these thoughts can also imagine how things could have been worse (known as *downward* counterfactuals), more commonly people's thoughts about negative events are drawn to how things could have been better, known as *upward* counterfactuals [1]. (Given that upward counterfactuals are substantially more common than downward in daily life [2], and that these thoughts involve distinct patterns of emotions and motivations [3], in the current research we focus exclusively on upward counterfactuals.) Counterfactual thoughts play an important role in causal reasoning, motivation, and planning. In the current research, we therefore examine whether students' counterfactual thoughts about their first exam in a course predicts their subsequent behavior and performance in the course.

Counterfactual thoughts play an important role in causal reasoning [4]–[6]. If an individual has the thought "if traffic hadn't been so bad, I wouldn't have been late," this implies that the cause of the tardiness was traffic and not the individual's departure time, speed, route, etc. For this reason, counterfactuals can play an important role in judgements of blame and responsibility [7]. In turn, this means they also influence performance by affecting behavioral intentions and motivation[8].

Behavioral intentions are plans to enact a specific behavior in the future. They differ from more general goals in that they specify an action that will be taken, rather than a desired end result. For instance, someone may have a goal to run a marathon; the behavioral intentions involved in doing so may be "follow a daily training plan","find a local running club to train with", "register for the marathon" and so on. Behavioral intentions are particularly useful when a goal is either complex and needs to be broken into component steps to achieve or when a goal is simple but requires self regulation. For instance, a student in a course with a major final project will be more successful if they form intentions for each of the component steps, rather than simply having a goal to "do well on the project" without more specific plans [9]; a student in a course with a heavy reading load may need to form the intention to do a little reading every day, rather than trying to push through several weeks of reading in a single weekend [10].

Counterfactuals facilitate behavioral intentions [11], [12]. Because they identify a possible cause of the outcome ("If I'd read the textbook, I wouldn't have missed that question"), they offer insight for future behavior ("In the future, I will be sure to review the textbook and not just my lecture notes before an exam"). The effect of counterfactuals on intentions is strongest when the intentions concern a specific, controllable behavior ("read the textbook"), rather than a trait ("be more conscientious") or more general behavior ("study more") [13]. Moreover, a specific counterfactual can facilitate a different but related intention (e.g. "If only I had read the textbook" can facilitate "in the future I will do practice problems"). Thus, given the role of behavioral intentions in goal pursuit, one way that counterfactuals can improve performance is by increasing relevant behavioral intentions.

Upward counterfactuals are particularly likely to be generated when individuals are motivated to self-improve [1], [3], [14]. In turn, counterfactuals can also increase motivation to pursue a goal. Upward counterfactuals following a failure generally lead to negative emotions, including regret [15], [16]. Individuals often respond to this negative affect by increasing effort to meet the threatened goal [15], [17]. For instance, individuals process nutrition labels more carefully after generating health-related counterfactuals [18]. Thus, generating counterfactuals about the first exam in the course may lead students to engage with the course more thoughtfully and effortfully, and therefore increase course grades.

Self-efficacy, an individual's belief that he or she is able to achieve a desired outcome, plays an important role in goal pursuit. When faced with a challenge or set back in attaining a desired goal, individuals must decide whether to increase effort to attain the goal or to disengage from pursuing the goal. Individuals must believe that goal attainment is possible in order to continue pursuing the goal (versus disengaging) [19]–[21]. Self-efficacy is particularly important in academic contexts. In fact, self-efficacy predicted engineering majors' GPA above and beyond high school GPA and SAT scores [22]. Likewise, self-efficacy predicted persistence in engineering majors above and beyond interest and college GPA [23]. Moreover, some research suggests that contextual factors such as social support have an effect on whether students pursue the engineering major primarily via the impact of these factors on students' self efficacy [24],

[25]. The importance of self-efficacy in both major choice and performance makes gender [26] and racial and ethnic [22] disparities in self-efficacy particularly problematic.

Because counterfactuals imply a cause for a negative event, they can increase a sense of personal control over an outcome [27], [28]. Generating upward counterfactuals following the first exam exam in the course led to students reporting a greater sense of control over their performance on the second exam [29]. That is, having the thought "if I had done practice problems, I would have done better on the exam" suggests that the outcome of the exam was at least in part under the individual's control; the fact that the cause is a specific action, rather than a stable trait (cf. "if only I were smarter") suggests the student's exam performance could change in the future if the antecedent behaviors were different. This is true even if individuals generate counterfactuals about outcomes that are not themselves changeable [30]. Thus, by increasing efficacy, counterfactuals may improve performance.

Counterfactuals therefore appear to offer a number of possible benefits to student performance following initial failure. The ability to overcome initial setbacks is particularly important given that in introductory cognate courses at our university in which engineering majors must earn at least a C, nearly 30% of students earn a D, F, or withdraw with a transcript notation. This poor performance in early courses can delay the time to degree, imposing financial burdens on students and families, and may contribute to attrition from engineering; engineering students who exit the major are more likely to have failed or withdrawn from first year courses [31]. The study skills that are critical to student success in engineering [32] are often addressed too late to help students stay on track in their first semesters of college [33].

Ideally, students would respond to initial poor performance in a course by developing new strategies to improve performance and successfully pass the course and stay on track in the major. Counterfactual thoughts are an important and functional means of responding to failure in a way that increases the likelihood of future success. In the current research, we investigate whether students who generate upward counterfactuals after the first exam facilitate intentions, increase effort, and/or foster self-efficacy, as well as whether students are ultimately more likely to successfully pass the class. We therefore investigate two sets of research questions:

Question 1a: Are students who generate counterfactuals more likely to identify behavioral intentions in the course?

Question 1b: Do students who generate counterfactuals engage in more effort in the course?

Question 1c: Do students who generate counterfactuals increase their self-efficacy in the course?

Question 2: Are students who generate counterfactuals more likely to successfully complete the course with a C or better?

Method

The present research is part of a larger longitudinal study (*NSF EEC 1530627*). The analyses presented here are new; however, other data from this study have been presented in previous work and other work in these Proceedings [34], [35], and similar descriptions of the population, materials, and procedures appear in those works.

Participants

Students at a mid-sized state university in the midwest of the United States who were enrolled in calculus-based physics were contacted in the first month of the semester and invited to participate in a series of paid surveys. In the present research, we include only the 120 students (Age M (s.d.) = 18.37 (0.56); 75 male, 45 female; 107 white, 8 African American, 3 Native American, 8 Asian or Asian American; 9 Hispanic) who indicated that they had either declared or intended to declare a major in engineering.

Procedure

1) Intake survey. Participants clicked on a link in the invitation email to access the survey. Participants first provided informed consent for the surveys and a FERPA release allowing access to their course grade and other educational information. Next, they provided demographic information including their age, racial and ethnic identity, and gender. Participants then indicated their current year in school, whether they were currently a major in the College of Engineering and Computing, intended to declare a major in engineering/computing, or were/intended to major in another university division. They indicated their SAT/ACT score, high school GPA, their highest level of high school physics and mathematics, and whether they had taken an AP and/or an IB exam in Physics or Mathematics and their score(s) if so.

Participants then completed additional measures unrelated to the present research questions.

2) Post-exam survey. Participants who had completed the intake survey received an email invitation to take the follow-up survey using a link provided in the email. Participants indicated whether their exam had been returned; students who indicated that the exam had not been returned were instructed to wait to take the survey until after it had been returned. Participants provided their exam grade as a numerical percentage (0-100).

Participants were asked to complete a brief writing task about the exam. Participants were prompted “After an exam, students often can’t help thinking about the exam: how they did, what they did or didn’t do to prepare, how they might have done better or worse. In the space below, we’d like you to briefly describe the thoughts you have about the exam right now, at the present moment.” Each written response was reviewed by two trained coders. Responses were coded as a counterfactual if the participant made a statement that both identified an antecedent event that differed from reality and that included a comparison to reality. Thus “I didn’t go to the review session” would not be coded as a counterfactual, as this was a factual statement, but “I should have gone to the review session” identifies an action not taken and suggests that reality would have been better had the action occurred, and would be coded as a counterfactual. Disagreements were resolved by the first author.

Participants were then asked to what extent their thoughts were focused on upward counterfactuals focused on their own actions (“Right now, my thoughts about Exam 1 are focused on… how things might have been better if I had done something differently") as well as other possible foci.

Next, participants' self-efficacy was measured with 7 items (alpha = .92), each measured on a 7 point scale with Likert response options "Strongly disagree", "Disagree"; "Somewhat disagree"; "Neither agree nor disagree"; "Somewhat agree"; "Agree"; "Strongly agree". : "I am doing well in the course"; "I am doing poorly in the course" (reverse-scored); "I feel like I can successfully complete the course with a C or higher"; "I'm not sure that I can pass the course" (reverse-scored); "I'm thinking of dropping the course" (reverse-scored); "It is possible for me to succeed in this course"; "I'm confident that I can get the grade I want in this course". Participants were asked to indicate how much they agreed with each statement as they thought about the course "right now, in the present moment." Participants completed additional measures unrelated to the present research questions.

Finally, participants were asked to write about the future. Participants were prompted "We are interested in your thoughts and feelings about this course in the remainder of the semester. In the space below, please describe your thoughts and feelings about the remaining weeks in the course. What do you hope or expect that you, your classmates, and your instructor may do?" Each written response was reviewed by two trained coders. Responses were coded as an intention if they identified a specific action that the author was going to personally take. Thus statements like "I hope it gets easier to keep up with the reading" or "I'm worried that I'm going to keep having problems understanding the examples" would not be coded as an intention, as there is no action the writer has identified himself or herself as taking, whereas "I'm going to be sure to review my notes right after class and add anything I missed" would be coded as an intention because a personal action was identified. Disagreements were resolved by the first author.

3) Follow up survey. Approximately 1 month after the post-exam survey, all participants who completed the post-exam survey were emailed an invitation email with a link to a follow up survey. Participants completed a rating unrelated to the present research and then rated their current efficacy in the course using the same measure in the previous surveys, with the exception of the item asking if participants were considering dropping the course (alpha = .93).

Participants were shown a list of 19 different behaviors of varying relevance to the course (e.g., "Read the textbook"; "Done additional practice problems"; "Posted a question to an online discussion forum, e.g. [campus LMS system], Piazza"; "Gone to the [campus] Writing Center for an assignment in this class"). Participants were instructed "Different students adopt different strategies in their courses. Below is a list of things some students might or might not do in different courses. We are interested in the things you are and are not doing in [your physics course]. Please ONLY indicate the things you've done in [your physics course], not any other courses you are taking. Think back over the past 2 weeks. Have you done any of the following things in [your physics course] during the past 2 weeks? Please give your best estimate of how many times you've done each of these things." Participants indicated how often they had engaged in each behavior in the past 2 weeks using a rating scale with options "Haven't done"; "1 day"; "2 days"; "3 days"; "4 days"; "5 days"; "More than 5 days". Ratings of these 19 behaviors were averaged to provide a composite measure of effort in the course (alpha = .81).

4) Instructor data. After the grade submission system had closed for the semester, instructors were contacted with a list of participants and asked to provide the final letter grade in the course for each student. Grades of C or better were dummy coded as 1 and grades below a C as well as students who had dropped the course were dummy coded as a 0 in a variable indicating whether students had successfully completed the course.

Results

We first examined 3 possible means by which counterfactuals might impact performance: intentions, effort, and efficacy.

The first counterfactual mechanism we explored stemmed from Question 1a: Are students who generate counterfactuals more likely to identify behavioral intentions in the course? We therefore conducted a chi-square analysis of the association of whether the participant had identified an intention (yes vs. no) and successful course completion (yes vs. no). As predicted, counterfactuals had a significant effect on intention generation (chi-square(1) = 4.55, p = .03): 55.9% of students who generated a counterfactual identified a personal intention, compared to 31.8% of participants who did not. Consistent with past research, counterfactuals increased the likelihood of intention generation.

We next looked at Question 1b: Do students who generate counterfactuals engage in more effort in the course? Contrary to predictions, students who had generated a counterfactual did not report engaging in significantly more effort in the course (Ms (s.d.) = 3.04 (0.85) vs. 2.84 (0.71)), t(59) = 1.03, p = .31.

Finally, we examined Question 1c: Do students who generate counterfactuals increase their self-efficacy in the course? Contrary to predictions, students who had generated a counterfactual did not report greater self-efficacy either immediately after the exam (Ms (s.d.) = 5.52 (1.13) vs. 5.46 (1.22), t(76) = 0.21, p = .84) or one month later (Ms (s.d.) = 4.58 (1.50) vs. 5.01(1.28), t(59) = 1.20, p = .24).

The final goal of this study was to answer Question 2: Are students who generate counterfactuals more likely to successfully complete the course (i.e., with a C or better)? To examine this, we conducted a chi-square analysis examining the association between counterfactual generation (yes vs. no) and successful course completion (yes vs. no). 80.8% of participants who had generated a counterfactual focused on their own actions successfully completed the course, compared to 75.7% of participants who did not list a counterfactual; this difference was not significant (chi-square(1) = 0.23, p = .63). We also conducted a binary logistic regression of the successful completion variable on both the normalized exam grade and on the counterfactual thought dummy variable to control for initial exam performance. Students who generated a counterfactual had approximately 50% higher odds of passing the course (Odds ratio = 1.55, B(std. error) = 0.44 (0.69)), though this effect was not statistically significant (Wald Chi-square (1) = 0.40, p = .53).

Discussion

This study provided an initial, correlational investigation of the impact of counterfactuals on course performance in a pre-engineering course with a high rate of students not successfully completing the course with the minimum required grade. Although counterfactuals were associated with greater rates of generating behavioral intentions, they were not significantly associated with greater efficacy, effort, or ultimately with successful completion of the course.

There were a number of issues with the current research that may have hampered our ability to draw causal conclusions. Most substantially, the current data suffered a lack of statistical power. When we eliminate participants who were not intended engineers, only 78 participants completed the post-exam survey that measured counterfactuals. Given that course completion is complex and multiply determined, and thus statistically "noisy", it seems almost certain that we lacked adequate power to detect an effect at any likely magnitude (in fact, we had under 12% power to detect an odds ratio of 1.5 given the current sample size). Moreover, it is important to note that this research is correlational in nature. Although counterfactuals were associated with intentions, it isn't possible to make a causal conclusion in the present data. It is possible that a third variable, such as student conscientiousness or the willingness to engage in the writing tasks, increased both counterfactuals and intentions simultaneously. Thus, we are currently conducting a larger-scale experimental investigation in which participants are randomly assigned to write about counterfactuals or not in order to directly determine the effects of these thoughts on performance and motivational variables.

Although counterfactuals were significantly associated with intentions, as predicted, they were not associated with efficacy, effort, or course completion. It may be the case that counterfactuals offer less benefit to students with relatively strong initial performance, as these students both have less room to improve and, if they accurately perceive their performance, should experience greater efficacy in the course independent of any counterfactual thoughts. If this is the case, counterfactuals would not show an overall effect because they are most effective after setbacks (i.e. only have a positive effect for students with poor initial performance). Again, the small sample size means that we lack adequate statistical power to test the possible moderating effects of initial poor performance, but we hope to examine this in the larger-scale intervention currently underway.

In sum, this research offered some evidence that counterfactual thoughts about "what might have been" in past performance could play a role in students' intentions about what is yet to come in the course. Contrary to predictions, these effects did not extend to students' ratings of efficacy or to their behavior or success in the course. Future research will continue to explore whether counterfactuals can offer a useful strategy to increase student success in engineering majors.

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