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# A Growth-Theory-of-Interest Intervention Increases Interest in Math and Science Coursework Among Liberal Arts Undergraduates

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College students are often urged to "find their passion," but if students believe that passions or interests are fixed, they may not develop interest in fields beyond the academic identity with which they enter college. Can a brief intervention that portrays interests as developable, not fixed, boost interest, and even grades, in mandatory math and science coursework among students who do not identify as a "math or science person"? This would be especially significant because college provides the foundation for developing skills and interests that guide later professional paths. After a successful pilot study at a small liberal arts college ($N = 175$), we conducted a randomized, controlled field-experiment with matriculating first-year undergraduates ($N = 580$) in the school of arts and social sciences of a large university. Students completed a 30-min growth-theory-of-interest (vs. control) online module before starting school. At the end of their first and second semesters, they reported their interest in their two required first-year math/science courses. Official final grades were obtained at the end of the year. As predicted, among those who entered college less identified with math and science, the intervention (vs. control) increased interest and final grades in both first-year math/science courses (one conditional effect was marginal). The results suggest that by representing interests as not merely "found" but as having the potential to grow, colleges can encourage the development of skilled, interdisciplinary scholars.

***Educational Impact and Implications Statement***

This study showed that colleges can benefit students by representing interests as developable, not as fixed and unchanging. Before starting college, incoming first-year students completed an intervention (a 30-min online module) that promoted this mindset through reading and reflective writing exercises. Among students who did not consider themselves to be "a math or science person" before college, the intervention led to greater interest and higher achievement in mandatory math/science courses across the first year of college, as compared to students who had completed a control module on an unrelated topic. These results suggest that colleges can help their students achieve in science, technology, engineering, and math areas by encouraging them to *develop* their interests, rather than allowing them to believe that interests are found fully formed.

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The method, materials, and hypotheses for the pilot study were preregistered at https://osf.io/r5ua4 (prematriculation) and https://osf.io/bdavz (follow-up). The method, materials, and hypotheses for the Main Study were preregistered at https://osf.io/ad4vx (prematriculation), https://osf.io/c9zu3 (Semester 1 follow-up), and https://osf.io/7nyvp (Semester 2 follow-up). To view Method, Participants, and Hypotheses components, select "Components," then the desired component, then "Wiki." To view study materials, select the Materials component, then "Files," then "Archive of OSF Storage." The data reported in this manuscript are available at https://osf.io/dg57z.

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The data are available at https://osf.io/dg57z

The experiment materials are available at https://osf.io/r5ua4, https://osf.io/bdavz, https://osf.io/ad4vx, https://osf.io/c9zu3, and https://osf.io/7nyvp

The preregistered design is available at https://osf.io/r5ua4, https://osf.io/bdavz, https://osf.io/ad4vx, https://osf.io/c9zu3, and https://osf.io/7nyvp

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A common mantra urges students to "find your passion" in college. However, this approach may discourage students from developing interests beyond those they have already "found." Indeed, many students enter college thinking they are not a "math or science person" and that's that. Any required math or science courses they take may be seen as chores to endure rather than interesting or broadening opportunities to pursue.

Such sentiments are unfortunate because they discourage young adults from pursuing the wealth of interdisciplinary opportunities that college offers. Moreover, being conversant in science, technology, engineering, and math (STEM) plays a large role in today's job market (National Research Council, 2013), and innovations often require insights across arts and sciences (National Academies of Sciences, Engineering, and Medicine, 2018). In this research, we therefore ask: Can representing interests as developable, not fixed, open first-year college students who think they are not a "math and science person" to the possibility that math/science coursework is interesting and thus enhance learning? To examine this possibility, we designed and tested a brief, single-session growth-theory-of-interest intervention. Liberal arts undergraduates completed the online module, or control materials, just before beginning college. Later in the year, we assessed students' interest and achievement in their mandatory first-year math/science courses.

## The Role of Interest in Educational Outcomes

When students are interested in their coursework, it can enhance the learning process (see O'Keefe et al., 2017; O'Keefe & Harackiewicz, 2017; Renninger & Hidi, 2015). Studies show that increased interest in coursework can improve students' motivation (e.g., Harackiewicz et al., 2008), self-regulatory efforts (see Thoman et al., 2017), and learning (e.g., Hulleman & Harackiewicz, 2009; Ranellucci et al., 2015) and can encourage further engagement in a subject (e.g., Harackiewicz et al., 2008; Hulleman et al., 2008). In one investigation, researchers manipulated whether students in a high school algebra class completed more interesting or less interesting versions of the same story problems during computer tutorials (Bernacki & Walkington, 2018). To make the problems more interesting, researchers personalized each student's problems to reflect topics that the student had earlier reported an interest in, such as sports, music, or food. Results showed that students who completed the more interesting versions later performed better on an algebra exam than those who completed the less interesting versions.

## Developing Interest, Not "Finding" It: A Growth Theory of Interest

Interest has clear benefits for academic motivation and achievement. Yet it is not always possible to simply change instructional methods or course material to make a subject more interesting, such as in the study of algebra story problems described above. Therefore, it is critical to understand how people develop interest and how to lift psychological barriers that might prevent the development of interests.

The leading theorizing about interest development (e.g., Hidi & Renninger, 2006) suggests that well-developed interests, in which an individual holds an enduring affinity for particular content or activities, typically begin with a spark of curiosity and enjoyment evoked by something external to the person—for example, a well-written work of literature or an exciting science demonstration. To help explain how such situationally induced states of interest can evolve into well-developed, internalized interests, Hidi and Renninger proposed the Four-Phase Model of Interest Development (Hidi & Renninger, 2006; Renninger & Hidi, 2015). Through repeated engagement with content or activities in the areas in which interest was externally triggered, one begins to develop more positive feelings toward the topic and to find greater personal relevance and value in it. Through this process, the interest becomes internalized and integrated into one's identity, no longer needing to be evoked by outside material, and the person freely chooses to reengage in the content or activity.

However, there is an important gap in this prominent model of interest development. It tacitly assumes that virtually all people can develop new interests given particular circumstances, but it does not consider people's *beliefs* about whether interests can be developed in the first place. This is especially important in light of the fact that some people view interests as inherent and relatively unchangeable (a *fixed theory of interest*) as opposed to developable (a *growth theory of interest*; O'Keefe et al., 2018a). A fixed theory of interest may forestall the interest development process. Indeed, recent research suggests that those with a fixed theory may not be open to new interests in the first place (O'Keefe et al., 2018a; O'Keefe, Horberg, et al., 2021).

Consistent with this theorizing, in recent laboratory studies, students with more of a fixed theory of interest—who endorse statements like, "You can be exposed to new things, but your core interests won't really change"—were less open to material outside of their existing academic identity (i.e., their well-developed interests), as compared to students with more of a growth theory (O'Keefe et al., 2018a). In one study, students with an academic identity either in math/science or in arts/humanities/social sciences read two scholarly articles, one in each area. Unsurprisingly, students found the article within their academic identity interesting regardless of their theory of interest. However, students who held a fixed (vs. growth) theory of interest reported less interest in the article outside their academic identity. Moreover, the disparity between those with a growth and a fixed theory of interest grew larger when the material became more challenging.

Implicit theories can also influence whether people attempt to upregulate their interest to stay motivated during boring or tedious tasks (Thoman et al., 2020). For example, when participants in a lab study worked on copying matrices of letters (an inherently boring task), those who viewed interest as malleable used more strategies to boost their interest, such as varying their handwriting or the order in which they copied letters, relative to those with a fixed theory.

These studies demonstrate that beliefs about interest can facilitate or hinder students' development of new interests. However, they are limited in their theoretical and practical value. First, most were confined to the laboratory, and to immediate responses to decontextualized experimental stimuli assessed within a single session. The lack of real-world, longitudinal research is a critical gap, particularly in education research informed by social-psychological theories (see Berkman & Wilson, 2021). Unlike in lab experiments, in which a mental framework is temporarily induced in a highly controlled setting, in the real world, students are bombarded with countless influences and messages over time, especially as they begin university. Given this complexity, an important theoretical question is whether a single online activity completed at the beginning of the academic year—one that changes nothing about a student's environment or curriculum—could cut through and survive the complexities of the first year of college to cause a sustained shift in students' beliefs about the nature of interests. A further critical question is whether this change—coming to view interests as cultivatable—could leave a detectable trace in students' real academic interests months later, as our intervention was hypothesized to do.

A second limitation of past research is that it has not investigated whether implicit theories of interest can affect performance, an outcome that is of both inherent educational importance and is critical to theory. Therefore, the present research examines whether an intervention to promote a growth theory of interest can increase not only students' interest in academic material outside of their preexisting academic identity but also their course grades. Doing so would suggest that a growth theory of interest can promote an interest-based pathway to interdisciplinary learning and achievement.

### A Novel Intervention to Promote a Growth Theory of Interest

In theorizing that our novel, relatively brief intervention can yield long-term gains, we draw on other "light touch" social-psychological interventions. Research finds that such interventions can be delivered effectively in the transition to college and, when this is done, can initiate beneficial recursive cycles, wherein new ways of thinking yield behaviors and rewards that reinforce those ways of thinking, begetting future rewards (e.g., Brady et al., 2020; Walton & Cohen, 2011; Yeager et al., 2016; see also Harackiewicz & Priniski, 2018; O'Keefe, Lee et al., 2021; Walton & Wilson, 2018). Here, by coming to view interests as developable, a student at a pivotal point early in their academic career may be more open to material from mandatory courses outside their preexisting interests. They may then engage more deeply in this coursework, enjoy it more, and perhaps even achieve higher grades. In this way, the intervention, although it is one of many activities that busy students engage in, could have a meaningful impact on students' course interest and grades months later.

One kind of social-psychological intervention explored in past research addresses students' beliefs about the nature of intellectual abilities (Paunesku et al., 2015; Yeager et al., 2016, 2019). Teaching a growth theory (or "mindset") of intelligence—the idea that intellectual abilities are improvable, not fixed—can help students interpret initial academic difficulties as common and improvable (rather than a signal of low ability) and, in turn, enhance academic progress, especially among students at risk for lower achievement. In one study, lower-achieving (based on prior performance) ninth-grade students who completed a growth-theory-of-intelligence intervention went on to earn a higher grade point average (GPA) in their core courses in ninth grade, relative to peers who completed control materials unrelated to beliefs about intelligence (i.e., on how the brain functions; Yeager et al., 2019).

Yet beliefs about the malleability of ability are quite different from beliefs about the malleability of interests. Even students who are confident in their abilities in an area, or who see the potential for those abilities to grow, may reject that area as dull.

Our intervention also complements existing efforts to promote academic interests. Such efforts typically focus on a specific subject. For example, inviting students to consider the personal relevance of material in a science course, or the usefulness of science generally, can boost interest in science (e.g., Harackiewicz et al., 2012). In one study (Hulleman & Harackiewicz, 2009), 9th- and 10th-grade students wrote essays periodically throughout a semester about the material in their science course. In the treatment condition, students wrote about the relevance and usefulness of the material to their everyday lives; in the control condition, students summarized its content. Results showed that, among those who held low expectations of success at the beginning of the semester, writing about the personal relevance of science led to higher interest and higher grades in the course, relative to the control condition.

While interventions like this directly address a specific academic subject, we address students' underlying beliefs about the nature of interests in general. In doing so, we propose that it is possible to empower students to cultivate interests in areas in which they do not already hold interest without targeting any specific content. Furthermore, we test whether the benefits of this *growth-theory-of-interest intervention* would arise independently of a growth theory of intelligence, showing the distinction between these constructs.

## Overview of the Present Research

As the first tests of a growth-theory-of-interest intervention, our primary purpose was to determine whether this intervention (vs. an active control) could cause meaningful improvements in real-world outcomes that matter for students over time. In the present research, we examined effects on students' interest and grades in mandatory first-year math- and science-related courses. We were particularly interested in students whose preexisting academic identity fell outside these fields and who, therefore, would presumably lack intrinsic reasons (like interest) to engage with these courses and may risk doing poorly in them as a result (see O'Keefe & Harackiewicz, 2017), despite an ability to do well. To investigate this question, we worked with selective universities where students are proficient in math/science yet vary in their identification with these fields. This population allows us to examine the role of interest, apart from ability or preparation. If the growth-theory-of-interest intervention were to raise interest and/or grades in first-year math/science courses among students who have little identification with these fields when they enter college (i.e., a low preexisting math/science identity) it would both illustrate the costs of a fixed theory of interest and show how colleges and universities can help students make the most of their varied curricula, become interdisciplinary thinkers, and prepare for a job market that increasingly requires STEM knowledge.

## Preregistered Hypotheses

Our hypotheses focus on direct effects of the intervention on course interest (the most theoretically relevant outcome) and on course performance. The primary preregistered hypotheses are as follows (additional preregistered hypotheses and results are described in the online supplemental material).

First, we hypothesized that students who completed the growth-theory-of-interest intervention, as compared to the control materials, would report a stronger growth theory of interest over the course of the academic year. This is not a mere manipulation check, as a treatment effect would reflect enduring change in students' beliefs about the nature of interest months after the brief online exercise.

Second, we hypothesized that the growth-theory-of-interest intervention would increase students' interest in courses outside of their well-developed preexisting academic identity, relative to the control condition. As students' predominant academic identity (labeled "preexisting core interests" in the preregistration) lay in the arts, humanities, and social sciences and not in math and science, we expected increases in interest in math/science courses, perhaps particularly for students with lower levels of preexisting academic identity in math and science. (Note that we did not hypothesize that the intervention would influence students' math/science *identity*—academic identity was collected at baseline only to determine students' preexisting core areas of interest.)

Third, given research showing that increased interest can influence performance and achievement (e.g., Harackiewicz et al., 2008; O'Keefe & Linnenbrink-Garcia, 2014), we hypothesized that the intervention would increase students' final grades in courses outside of their preexisting academic identity. We therefore expected higher final grades in students' required math/science courses, again perhaps particularly for students with lower levels of preexisting math/science identity.

We did not preregister specific analyses. Given our targeted sample of arts/humanities/social sciences students whose preexisting math/science identity was low on average, yet still showed variation, our preregistered hypotheses regarding interest and grades could manifest either as a main effect of treatment condition or specifically for students whose preexisting math/science identity was particularly low. This distinction was not explicit in our preregistration. Thus, below we report analyses of the main effect of condition as well as the Condition × Math/Science Identity interaction.

Finally, we hypothesized that the intervention would not increase or detract from interest or achievement in courses within students' preexisting academic identity, that is, their arts/humanities and social sciences courses. This interest was already expected to be high and, more importantly, fixed theories about the development of interests should not be a barrier to interest in courses for which students already have a strong academic identity. If so, boosting interest and achievement in math/science courses would reflect the development of more diverse scholars, as students would supplement a primary focus on non-STEM fields with a stronger math and science education.

# Pilot Study

Prior to the Main Study, we conducted a preregistered, randomized, controlled field-experiment in a sample and manner similar to that of the main study (see Author Note for preregistration details). The purpose of this study was to serve as the first test of the intervention and was preregistered as such. While it yielded the hypothesized positive effects on our primary outcome—namely, it increased interest in students' required first-year math/science course—the sample was relatively small and, thus, the study was underpowered. Therefore, we present these data as a pilot, and focus on the main study, which was conducted subsequently and with a significantly larger sample.

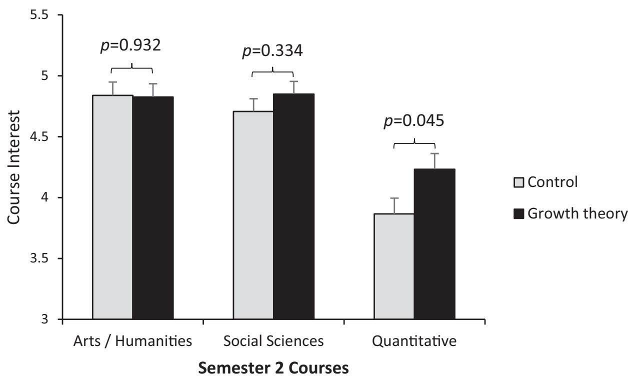
The pilot study is described in full in the online supplemental material. Before the academic year began, we delivered the growth-theory-of-interest intervention (vs. active control materials, which focused on optimizing study skills) through an online module to incoming first-year students ($N = 175$) at a selective, internationally diverse liberal arts college in Singapore (an English-speaking country) that attracts students with a strong identification with the arts, humanities, and social sciences, but not math and science (see the online supplemental material for all supporting evidence). An advantage of conducting this research at this college was that students tended to have high aptitude in math and science (Bhattacharjee, 2004), which was the case in this sample (average Math score on the Scholastic Assessment Test [SAT] was 745). As stated earlier, this helped us examine the effect of interest in math/science where a lack of ability or preparation was not a barrier. The materials and procedure were similar to those detailed in the Main Study.

The primary outcome was assessed in a follow-up survey 8 months after the intervention, near the end of students' first year ($n = 161$). Our primary interest was in students' required second-semester quantitative course, which focused on math and science topics like probability and sampling theory, correlation and regression, fundamental programming concepts like loops and conditionals, and data analysis in the R programming language. As predicted, at this distal timepoint, students who received the prematriculation growth-theory-of-interest (vs. control) intervention (a) endorsed a growth theory of interest more strongly and (b) reported greater interest in this second-semester quantitative course (see Figure 1). Both hypotheses were preregistered. Additionally, we examined students' interest in their required arts/humanities and social sciences courses. This did not vary by condition, suggesting that the effect was specific to areas for which students had a low preexisting interest, as predicted (also see O'Keefe et al., 2018a), and that the gain in interests did not come at the cost of the interests students had upon entering college. Although we did not find a direct effect on final grades in the quantitative course (as was preregistered), further analyses showed that interest in the quantitative course predicted significantly higher grades in that course. Thus, there was a significant indirect effect of the intervention on increased quantitative course grades via increased quantitative course interest: Better grades were predicted by an increase in interest, which had been caused by the intervention.

Although this was a pilot study, the findings are of value. First, despite a relatively small sample size, confidence in the central results is strengthened by the fact that the hypotheses were preregistered and the results conceptually replicated in the main study that follows. Second, randomized, controlled intervention studies with meaningful, objective, long-term outcomes are uncommon as they require substantial time, effort, and resources. However, they provide especially useful data on what practices can actually improve school outcomes for students (e.g., Berkman & Wilson, 2021).

**Figure 1**

*Interest in Required Second-Semester Courses by Condition in the Pilot Study (n = 161)*




*Note.* The full scale ranged from 1 (*strongly disagree*) to 6 (*strongly agree*). Bars depict adjusted means controlling for covariates (gender, age, preexisting math/science identity, and preexisting math/science perceived competence). Unadjusted means are nearly identical.

From these perspectives, the pilot study contributes to cumulative evidence, despite the limitations in power.[1]

## Main Study

To replicate the Pilot Study with a larger sample, we conducted the Main Study at a different institution in Singapore, at which students also tended to have high aptitude in all areas but a range of levels of math/science identity. This sample provided greater power to detect a direct effect on grades in students' mandatory math/science courses. Furthermore, to better detect how the intervention affected the experience of students with a low (vs. high) preexisting math/science identity, we improved the assessment of preexisting math/science academic identity by pinpointing the extent to which this identification was based on interest (see "Method" section). Finally, students in the Main Study were required to complete two math/science courses, enabling us to test our hypotheses in two different relevant contexts.

Thus, in the Main Study, we investigated the effects of the growth-theory-of-interest (vs. study-skills control) intervention, as a function of preexisting math/science identity, on students' interest and grades in their two required first-year math/science courses.

## Method

The study (as well as the pilot) complies with all relevant ethical regulations. Study protocols were approved by the Institutional Review Board at the corresponding author's institution.

### *Participants*

Participants were recruited from the school of arts and social sciences within a different selective university in Singapore than the Pilot Study. This was a large institution where students tend to have high academic ability in all areas, including math (e.g., minimum SAT score for admission is 650 in Math, 600 in Reading and Writing). Students were pursuing degrees in the arts, humanities, or social sciences but were required to complete two math/science courses early in university. As reported below (see the "Prematriculation Survey" section), students in our sample began college with a high identity in the areas of arts/humanities and social sciences, but identity in math and science was low for most students. However, there was variability in students' math/science identity.

Our preregistered sample size decision was to invite the entire incoming cohort of students enrolled in the university's school of arts and social sciences. Five-hundred-eighty students opted into the study at Time 1 (70.3% female; $M_{\text{age}} = 19.66$, $SD = 1.24$), which represented 32.7% of the cohort. This sample size provides high power ($1 - \beta = 0.95$) to detect a small-to-medium effect size of $f = 0.15$ ($\alpha = .05$), as we found on math/science course interest in the pilot study, an effect consistent with the effect sizes of past brief online social-psychological interventions relating to implicit theories and involving real-world outcomes that unfold over time (see Lazowski & Hulleman, 2016).

### *Procedure*

Guided by successful techniques in social-psychological intervention research on other topics (e.g., social-belonging interventions, Yeager et al., 2016), we designed a novel growth-theory-of-interest intervention that could be delivered efficiently, as an online module, to a cohort of incoming college students. During first-year orientation, several weeks before the start of classes, students received a brief announcement from a senior university administrator describing an opportunity to take part in a survey about their transition to university. Then, the week before classes began (Time 1), students received an email from the same administrator, which described the research as an initiative to help the school better understand new students and learn about their academic experiences. Students were told that they would complete three surveys throughout the year, for which they would receive \$10 SGD (~\$7.50 USD) per survey. By describing the materials as an institutional initiative and delivering them through senior administrators, we aimed to bolster the perceived legitimacy of the materials and encourage high engagement and retention.

Participating students completed the Time 1 materials online. This involved a survey including measures of their preexisting academic identities in math, science, arts, humanities, and social sciences (see

[1] The effects of the treatment on other preregistered outcomes of the Pilot study are presented in the online supplemental material. Specifically, we tested the direct and indirect effects (via math/science course interest) of the treatment on outcomes regarding interdisciplinarity: (a) greater intentions to minor in math/science, (b) greater likelihood of completing a future math/science elective, (c) perceiving stronger connections between students' arts/humanities/social sciences courses and math/science courses, (d) increased learning goals, relative to performance goals, in the math/science course, and (e) engaging in more math/science-related extracurricular activities. We also examined whether the intervention led students to (f) increase the number of academic areas with which they identified. Previous presentations of this work reported the Pilot Study as "Study 1" and reported several of the aforementioned indirect effects in the main text, in addition to the primary outcomes. In addition to the results of these outcomes, we detail changes made since earlier presentations of this research under "Project Updates" in the online supplemental material.

below). These measures were followed by the randomized treatment or control materials. We compared the effects of the growth-theory-of-interest materials to an active, high-quality control condition focused on optimizing study skills. While specific forms of study-skills training can benefit students by helping them use learning resources more effectively (e.g., Chen et al., 2017), the growth-theory-of-interest intervention should specifically lead to higher interest in math/science coursework, and only this intervention should predict higher math/science course grades through increased interest.

The primary outcome was students' interest in their required math/science courses in their first year, which was assessed on follow-up surveys approximately 12 weeks into each of the two semesters. Figure 2 depicts the timeline and procedure. Note that, because the randomized treatment materials were delivered before students began their courses, we could not assess course interest pretreatment to examine how it changed posttreatment. Instead, we tested whether the growth-theory-of-interest intervention increased interest (and grades) in math/science courses relative to the study-skills control condition, as is common in other intervention research (e.g., Walton & Cohen, 2011; Walton et al., 2015). Moreover, while there is value to including multiple control conditions, as we discuss in the General Discussion, similar control conditions in past research did not affect grades or other educational outcomes, relative to passive, no-treatment control conditions or to other randomized active control conditions.[2]

Students were required to take two math/science courses early in college. First was a quantitative course similar to the quantitative course in the Pilot Study (i.e., focusing on topics in statistics, mathematical reasoning, scientific data analysis, etc.). Second was a computation course, which taught students how to approach complex problem-solving using computational techniques. Topics included problem formulation, abstraction, decomposition, pattern recognition, and algorithm design; students learned the fundamentals of coding, diagnostic analytics, and computational modeling. Students also took two required arts/humanities/social sciences courses early in college, both on writing for the arts, humanities, and social sciences. These focused on communicating with, respectively, academic audiences and the general public. Students were assigned to these courses by the registrar (i.e., they did not choose when to complete them). During their first year, nearly everyone completed at least one of the required math/science courses as well as at least one of the required arts/humanities/social sciences courses.

All participating students were invited to complete paid follow-up surveys (a) at the end of the first semester, approximately 3 months after the intervention ($n = 550$, 94.8% retention) and (b) at the end of the second semester, approximately 8 months after the intervention ($n = 537$, 92.6% retention). At both time points, the invitation emails referenced "an online activity about your transition to [*College*]" that the student had completed at the beginning of the academic year, and stated that the school wanted to "learn about their experiences since then." However, the emails did not mention the content of the randomized material.

Students who completed the follow-up surveys did not differ from those who did not on any covariate or predictor (i.e., age, gender, preexisting math/science identity, preexisting perceived math/science competence) nor by treatment condition (all $ps > .250$).

Students' final letter grades for the required courses they took in the first year were obtained from the university registrar at the end of Year 1 ($n = 576$; four students transferred or withdrew).

### *Prematriculation Survey*

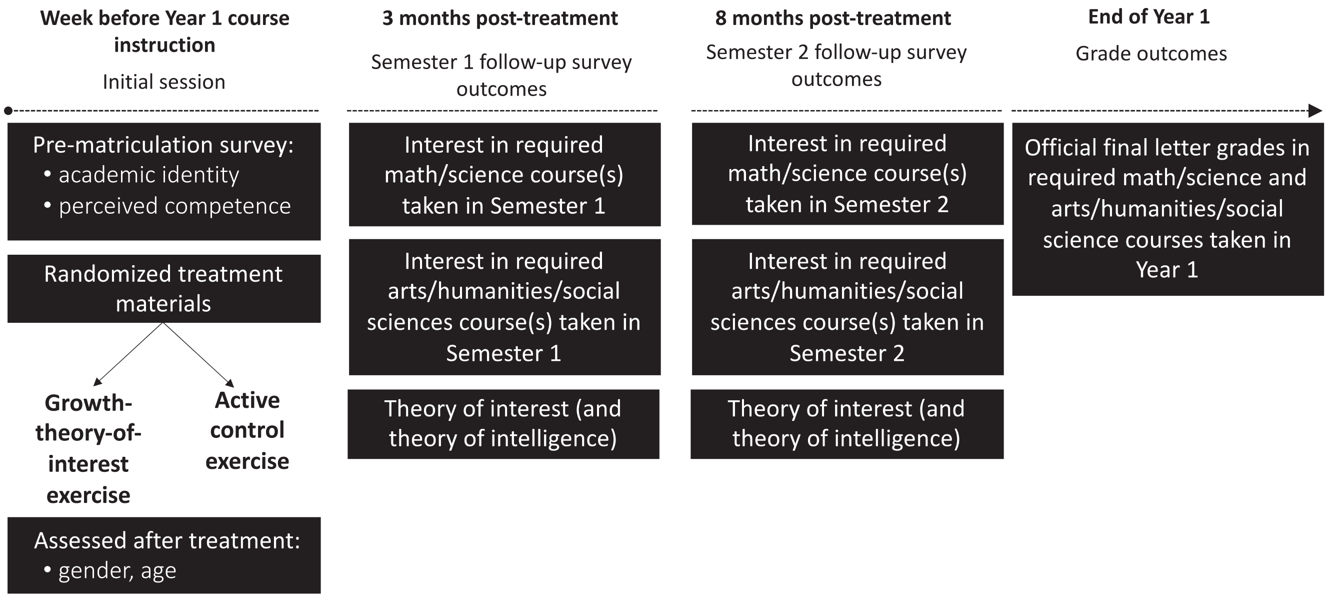
The prematriculation survey—which was administered just before randomized treatment materials—assessed students' gender, age, academic identity, and perceived competence in specific subject areas. See Table S6 in the online supplemental material for descriptive statistics of all measures. Variations in degrees of freedom within the same survey (prematriculation or follow-ups) are due to missing data (e.g., students skipping an item).

Following prior laboratory research on implicit theories of interest (O'Keefe et al., 2018a), we assessed students' academic identity at baseline, namely, when they entered college—this was the extent to which students saw themselves as a person with interests in math/science and in arts/humanities/social sciences. To capture the extent to which students' identity reflected their academic interests as opposed to other dimensions of their identity (e.g., their abilities, achievements, or external pressures), students were instructed to consider what they "enjoy and care about," two central components of well-developed interest, as they answered the items (O'Keefe et al., 2017; Renninger & Hidi, 2015). Two items assessed students' academic identity in math and science ("I am a Math-oriented person," "I am a Science-oriented person") and two assessed their academic identity in non-STEM areas ("I am an Arts/Humanities-oriented person," "I am a Social Science-oriented person"; 1 = *strongly disagree*, 6 = *strongly agree*). By assessing students' preexisting academic identity, rather than their level of interest in each area, we sought to mitigate the possibility that students who then immediately completed the growth-theory intervention—which focused on the nature of interest—would connect these materials to the baseline items and guess the purpose of our research. Had this awareness of our hypotheses occurred, it could have led to demand processes in responses to the intervention materials, potentially rendering this experience less authentic. (Due to similar concerns, we also did not assess theories of interest in the prematriculation survey for students in the treatment condition.)

The math and science academic identity items correlated positively, $r(578) = .42$, $p < .001$, and both were negatively correlated with arts/humanities identity, $r_{\text{math}}(578) = -.37$, $p < .001$; $r_{\text{science}}(578) = -.25$, $p < .001$, and were unrelated to social sciences identity, $r_{\text{math}}(578) = -.03$, $p = .447$; $r_{\text{science}}(578) = -.003$, $p = .950$. We averaged students' math and science academic identity ratings

[2] Walton and Cohen (2011) tested the social-belonging intervention against two different active control conditions, including one focused on how academic difficulties lessen over time as study skills improve, and against students in the same college cohort who did not participate in the study. The randomized control groups did not differ from each other (and were thus combined for hypothesis testing) nor from the campus-wide group. Moreover, GPA in the intervention condition was significantly higher than both the randomized control conditions and the campus-wide group when analyzed separately. Likewise, Walton et al. (2015) tested social-belonging and affirmation-training interventions against an active study-skills control condition and a passive, no-treatment control condition, among women in male-dominated engineering fields. The active and passive control conditions again did not differ in GPA, and so were combined in hypothesis tests.

**Figure 2**
*Overview of the Timeline and Procedure*






since both of their mandatory quantitative and computation courses involved math and science ($M = 3.29$, $SD = 1.14$).

Similarly, we averaged students' arts/humanities and social sciences academic identity ratings ($M = 4.85$, $SD = 0.76$) since their two other mandatory courses involved both of these areas (communication for the arts and social sciences). Arts/humanities and social sciences identity also correlated positively with each other, albeit more weakly, $r(578) = .16$, $p < .001$.

Confirming the predominant focus of this sample, students' preexisting academic identity was higher in arts/humanities/social sciences ($M = 4.85$, $SD = 0.76$) than in math/science ($M = 3.29$, $SD = 1.14$), paired $t(579) = 24.35$, $p < .001$, $d = 1.01$. Almost all students (90%) began college with a high academic identity in arts/humanities/social sciences (i.e., above the scale midpoint of 3.5). However, there was variability, as some students reported a high academic identity in both math/science and arts/humanities/social sciences. While a majority (65%) reported a low preexisting math/science identity (i.e., at or below the scale midpoint), a meaningful minority (35%) reported a high math/science identity.

Students also completed demographic measures and items that, given prior research (e.g., O'Keefe et al., 2018a; Walton et al., 2015), we anticipated could predict our primary outcomes and thus serve as covariates: gender, age, and preexisting self-perceived competence in each academic area in which they would be taking courses (i.e., "How much competence do you feel you have in" math, science, arts/humanities, and social sciences courses; 1 = *almost none*, 7 = *a great deal*). Self-perceived math and science competence correlated, $r(576) = .56$, $p < .001$, and were averaged into a perceived math/science competence score ($M = 3.30$, $SD = 1.38$). Self-perceived arts/humanities and social sciences competence also correlated, $r(577) = .40$, $p < .001$, and were averaged into a perceived arts/humanities/social sciences competence score ($M = 4.99$, $SD = 1.00$). Gender and age assessments followed the randomized materials described below.

### *Randomized Growth-Theory-of-Interest and Active Control Materials*

Immediately after the prematriculation survey measures, students were randomly assigned to complete either the growth-theory-of-interest or study-skills (i.e., active control) materials. Randomization was performed automatically by the survey software (Qualtrics), and researchers and educators were blind to treatment condition. The two conditions were identical in structure but differed in content. Their structure made use of several well-documented and validated persuasion techniques (described below), following successful past social-psychological interventions (e.g., social belonging; Walton & Cohen, 2007; Yeager et al., 2016).

The median completion time of the prematriculation survey plus randomized materials was 29 min for the growth-theory-of-interest condition and 28 min for the control condition (the distribution was positively skewed, $z = 37.92$, $p < .001$). Median completion time did not differ across conditions, $\chi^2(1) = 0.99$, $p = .319$.

**Growth-Theory-of-Interest Intervention.** The growth-theory-of-interest materials contained several reading and reflective writing components that portrayed interests as cultivated, not fixed, and conveyed how adopting this mindset could help people develop and sustain new interests. By highlighting these benefits, we sought to provide a compelling motivation for new college students to engage with the experimental materials. However, these materials were not presented as an intervention or as reflecting a deficit in students or a need for them to change, as this could elicit demand characteristics or be stigmatizing. Instead, consistent with many past social-psychological interventions (e.g., social-belonging interventions, Walton & Cohen, 2011), the materials were presented as an effort on the part of the university to gather information that would help them better understand their students and help future students in their transition to college. Participating students were thus positioned as experts and co-creators of an intervention for other students (e.g., see Walton & Cohen, 2011). Additionally, the materials highlighted many academic areas and did not focus specifically on math or science.

First, students read a single-page article written for a general audience, which represented new interests as developed—not fixed or discovered fully formed—and summarized actual research showing that this mindset can help people develop interests in new areas, even when this development is difficult (see Author Note for details about accessing materials). As reading a scientific message on the nature of interests is likely to be perceived as personally relevant and important as students begin to explore new topics in college, this material used the *central route* to persuasion. In this route, people process relevant messages by paying attention to the validity of the facts and arguments rather than to peripheral cues (Petty et al., 1981). Thus, a message about the science supporting a growth theory of interest—reporting on actual research findings (O'Keefe et al., 2018a)—may be persuasive to students embarking on their college career.

Next, students wrote a short essay (three to five sentences) about a time they personally developed interest in a new topic or activity (see Table S8 in the online supplemental material for essay prompts and examples of essay responses). They were told that their responses would be used by the college to help future incoming students think about their interests in college. The essay leveraged the *saying-is-believing effect*, a persuasion technique in which recipients are asked to freely advocate for a position to a relevant audience, which can increase endorsement of that idea (Aronson, 1999). By advocating for the view that interests can be developed, and linking this idea to their own experiences, students may endorse the belief more strongly for themselves. One participating student wrote, "I was initially not interested in History in [*secondary school*] as I always had the idea that history was boring and only required memory work. However I soon realized that history was not just about memorizing content, the analysis was the most important part. To my surprise, I found the subject extremely interesting despite how difficult it was, and started to really enjoy the coursework for the subject." Examination indicated that virtually all student essays were on topic.

Next, students read a summary of findings and four testimonials ostensibly from a recent survey of upper-year students at their college. The summary stated that students initially had concerns about taking courses outside of their preexisting interests but over time came to see interests as developed and, by applying this way of thinking, began to develop new interests even if they encountered boredom or difficulty at times. Four testimonials illustrated how students developed and maintained new academic interests in college. This element made use of *informational social influence* (Cialdini & Goldstein, 2004); older peers at one's college are likely to be seen as valid sources of information, so reading about how their interests developed in college may be highly persuasive. These testimonials were derived from discussions with upper-year students at the college but were edited to clarify the message, as in similar past field studies (Walton & Cohen, 2011). For instance, one testimonial described how a student with a preexisting interest in psychology developed new, complementary interests in neuroscience and history through an internship and a summer program (see Table S9 in the online supplemental material for testimonial examples).

Finally, students wrote a second essay, which again leveraged the saying-is-believing effect. See Table S8 in the online supplemental material for essay prompts and essay examples. A separate textbox was provided for students to respond to each component of the essay. Students were told that their responses might be shared with future students at their college to help them in their transition to college, again casting participants as helping others and encouraging them to provide useful, detailed responses. One student wrote that "By understanding that interests [develop], students will be able to draw connections between their interests and other topics which [were] unlikely to be part of their interests. Thus, they may cultivate an interest in other academic topics."

**Active Control (Study-Skills) Materials.** The control exercise followed the same structure and was also potentially beneficial, as it addressed study skills that could be useful in college. As in the intervention condition, the materials positioned students as experts and co-designers of an intervention for others, not as in need of help or as recipients of an intervention. As described below, the materials emulated the type of information college students are often taught to help them adjust to college. They also emphasized a growth process, namely that the development of better study skills is normal and common in college.

First, students read an article reporting research on optimal study skills (e.g., being an active rather than passive learner, improving time management). Next, they wrote a short essay about a time in their life when they discovered a new study skill that helped them in class (see Table S8 for essay prompts and essay examples). One student wrote, "I realized that active collaboration with peers helped me a great deal as we could learn from one another's mistakes through sharing marked essays and summary notes. I also learnt the importance of regularly reinforcing content, instead of last-minute cramming of facts and examples before the exam."

Next, students read a summary of survey findings and four testimonials from upper-year students at their college. The summary stated that older students reported initially having concerns about the increased workload in college but over time discovered more effective study skills and came to feel capable of handling it. The testimonials illustrated initial challenges students encountered while studying in college and how they overcame those challenges with improved study habits. Finally, students wrote a second short essay regarding (a) their concerns about the workload, (b) how to develop new study skills, and (c) how to apply new study skills. They were asked to illustrate these ideas by discussing their own approach to courses, again ostensibly to help future students in their transition to their college. Three textboxes were provided for students to respond to each component of the essay. One student wrote, "I believe picking up new skills is commonly done through emulating what kind of skills their peers or seniors use. Hence, talking and discussing with others is a good way to do so. I think it is through trial and error that someone can tweak a study skill so that their study habits can adapt to it." As in the intervention condition, virtually all essay responses were on topic.

Although study strategies can potentially benefit students academically (for a targeted example, see Chen et al., 2017), our control exercise did not focus on interests and their potential to develop. It thus provided a rigorous test of the growth-theory-of-interest intervention.

### *Follow-Up Surveys and Final Grades*

The central, preregistered dependent measures were (a) the degree to which students endorsed a growth (as compared to fixed) theory of interest over the first year, (b) students' interest in their required math/science and arts/humanities/social sciences courses reported in surveys, and (c) students' final grades in these courses from official academic records.

Toward the end of both the first and the second semester of their first year (a week or two before finals), students completed a brief online follow-up survey. Students received the survey link in an email from the same high-level administrator from whom they had received the previous materials. Below, we describe the measures relevant to our central hypotheses. For descriptive statistics, see Table S6 in the online supplemental material. Additional survey items and analyses relevant to preregistered hypotheses not central to the present paper are described in the online supplemental material (see "Supplemental Analyses: Testing Noncentral Preregistered Hypotheses").[3]

**Students' Interest in Their First-Year Courses.** In keeping with theory regarding the qualities of newly emerging interests (Hidi & Renninger, 2006), we assessed course interest with two items: One assessed students' enjoyment of the course work (e.g., "I enjoy the work I'm doing in [*course title*]") and a second assessed overall interest in the course content ("The material in [*course title*] is interesting to me"; 1 = *strongly disagree*, 6 = *strongly agree*). The same two items were used for each course. The items were averaged into a composite score for each course (interitem $rs \geq .85$; see Table S6), indexing students' overall level of interest in each math/science course—the quantitative ($M = 3.20$, $SD = 1.35$) and computation ($M = 3.43$, $SD = 1.44$) courses—as well as in each arts/humanities/social sciences course, namely, the academic communication ($M = 4.01$, $SD = 1.22$) and general-public ($M = 4.26$, $SD = 1.10$) communication of arts/humanities/social sciences content.

**Theories of Interest (and Theories of Intelligence).** Next, *implicit theories of interest* and *implicit theories of intelligence* were assessed using existing scales. The Implicit Theories of Interest Scale (O'Keefe et al., 2018a) included four items ("No matter how central your interests are to you, they can change substantially"; "Even if you have very strong interests, they can change dramatically"; "To be honest, your core interests will remain your core interests. They won't really change"; "You can be exposed to new things, but your core interests won't really change"; 1 = *strongly disagree*, 6 = *strongly agree*). The fixed-theory phrased items were reverse-coded before averaging to index endorsement of a growth theory of interest ($\alpha_{\text{first-sem.}} = 0.83$; $M_{\text{first-sem.}} = 3.35$, $SD_{\text{first-sem.}} = 0.92$; $\alpha_{\text{second-sem.}} = 0.84$; $M_{\text{second-sem.}} = 3.35$, $SD_{\text{second-sem.}} = 0.94$).

Similarly, the Implicit Theories of Intelligence Scale (Dweck, 1999) included four items ("You have a certain amount of intelligence, and you can't really do much to change it"; "Your intelligence is something about you that you can't change very much"; "To be honest, you can't really change how intelligent you are"; and "You can learn new things, but you can't really change your basic intelligence"; 1 = strongly disagree, 6 = strongly agree). Ratings were reverse-coded so that higher scores indicated a stronger growth theory of intelligence ($\alpha_{\text{first-sem.}} = 0.95$; $M_{\text{first-sem.}} = 3.56$, $SD_{\text{first-sem.}} = 1.13$; $\alpha_{\text{second-sem.}} = 0.96$; $M_{\text{second-sem.}} = 3.53$, $SD_{\text{second-sem.}} = 1.20$). Theories of intelligence correlated positively but weakly with theories of interest—first semester: $r(548) = .12$, $p = .005$; second semester: $r(531) = .23$, $p < .001$.

**Final Grades.** Official final letter grades for the four first-year required courses were obtained from the university registrar after Year 1. Records were provided using an 11-point letter grading system (from $F$ to $A+$) and were therefore converted to an 11-point coding system ($1 = F$, $11 = A+$; the university did not issue grades of $C-$ or $D-$).

## *Transparency and Openness*

The method, materials, and hypotheses were preregistered (see Author Note for details). We report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study, and we followed Journal Article Reporting Standards (JARS; Kazak, 2018). Data were analyzed using Mplus, Version 8.4, and are available at https://osf.io/dg57z.

# Results

## *Success of Random Assignment*

Confirming the success of random assignment, there was no condition difference on any demographic or prematriculation survey measure ($ps > .15$; see Table S2 in the online supplemental material).

## *Analytic Strategy and Preliminary Tests*

Analyses examined the intent-to-treat sample. All students who saw any randomized content, and for whom outcome measures were available (follow-up survey measures and/or course grades), were retained in analyses, even if they did not finish the randomized materials.

To examine the treatment effect as well as its interaction with preexisting math/science identity on interest and achievement in math/science courses over the first year, we conducted intent-to-treat analyses using full-information maximum likelihood, an effective method for handling missing data (Graham, 2009). All statistical tests were two-tailed.

Analyses controlled for relevant prematriculation survey measures available for all students that predicted our central outcome variables of interest and grades in the quantitative and the computation (i.e., math/science) courses, as has been done in past research (Walton & Cohen, 2007, 2011). These were preexisting perceived math/science competence, age, and gender (see Table S7 in the online supplemental material for simple correlations with central outcomes). Covariates were identical for all analyses reported here. Cohen's $d$ was calculated from values adjusted for covariates. Analyses without covariates produce similar results (see the online supplemental material for details).

We also examined whether the treatment condition interacted with covariates to predict math/science course interest or achievement. There were no interactions with gender or age, although there was one significant interaction with preexisting perceived math/science competence, which is discussed in the online supplemental material (see "Central Analyses: Interest in Math/Science and Arts/Humanities/Social Sciences Courses").

[3] Specifically, the online supplemental material presents tests of the direct and indirect effects (via math/science course interest) of the treatment on (a) greater intentions to minor in math/science, (b) increased satisfaction with academic experience, (c) increased overall health, (d) increased belongingness, and (e) decreased stress/anxiety in their math/science courses. We also examined whether the treatment would show the strongest effects on interest and grade outcomes for students with higher (vs. lower) independent self-construal.

### *Growth Theory of Interest*

First, we examined our preregistered hypothesis that the intervention would cause a sustained increase in a growth theory of interest, relative to the control condition through the first year. As predicted and replicating the Pilot Study, at the end of the first semester, 3 months after treatment, students reported a stronger growth theory of interest in the growth-theory-of-interest condition ($M = 3.51$, $SD = 0.94$) than in the control condition ($M = 3.17$, $SD = 0.85$), $b = 0.17$, $z = 4.52$, $p < .001$, 95% confidence interval (CI) [0.098, 0.247], $d = 0.39$. This effect persisted through the end of the second semester, 8 months after treatment (growth-theory-of-interest condition: $M = 3.49$, $SD = 0.93$; control condition: $M = 3.20$, $SD = 0.93$), $b = 0.14$, $z = 3.61$, $p < .001$, [0.066, 0.222], $d = 0.32$.

As theory-of-interest scores correlated, albeit weakly, with theory-of-intelligence scores (see "Method" section), we also examined whether this effect held controlling for theory of intelligence. It did, both at the end of the first semester, $b = 0.17$, $z = 4.57$, $p < .001$, 95% CI [0.099, 0.247], $d = 0.40$, and at the end of the second semester, $b = 0.15$, $z = 3.75$, $p < .001$, [0.070, 0.222], $d = 0.33$. Furthermore, there was no condition difference in theory-of-intelligence scores at the end of either semester ($ps > .300$; see the online supplemental material). Thus, the growth-theory-of-interest intervention specifically and durably promoted students' belief that interest can be developed.

### *Interest in Math/Science Courses*

Next, we examined students' interest in their two required first-year math/science courses. We tested the effects of condition, preexisting math/science identity, and the Condition × Preexisting Math/Science Identity interaction separately for each course.

First, the quantitative course was completed by 564 students (97.9% of the study sample). Of those in the course, 532 (94.3%) provided course interest ratings during the semester in which they took the course. As students were enrolled in one of the nine sections in the course (eight in the first semester, one in the second semester), analyses included eight dummy codes for section along with covariates; dummy variables are an effective approach to account for clustered data when the number of clusters is small (under 10; McNeish & Stapleton, 2016). This does not apply to the computation course or to the arts/humanities/social sciences courses, for which no section information was available from the university registrar.

Second, the computation course was completed by 252 students (43.2% of the sample; 96.8% of whom also took the quantitative course). Of these, 229 students (90.9%) provided course interest ratings. The computation course took place only in the second semester (students who did not take the computation course during the second semester would do so in their second year).

Table 1 summarizes the key findings, and Figure 3 illustrates the results. Not surprisingly, in both courses there was a significant main effect of preexisting math/science identity: Students with a low preexisting math/science identity reported less interest in both math/science courses. The main effect of condition (at the mean level of math/science identity) was not significant in the quantitative course, though it was in the computation course (as it was in the Pilot Study; see Table 1 and the online supplemental material).

However, as shown in Table 1, the effect of preexisting math/science identity was qualified by a significant interaction with treatment condition in both courses. The growth-theory-of-interest intervention (vs. control) led to significantly greater interest in both math/science courses among students with a relatively low ($-1$ *SD*) preexisting math/science identity but did not affect interest among students with a relatively high (+1 *SD*) preexisting math/science identity.

To further understand this effect, we calculated the point on the math/science identity scale at which the condition difference on interest became statistically significant. In both courses, the condition difference emerged in the lower half of the 6-point identity scale (2.31 in the quantitative course, 3.29 in the computation course, where 3.5 is the scale midpoint), which corresponds to the range of the scale in which students indicated that they "disagreed" that they were "a Math-" or "a Science-oriented person." Thus, as theorized, the intervention boosted course interest specifically among students who did not initially identify with math/science (not just among students with a lower math/science identity relative to other students in the sample).

Strikingly, in the growth-theory-of-interest condition, students who had low preexisting math/science identity reported as much interest in the computation course as students with high preexisting math/science identity. In the control condition, however, interest was lower for students with low (as compared to high) preexisting math/science identity). See Table 1 and Figure 3.

In summary, the growth-theory-of-interest intervention boosted interest in both math/science courses among students whose preexisting math/science identity was low.

### *Grades in Math/Science Courses*

Next, we examined students' final course grades. Table 1 presents the results of the regression models, and Figure 4 illustrates the results. There was no main effect of condition or of preexisting math/science identity in either course. However, as shown in Table 1, and in support of our theorizing, the Condition × Math/Science Identity interaction was again significant in both courses. Among students with a relatively low ($-1$ *SD*) preexisting math/science identity, the intervention (vs. control) marginally increased grades in the quantitative course and significantly increased grades in the computation course. Among students with a relatively high (+1 *SD*) preexisting math/science identity, the intervention did not affect grades.

Again, we calculated the point on the math/science identity scale at which the condition difference in course grades became significant. In both courses, it emerged in the "disagree" range of the 6-point identity scale (1.47 in the quantitative course, 2.58 in the computation course); that is, among students who did not initially identify with math and science.

As with course interest, the results were particularly striking in the computation course. Table 1 and Figure 4 show that, in this course, students in the growth-theory-of-interest condition with a low preexisting math/science identity earned grades equal to those with a high preexisting math/science identity. In the control condition, however, computation course grades were lower for students with a low (as compared to high) preexisting math/science identity.

In summary, the growth-theory-of-interest intervention significantly interacted with students' preexisting math/science identity to affect year-end grades in both math/science courses. Relative to the control condition, for students with a low preexisting math/science identity, the growth-theory-of-interest intervention marginally boosted final grades in one required math/science course and significantly boosted grades in the other.

**Table 1**
*Effects of Condition on Math/Science Course Outcomes as a Function of Preexisting Math/Science Identity*

| | Quantitative course | | | | | Computation course | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Effects and interactions | $b$ | $z$ | $p$ | 95% CI | $R^2$ | $b$ | $z$ | $p$ | 95% CI | $R^2$ |
| Course interest | | | | | | | | | | |
| Condition | 0.04 | 0.73 | .466 | [−0.066, 0.143] | .196 | 0.21 | 2.35 | .019 | [0.035, 0.387] | .122 |
| Math/Science Identity | 0.44 | 5.51 | <.001 | [0.282, 0.594] | | 0.45 | 3.41 | .001 | [0.191, 0.707] | |
| Condition × Math/Science Identity | −0.11 | 2.17 | .030 | [−0.218, −0.011] | | −0.23 | 2.51 | .012 | [−0.406, −0.050] | |
| Gender | 0.06 | 0.32 | .749 | [−0.291, 0.405] | | 0.19 | 0.54 | .591 | [−0.500, 0.877] | |
| Perceived math/science competence | 0.12 | 1.55 | .122 | [−0.033, 0.281] | | −0.09 | 0.69 | .489 | [−0.349, 0.167] | |
| Age | 0.04 | 0.56 | .576 | [−0.111, 0.200] | | −0.01 | 0.04 | .970 | [−0.245, 0.235] | |
| D1 section | 0.59 | 2.57 | .010 | [0.140, 1.039] | | — | — | — | — | |
| D2 section | −0.15 | 0.48 | .634 | [−0.785, 0.478] | | — | — | — | — | |
| D3 section | −0.14 | 0.35 | .727 | [−0.907, 0.632] | | — | — | — | — | |
| D4 section | −0.42 | 1.74 | .081 | [−0.892, 0.052] | | — | — | — | — | |
| D5 section | −0.05 | 0.18 | .857 | [−0.641, 0.533] | | — | — | — | — | |
| D6 section | 0.23 | 0.78 | .434 | [−0.343, 0.799] | | — | — | — | — | |
| D7 section | 0.58 | 1.42 | .155 | [−0.219, 1.383] | | — | — | — | — | |
| D8 section | −0.13 | 0.21 | .832 | [−1.324, 1.065] | | — | — | — | — | |
| Effect of condition at low (−1 *SD*) math/science identity | 0.15 | 2.05 | .040 | [0.007, 0.300] | | 0.44 | 3.47 | .001 | [0.191, 0.687] | |
| Effect of condition at high (+1 *SD*) math/science identity | −0.08 | 1.00 | .316 | [−0.223, 0.072] | | −0.02 | 0.13 | .893 | [−0.270, 0.235] | |
| Effect of math/science identity in control condition | 0.55 | 5.78 | <.001 | [0.365, 0.740] | | 0.68 | 3.98 | <.001 | [0.344, 1.010] | |
| Effect of math/science identity in growth-theory-of-interest condition | 0.32 | 3.40 | .001 | [0.137, 0.510] | | 0.22 | 1.48 | .139 | [−0.072, 0.513] | |
| Course grade | | | | | | | | | | |
| Condition | 0.03 | 0.41 | .684 | [−0.095, 0.145] | .104 | 0.08 | 0.90 | .370 | [−0.091, 0.243] | .043 |
| Math/Science Identity | 0.08 | 0.88 | .381 | [−0.099, 0.259] | | 0.12 | 0.99 | .322 | [−0.121, 0.366] | |
| Condition × Math/Science Identity | −0.12 | 2.05 | .041 | [−0.243, −0.005] | | −0.21 | 2.48 | .013 | [−0.381, −0.044] | |
| Gender | 0.70 | 3.40 | .001 | [0.295, 1.096] | | .18 | 0.52 | .604 | [−0.490, 0.842] | |
| Perceived math/science competence | −0.14 | 1.54 | .124 | [0.077, 0.438] | | .05 | 0.38 | .703 | [−0.197, 0.292] | |
| Age | 0.26 | 2.79 | .005 | [−0.321, 0.039] | | −.06 | 0.48 | .629 | [−0.294, 0.178] | |
| D1 section | 0.68 | 2.53 | .011 | [0.152, 1.198] | | — | — | — | — | |
| D2 section | −0.38 | 1.01 | .314 | [−1.129, 0.362] | | — | — | — | — | |
| D3 section | −0.42 | 0.95 | .340 | [−1.288, 0.445] | | — | — | — | — | |
| D4 section | 0.02 | 0.08 | .940 | [−0.537, 0.580] | | — | — | — | — | |
| D5 section | 0.02 | 0.05 | .957 | [−0.656, 0.693] | | — | — | — | — | |
| D6 section | 0.29 | 0.84 | .401 | [−0.386, 0.964] | | — | — | — | — | |
| D7 section | 0.29 | 0.59 | .554 | [−0.662, 1.234] | | — | — | — | — | |
| D8 section | 0.39 | 0.60 | .546 | [−0.877, 1.656] | | — | — | — | — | |
| Effect of condition at low (−1 *SD*) math/science identity | 0.15 | 1.74 | .082 | [−0.019, 0.317] | | 0.29 | 2.41 | .016 | [0.053, 0.525] | |
| Effect of condition at high (+1 *SD*) math/science identity | −0.10 | 1.15 | .251 | [−0.269, 0.070] | | −0.14 | 1.12 | .263 | [−0.375, 0.102] | |
| Effect of math/science identity in control condition | 0.20 | 1.85 | .064 | [−0.012, 0.421] | | 0.34 | 2.11 | .035 | [0.023, 0.648] | |
| Effect of math/science identity in growth-theory-of-interest condition | −0.04 | 0.41 | .683 | [−0.258, 0.169] | | −0.09 | 0.63 | .528 | [−0.369, 0.189] | |

*Note.* Condition was coded as *growth theory of interest* = 1, *control* = −1. Preexisting math/science identity was standardized. CI = confidence interval.

### *Mediation of Higher Grades via Increased Course Interest*

Given that the intervention, relative to control materials, tended to raise both interest and grades in math/science courses for students with a low preexisting math/science identity, we next examined whether the gains in course grades were mediated by increased interest. In other words, we tested the indirect effect of the intervention on final math/science course grades via increased math/science course interest for students with a low preexisting math/science identity. We did not expect a similar effect for students with a high preexisting math/science identity because, as reported earlier, the intervention did not affect interest or grades for these students. To test these predictions, we conducted a moderated mediation analysis and examined the indirect effect for low versus high math/science identity students (see Edwards & Konold, 2020; Hayes, 2015). We did so separately for the quantitative and computation courses.

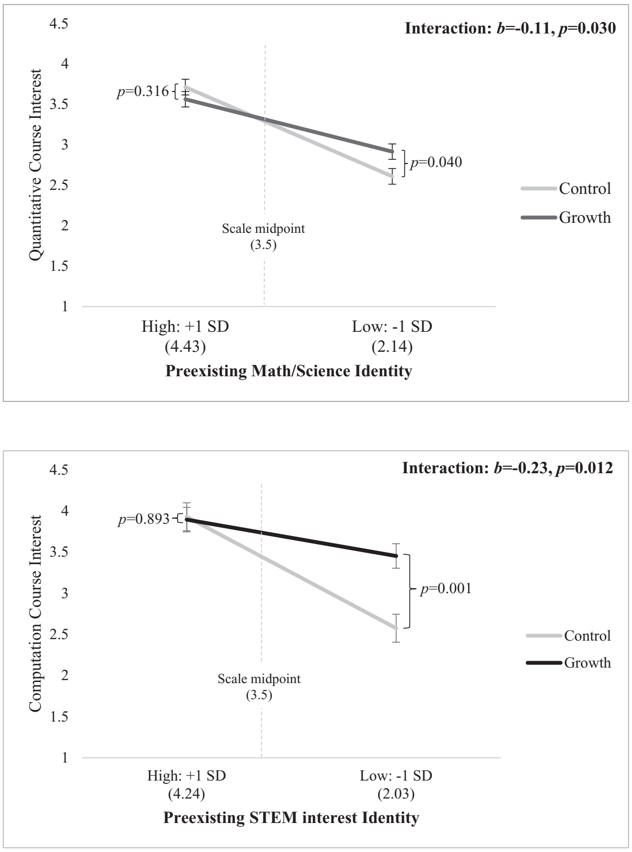
Figure 5 presents the process model and statistical results of each path in the analysis. The index of moderated mediation was tested with bias-corrected bootstrapping procedures using 10,000 samples.

As shown in Figure 5, in both math/science courses, course interest predicted higher final course grades. The test of moderated mediation was significant in the quantitative course, 95% CI [−0.041, −0.002], and in the computation course, [−0.141, −0.014]. As expected, there was a significant indirect effect of the intervention (vs. control) on final course grades via increased course interest for students with a relatively low (−1 *SD*) preexisting math/science identity, in both the quantitative course, [0.002, 0.057], and the computation course, [0.047, 0.233]. By contrast, for students with relatively high (+1 *SD*) preexisting math/science identity, there was no indirect effect for either math/science course.

These analyses are consistent with the interpretation that, by increasing students' interest in their two required math/science courses, the growth-theory-of-interest intervention (vs. control)

**Figure 3**

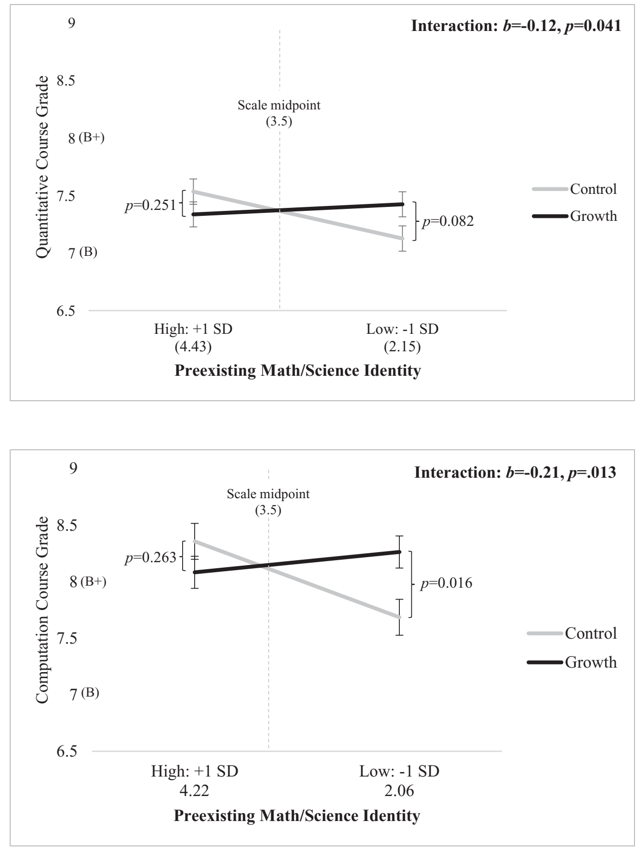
*Interest in Quantitative Course (n = 532) and Computation Course (n = 229) for Students With High Versus Low Preexisting Math/Science Identity*




*Note.* The full interest scale ranges from 1 (*strongly disagree*) to 6 (*strongly agree*). Error bars represent standard errors. Data points are predicted values from models controlling for covariates. Raw values of preexisting math/science identity appear in parentheses (scale range: 1–6); these raw values differ between the top and bottom panels because the samples are not identical across courses. The dashed gray lines indicate the midpoint (3.5) of the 6-point math/science identity scale.

**Figure 4**

*Grades in Quantitative Course (n = 564) and Computation Course (n = 252) for Students With High Versus Low Preexisting Math/Science Identity*




*Note.* The full scale ranges from 1 (*F*) to 11 (*A*+). Data points represent predicted values from models controlling for covariates. Error bars represent standard errors. Raw values of preexisting math/science identity appear in parentheses (scale range: 1–6); these raw values differ across the top and bottom panels because the samples are not identical across courses (nor are they identical with Figure 3, where the sample is restricted to students who responded to the end-of-semester surveys). The dashed gray lines indicate the midpoint (3.5) of the 6-point math/science identity scale.

improved final grades among students with a low (vs. high) preexisting math/science identity.

### *Interest and Grades in Arts/Humanities/Social Sciences Courses*

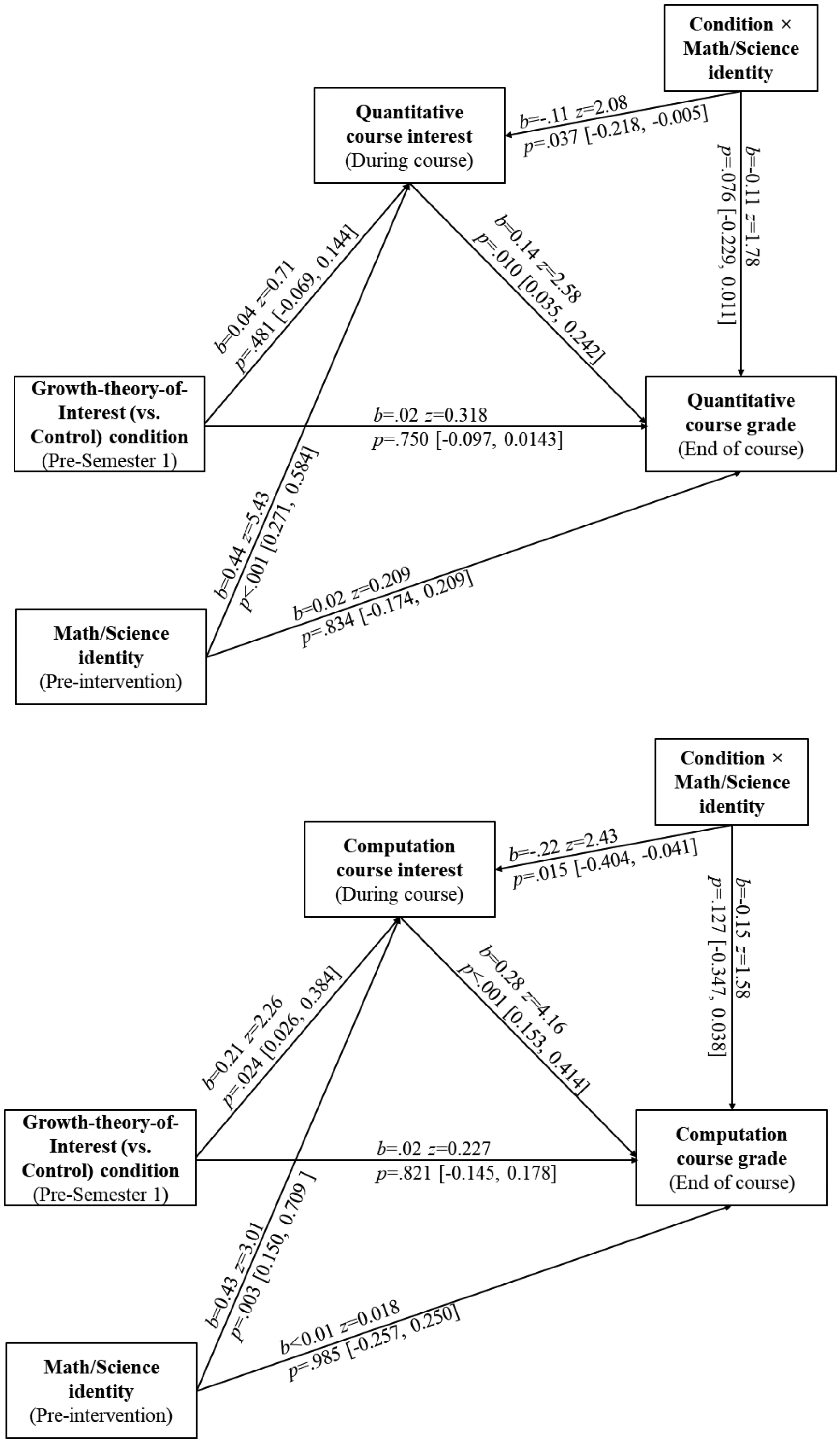
Our theorizing predicts that the growth-theory-of-interest intervention would increase interest and grades specifically in classes in which students have a low preexisting identity, and not affect students' experience in other classes. In our sample, these were math and science courses for students with a low preexisting identity in math and science. However, it is also possible that the intervention could raise interest and grades in all courses. Alternately, the increased interest and grades in math and science courses could come at a cost to students' interest and grades in courses that aligned with their preexisting academic identity.

To assess these possibilities, we examined students' two required arts/humanities/social sciences courses. Unlike the required math/science courses, there was no significant Condition × Preexisting Math/Science Identity interaction on interest (*p*s $>$ .500) or grades (*p*s $>$ .090) in either course. Higher preexisting math/science identity was unrelated to arts/humanities/social sciences course interest (*p*s $>$ .300), although it predicted relatively lower grades in both arts/humanities/social sciences courses (*p*s $<$ .030). There was also no main effect of condition on interest or grades, with one exception (*p*s $>$ .400). Students in the growth-theory-of-interest condition (vs. control) expressed lower interest in the general public communication course ($p = .017$; see the online supplemental material). Thus, seven of eight tests of the effect of the intervention on arts/humanities/social sciences courses (main effects and interactions on interest and grades in two courses) were not significant.

Although nonsignificant effects are not proof of null effects (potentially, differences could emerge with greater statistical power), these null findings were preregistered, rooted in theory, consistent with

**Figure 5**

*Moderated Mediation in Quantitative Course (n = 564) and Computation Course (n = 252)*




*Note.* Numbers in brackets are 95% confidence intervals. For clarity, covariates are not presented.

previous research (O'Keefe et al., 2018a), and replicate analyses of the arts/humanities/social sciences courses in the Pilot Study. At least with this sample, the intervention increased interest and grades specifically in courses outside students' preexisting academic identities without generally affecting interest and grades in courses aligned with students' academic identities.

## General Discussion

College offers superb opportunities for learning across disciplines. Yet if students view interests as fixed, they may fail to venture beyond fields for which they have already "found" a passion. For instance, if students do not see themselves as a "math or science person," they may not prepare for a wide array of quality career paths that value STEM interests and skills.

In both the pilot study and the main study, college students whose academic identity lay predominantly in the arts, humanities, and social sciences, but not in math and science, reported more interest in their mandatory first-year math and science courses when they had received the growth-theory-of-interest intervention (vs. active control materials) in a brief online module just before beginning college. In the pilot study, this effect emerged as a main effect on interest in a required second-semester math/science course, assessed 8 months after the intervention. In the main study, conducted with a larger sample at the school of arts and social sciences at a different university, it emerged as a significant moderated effect in each of two mandatory first-year math/science courses. Relative to the active control condition, the treatment significantly increased interest in both math/science courses among students with a low preexisting math/science identity upon entering university. Moreover, these same students earned higher grades (significantly in one math/science course and marginally in the other), and these gains in performance were statistically mediated by the greater course interest caused by the intervention. Thus, consistent with our theorizing, the students who least thought of themselves as a "math or science person" were those who benefited most, in terms of higher math and science course interest and better performance, from the growth-theory-of-interest intervention.

The intervention did not affect outcomes for students who already held a relatively high identity in math and science. As such, students were already disposed to find math/science courses interesting, they did not need to develop a new interest, and holding a fixed theory of interest was not expected to be a barrier for them (for theorizing and related laboratory findings, see O'Keefe et al., 2018a). Thus, lifting the fixed-theory barrier improved outcomes only for students with a low preexisting identity in math and science.

### Strengths and Educational Implications

The present research has notable strengths. While previous research on theories of interest has been confined to the laboratory (O'Keefe et al., 2018a; O'Keefe, Horberg, et al., 2021; see O'Keefe et al., 2018b), the present research used a randomized, controlled field-experiment and examined long-term educational outcomes in college students' first-year courses. These results are more than a mere demonstration of an important psychological process in an externally valid setting. The two courses examined in the present research had been selected by the university as a priority for its first-year students because it believed that the skills taught in them would aid their subsequent education and professional careers. In the quantitative course, students learned to use data and statistics to draw inferences, identify causes, and elucidate relations among variables in the real world. In the computation course, students learned computational tools and approaches to formulating problems and designing solutions. The broader purpose of these courses was to equip students who had primary interests in the arts, humanities, and social sciences with the ability to use mathematical and scientific techniques to enhance critical thinking and, ultimately, be better prepared for the workplace. The growth-theory-of-interest intervention helped students take advantage of these opportunities.

### Limitations and Future Directions

As the first real-world demonstration that a brief intervention can sustainably promote a growth theory of interest and enhance the development of new interests, the present research raises important questions that will be exciting to explore in future research. Among these are how a growth theory of interest might benefit women or other groups underrepresented in particular STEM contexts. Also exciting to explore will be the specific processes by which the intervention can boost interest in coursework and performance over time. As with every intervention, it will also be important to explore the robustness and bounds of the effect in other populations and school contexts. And it will be important to test the intervention against other active control conditions as well as a passive (e.g., no-treatment) control condition, to further estimate the treatment effect and rule out any influence, positive or negative, of the specific control condition used here.

#### *Process*

A specific question of importance is to learn more about how the intervention works. Theoretically, the intervention provides a relatively simple psychological framework that encourages students to entertain interests outside of their existing academic identity. Many of our participants began their first year of college believing that they were not the "math or science" type, as evidenced by their low preexisting math/science identity scores. Indeed, some students spontaneously elaborated on their lack of identification with math and science when describing their existing interests in response to an intervention prompt before college. As one student wrote, "I always believed that I was not a mathematics person" while another commented, "Although I did relatively well in all my 'hard science/math' subjects, I always felt that my heart was in the arts, in subjects like philosophy and anthropology." The intervention refocused students on the possibility of growing new interests beyond their existing identity. In reflecting on how the idea that interests can develop can help students, one student articulated this incisively: "Understanding that interests may arise where there [were] none allows me more freedom to delve into areas of study I have previously been too hesitant to approach."

How might this shift in perspective alter the way students interpret and act in everyday situations? In a required math or science course, an arts student with a fixed theory might approach their lessons with the goal of merely memorizing the material and obtaining a minimally satisfactory performance, without seriously considering that the material could be of interest or connect to their existing interests. By contrast, a student with a growth theory might approach the same lessons with an openness to appreciating and enjoying aspects of the material or connecting it to their existing interests. This latter student might invest more time or effort into processing the material deeply—from asking more questions in class, to discussing the material with others, to exploring other activities even outside of class relevant to the coursework—which may help them uncover aspects of the course material that are of interest to them. In turn, such behaviors might account for the increased interest students reported at the end of their math and science courses and their higher performance, particularly when the material becomes difficult (see O'Keefe et al., 2018a, Study 5). Moreover, these behaviors may confirm students' growth theory of interest, and thus initiate a self-reinforcing process. These possibilities will be exciting to pursue in future research.

### Downstream Implications

It is important that the growth-theory intervention helped students develop greater *interest* in math and science. As noted earlier, engagement in academic subjects that arises from intrinsic motivation is more likely to last (O'Keefe et al., 2017, 2018a; Sansone & Smith, 2000) and more likely to be integrated with other interests (O'Keefe, Horberg, et al., 2021). Would the growth-theory-of-interest intervention then inspire students to pursue a more interdisciplinary education (see "Pilot Study" in the online supplemental material)? Future studies could examine longer-term outcomes, such as students' enrollment in future elective math and science courses or their pursuit of career trajectories that bridge STEM and the humanities, as suggested by recent laboratory research (O'Keefe, Horberg, et al., 2021).

### Contextual Boundary Conditions

No psychological intervention is a magic bullet (Yeager & Walton, 2011). It is important to consider when a growth-theory-of-interest intervention is more and less likely to raise course interest. First, students are unlikely to develop interest in new academic areas without structures that support learning in those areas. The schools in which we conducted this research required arts-focused students to complete math/science courses early in college. These courses were designed to teach quantitative and computational skills embedded within real-world issues and examples. This provided a key opportunity for students to explore areas beyond their academic identities in a setting conducive to developing interest. If such opportunities are unavailable or are not facilitated, students may not be able to put a growth theory of interest to work (see Yeager, Carroll, et al., 2022). Second, through these requirements, the institution may signal a norm of broad intellectual exploration, legitimizing the idea of a growth theory of interest and permitting students to act on it. In contexts where this idea is counter-normative—if, for instance, openness to new areas is seen as reflecting a lack of commitment to one's focal area of study—treatment effects may be less likely (Walton & Yeager, 2020; Yeager et al., 2019).

### Social and Cultural Context

Another question involves how the intervention might intersect with strong negative stereotypes about ability in math and science (e.g., Plante et al., 2019), or worries about belonging in these fields (e.g., Cheryan et al., 2009; Leslie et al., 2015; Spencer et al., 1999; Walton et al., 2015). Insofar as the intervention does not dispel these stereotypes or mitigate belonging uncertainty, a growth theory of interest may not be sufficient on its own to increase engagement in math and science in the long run for students who face such stereotypes, such as for women and other groups who are underrepresented in STEM. In the present study, although the intervention was effective in a sample where women represented the majority (70% of participants in the Main Study were women), stereotypes about men's superior math and science skills might not be as strong in Singapore as elsewhere. For example, both girls and boys are highly encouraged to excel in math and science from a young age, and their performance on standardized math and science exams is among the best in the world (Bybee & Kennedy, 2005).

As our study was not ideal for exploring these questions, it will be important to test the effectiveness of the intervention in institutional and sociocultural settings with, for example, strong racial–ethnic and gender stereotypes about math and science ability and belonging. Such research may also explore ways to combine a growth-theory-of-interest intervention, to open students to interest in math and science, with social belonging and/or growth-theory-of-intelligence interventions to help them sustain this interest as stereotype-related challenges emerge (see Yeager, Bryan, et al., 2022). It may also be possible to tailor the growth-theory-of-interest intervention to combat negative stereotypes or promote a growth theory of interest in the context of the threat and worries about belonging that manifest in such contexts. For example, an intervention could communicate that a growing number of women are developing interests in math and science fields (a dynamic norm; see Sparkman & Walton, 2017) perhaps because such fields enable women to fulfill goals to help people and work with others (i.e., to emphasize communal affordances, see Diekman et al., 2017; see also Brown et al., 2015; Howe et al., 2021). It would be exciting if integrating a growth theory of interest with other factors could mitigate group disparities in STEM interest and achievement.

With respect to the cultural context of this inaugural test of the growth-theory-of-interest intervention, the Singaporean post-secondary institutions examined here had distinct advantages. First, the intervention revealed that the effects of a growth theory of interest, which were originally tested in the United States (O'Keefe et al., 2018a), extend to a different culture—even to a culture where interest and passion are typically considered less critical for motivation (O'Keefe et al., 2022). More broadly, almost all original tests of psychological interventions focus on a single context, usually in the United States, although it is essential to understand the effects of psychological interventions in broader cultural communities. Second, as we have discussed, the present culture was well-suited for testing the intervention because of the high premium Singapore places on math and science and because its students often are skilled in those areas (Bhattacharjee, 2004). As noted, even as many students in our sample lacked an identity in math and science, they nonetheless had a strong background in these areas (Kelly et al., 2020), which helped to isolate the effects of a lack of academic identity from a lack of ability or preparation. An important question for future research is whether the present results generalize to students lower in math/science ability or preparation. Certainly, the intervention may not be as effective among students for whom a lack of ability or preparation serves as a constraint (or who hold a fixed theory about intelligence). However, if at least some cases of poor performance stem from a lack of interest, then adopting a growth theory of interest could short-circuit this negative cycle.

### *Beyond Math and Science*

Unlike past interventions in STEM contexts, our growth-theory-of-interest intervention did not focus specifically on math and science fields or on students' particular courses, such as the personal relevance of the material (Hulleman & Harackiewicz, 2009) or a sense of belonging in those contexts (Binning et al., 2019; Walton et al., 2015). It merely represented interest as developable. The goal was not to encourage students to pursue math and science fields per se, but to remove a psychological barrier—the belief that interests are fixed—that could prevent students from developing new interests as they began college. In the contexts investigated here, this meant developing a greater interest in math and science. Yet our theory suggests that this approach should broaden interests among any population with a narrowed focus. If so, could this intervention foster greater enjoyment of the arts and social sciences among STEM students? This would be beneficial because many engineers, mathematicians, and scientists work in organizations and companies that require the use of skills that emphasize aspects of humanities and social sciences education O'Keefe et al., 2018b. An education that is supplemented with subjects like psychology, sociology, ethics, philosophy, and economics can help students better understand and serve people, groups, and society, prepare them to work effectively with co-workers, clients, and companies (e.g., Hynes & Swenson, 2013; Josa & Aguado, 2021), and to think in new and innovative ways (O'Keefe, Horberg, et al., 2021).

Indeed, there is particular value to enhancing interests that bridge the conventional arts-science distinction, in either direction. Many of the most innovative companies today—Apple, Pixar, Impossible Foods, among others—attribute their creative achievements to their success in connecting math, science, and technology with the humanities or social sciences, including their understanding of culture and recognition of the values that people have and the challenges they face. As fields increasingly specialize, it becomes even more important for people to draw connections across fields and develop interdisciplinary insights and solutions. Thus, the importance of viewing interests as developable may only increase.

## Conclusion

Early in college, students have countless opportunities to explore new topics. Our research shows that students can take better advantage of these opportunities if offered the perspective that interests can develop. The effectiveness of our brief online module suggests that colleges and universities can create value by fostering campus climates that reinforce the idea that interests can and do grow, such as by communicating that this way of thinking about and approaching coursework is normative and shared by peers (e.g., Murrar et al., 2020; Paluck et al., 2016). By creating cultures that support a growth theory of interest, universities may help students become interdisciplinary scholars and reap the long-term benefits of the diverse academic opportunities they offer.

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