Transforming the Lowest-Performing Students: An Intervention That Worked

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We conducted a small-scale study to investigate if a brief timely intervention focusing on specific study strategies would improve student performance in university science courses. We targeted low-performing students after the first midterm exam in two courses (enrollments of 67 and 185) with different student populations, one with students in a very selective physics program and the other with a broad range of students in a general science elective course. In this intervention, instructors either met personally with students or sent them a personalized e-mail. Students who met with an instructor and discussed specific study strategies improved their performance from one exam to the next by up to 32 ± 7%, without increasing their study time. These students also reported changing their study strategies during the term more than other students. Students who received an e-mail also improved their performance but not more than would be expected without an intervention. These results show that a focused discussion advising a small number of specific study strategies can have a large impact on the lowest-performing students in contexts in which the new study strategies are aligned with course structure, expectations, and assessments. This is in sharp contrast to results obtained from most general study-skills interventions.

Most postsecondary science teachers are familiar with a depressing pattern: scores on early exams and assignments seem to establish how well nearly all the students will do in a course. Nothing the professor does in the many subsequent weeks of instruction seems to help students who start out poorly (Jensen & Moore, 2008). Several published studies (Freeman et al., 2007; Jensen & Moore, 2008, 2009; Moore, 2005) and countless unpublished examples illustrate optional educational interventions that were intended to improve the performance of low-performing, postsecondary science students but were unsuccessful. These interventions include providing extra review sessions, practice problems, additional office hours, help rooms, and more. The high-performing students typically avail themselves of these additional resources and improve, whereas the lower performing students do not (Jensen & Moore, 2008, 2009; Moore 2005), though low performers self-motivated to seek help can show substantial gains with course-specific coaching (e.g., Chaplin, 2007). Hattie, Biggs, and Purdie's (1996) comprehensive meta-analysis of general learning skills interventions with university students found that "the effects on study skills are minimal" (p. 126). A likely reason for this failure is that general study skills interventions are too broad in their scope and too distant from where they will be applied.

General studies in psychology show that goals that are specific and reasonably achievable in the short run are effective at improving performance, whereas very general and/or long-term goals are not (Latham & Yulk, 1975; Steers & Porter, 1974). These relationships have been replicated in university classroom situations. For example, Morgan (1985) showed that students setting specific learning goals articulating what they would be able to do as a result of their near-term studying showed improved learning, whereas those who set distant goals or goals based on amount of time for studying did not. These researchers attribute much of the benefit of specific goals to the fact these goals allow more effective self-monitoring of learning. Researchers on memory and meta-memory (Bjork, 1994) have shown that retention is improved by doing anything that involves more extensive processing of the material, and that self-testing is one of the most effective ways of carrying out such deeper processing. Targeted self-testing improves metacognition by providing students with a more accurate picture of what they have and have not mastered. Other strategies, related to self-testing that improve self-monitoring include generating summaries (Thiede & Anderson, 2003) or even keywords (Thiede, Anderson, & Therriault, 2003). However, simple rereading after a delay, a standard review practice used by many students, increases neither self-monitoring accuracy nor performance (Dunlosky &

Rawson, 2005), and worse, familiarity can instill a false sense of mastery (Reder & Ritter, 1992) under some circumstances.

Even upper-level science students do not automatically self-test, self-monitor, or make deliberate efforts to learn from mistakes (Mason & Singh, 2010). The study skills intervention described here applies research on goal-setting and self-testing to course-specific contexts with a deliberate focus on low-performing students not expected to seek help on their own.

A targeted intervention to improve study habits

We conducted a small-scale experiment in which the academic success of students who began poorly was greatly improved through a timely personal intervention by course instructors that concentrated on changing student study habits. Our intervention encouraged students to take a few specific actions dealing with deeper processing of the course material through self-testing, particularly as defined by the specific course learning goals. Although our choice of intervention advice was somewhat ad hoc, our approach aligns with tested theories about learning and goal setting. The criteria Morgan (1985) used for the goals students were trained to set are very similar to the criteria for the learning goals we articulated in the two courses studied here. Students were strongly encouraged in the interventions to use these specific learning goals and past assessments to self-test and to consult notes and supplementary reading material in a targeted manner.

Our setting

The intervention described here was conducted in two science courses with different student populations at a large, selective, public research university. Students at this Canadian university are comparable to those at the most elite U.S. public institutions (Wieman & Sudmant, 2008).

The first course in which we conducted an intervention was an introduction to modern physics (Course A), which covers standard topics in quantum mechanics and special relativity. Course A was taken by 67 students at the end of their second year in the engineering physics program, a selective and demanding program. The second was an introductory oceanography survey course (Course B). Course B attracted 185 students from a wide range of arts and science majors. The teaching in both courses was highly interactive, with clicker questions and peer discussion (Mazur, 1997) and many student questions. Course A also had regular small group in-class activities, two midterm exams, a final exam, graded weekly homework, and preclass reading assignments. Course B had three midterm exams, a final exam, and five graded homework assignments. Both courses provided learning goals to all students, and exams were aligned with these goals.

The interventions conducted in the two courses share fundamental approaches but differ in details. We collected somewhat different data in each course. Although this means we do not have replication of all data sets, given the combination of information collected in both courses, we are able to discuss a broader range of issues regarding effects on students.

Who gets an intervention?

We identified students to target on the basis of low scores on the first midterm. In Course A, we targeted the 18 students who scored in the bottom quartile. In Course B, we targeted the 35 students who had failed Midterm 1. In course B, we further divided the failing students on the basis of their self-reported study time (reported directly on the exam), under the assumption that those who studied more than the class median (six hours), yet failed, had inefficient study strategies and likely could benefit most ($n = 16$).

We timed each intervention to take place immediately after the first midterm when students' interest in improving their study habits was likely to be high. Students received a personalized e-mail communicating that the instructors were concerned about their performance. In Course A, all 18 students were asked to meet with an instructor, and 13 did (2 of these 13 were out with extended illness after the intervention and so are not considered in the subsequent analysis and discussion). In Course B, the 16 students who both failed and reported studying more than six hours were asked to meet, and 7 did. These groups are considered the "meeting" intervention students. This approach is imperfect, because our meeting intervention students self-selected to respond to our invitations; however, we have no reason to expect that these particular students would have sought help on their own. In addition, in Course B, the remaining 19 students received a different e-mail, with no invitation to meet but with specific study advice. About 20% of the students in each course received some kind of intervention.

Face-to-face meeting interventions

Face-to-face intervention meetings typically lasted 15–25 minutes. In Course A, students met individually with an instructor; in Course B, up to three students met with an instructor simultaneously. Following a brief introduction, students were asked how they spent their study time. Commonly, they answered that they tried to memorize everything, without any indication that they had prioritized on the basis of relative importance. We then discussed how students could use the course learning goals more effectively to target their studying. We showed specific examples of learning goals (e.g., from Course B: "Compare the amount and type of energy emitted by objects at different temperatures"), practice questions and/or homework problems, and exam questions from the first midterm (e.g., aligned with the learning goal above: "This diagram shows the wavelengths of maximum emission for the sun and the earth. Where would the wavelength of maximum emission occur for a human?"), and pointed out how they were all related. We showed students that the exam was based on the learning goals and that each exam question addressed a learning goal. We also mentioned study tips that were based on Bjork (2001) and that recommend testing one's learning while studying. We emphasized that to improve exam performance, students should actively test themselves on the stated learning goals as they studied. Specific recommended actions included the following:

- Attempt to "do" each learning goal by generating your own explanations.
- Consult course resources (notes, reading, homework, sample problems and solutions) in a targeted manner, to improve your ability with a specific learning goal. Do not simply reread.
- Match available assessments (e.g., clicker questions, practice questions, homework problems) to specific learning goals, and test yourself on all of those items by creating your own responses before looking at answers. Imagine alternate ways to test the goal, and test yourself with your own (or other students') questions.
- Attend weekly (optional) problem-solving sessions (Course A only).

These recommended practices had been provided to all students in both classes before the first midterm. Nevertheless, in the intervention meetings, the study practices listed previously were seldom, if ever, mentioned by students.

TABLE 1

Midterm scores and comparisons among groups.

Group (*n*)	Midterm 1 mean (SD)	Midterm 2 mean (SD)	M2-M1(SD)	*p*-value	Effect size
Course A				< .001*	
Meeting(11)	65.5 (8.8)	84.0 (8.1)	19±4 (13)	< .001# .8§	1.6# 0.14§
E-mail (5)	58.6 (11.6)	75.3 (8.7)	17±5 (12)	.003#	1.5#
Others (48)	84.2 (9.6)	84.0 (9.6)	0±2 (12)		
Course B				< .001*	
Meeting (7)	37.1 (11.2)	69.1 (11.2)	32±7 (17)	< .001# .08§	2.2# 0.76§
E-mail (28)	38.7 (8.1)	58.7 (15.6)	20±3 (15)	< .001#	1.3#
Others (134)	70.9 (11.3)	71.9 (15.4)	1±1 (14)		

Note: All p-values for interaction between midterm score and treatment, from repeated measures analysis of variance with midterm score as a within-subject factor and treatment as a between-subject factor. M1 = Midterm 1; M2 = Midterm 2.

*Comparison among three treatment groups (meeting, e-mail, and others)

#Comparison between others and each intervention group separately

§Comparison between meeting and e-mail treatment groups

E-mail interventions

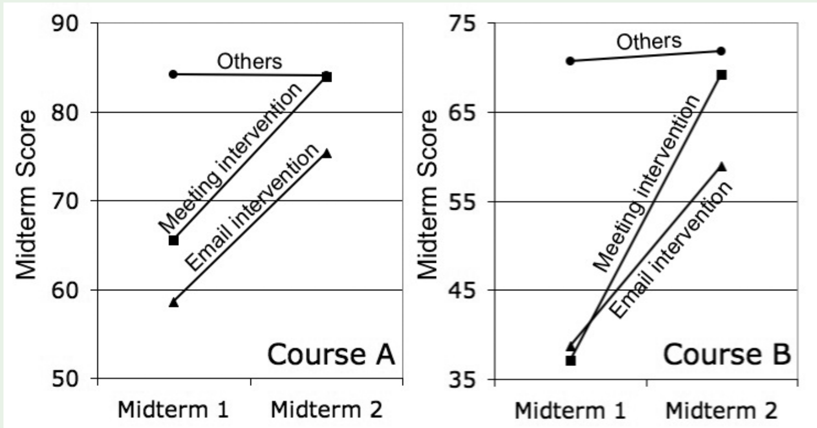
Although our original intentions were to meet with all the targeted students, five students in Course A and nine students in Course B who were invited to a face-to-face meeting with the instructor did not come. These students did not receive any additional study advice beyond what was provided to all students in these courses. In Course B, we compared these 9 students with the 19 students who received the e-mail with specific advice (those who failed Midterm 1, studied less than six hours) but were not invited to a meeting. These two groups have very similar average Midterm 1 scores ($p = .95$) and similar gains on Midterm 2 compared with Midterm 1 ($p = .85$). On the basis of this comparison, we have combined all students who received any type of e-mail, with or without study advice, but did not meet with instructors, as the "e-mail" intervention students ($n = 5$ for Course A; $n = 28$ for Course B).

Surveys and interviews

To gather information about any changes students made to their study practices, the students in the bottom and next-to-bottom quartiles in Course A ($n = 23$) completed a formal verbal survey about their study practices shortly after the end of the term, about six weeks after the intervention. This survey was verbally administered and audio-recorded by

FIGURE 1

Comparison of exam performance and gains among the meeting intervention groups, e-mail intervention groups, and all other students for Course A and Course B.



a person uninvolved with the course. Questions were asked about students' typical study practices, their study practices in Course A, whether and how they had changed their study practices during Course A, and what advice that they would give other students—both specifically for Course A and for science courses in general. To categorize student self-reported study practices, the codes "notes," "homework," "learning goals," "book," "prereading," "review sessions," "studied more," and "other" emerged from evaluation of students' recorded open-ended responses to the verbal survey questions. Once these codes were established, responses were independently coded by two of the authors, with interrater reliability over 90%. In addition, 25 students in Course A, including most of the verbally surveyed students, participated in more informal, less-structured interviews with one of the course instructors. In Course B, at the end of term, students completed an online survey question about whether they changed their study habits.

Results and discussion

Intervention students improve performance

Both meeting and e-mail intervention groups significantly increased their average scores on Midterm 2 over Midterm 1 compared with those not in the intervention groups ("others" in Table 1 and Figure 1). A two-way repeated measures analysis of variance (ANOVA) with midterm scores as a within-subject factor and treatment (meeting, e-mail, and others) as a between-subject factor shows a significant interaction between midterm scores and treatment in both courses, $F(2, 61) = 14.2, p < .001$ for Course A; $F(2, 166) = 32.1, p < .001$ for Course B. The extremes in the meeting intervention group are remarkable, with a student improving from 49% to 91% in Course A and from 16% to 80% in Course B. Nearly all individuals in the intervention groups increased their scores from Midterm 1 to Midterm 2, whereas only about half of those not in the intervention groups increased their scores. Although two of our intervention groups are quite small (Course A e-mail and Course B meeting), effect sizes for the intervention groups range up to 2.2 for gains made by the meeting intervention students in Course B (Table 1).

Improvement beyond "regression to the mean"

To test whether the lowest-performing students likely would have increased their Midterm 2 exam scores anyway, in Course B we compared (a) meeting intervention students ($n = 7$), (b) e-mail intervention students ($n = 28$), and (c) "usual low" students who failed Midterm 1 in this course during four other terms, when no intervention was offered ($n = 164$). The usual low group represents the expected regression to the mean for low-performing students in the absence of an intervention. A fourth group, "usual other" students who passed Midterm 1 during any of five offerings of the course (including the term in which interventions were offered; $n = 574$), represent regression to the mean for higher-performing students (Figure 2).

To account for variability in exam averages and variance in different terms, all Midterm 1 and Midterm 2 exam scores were transformed to z-scores within each exam. We ran a two-way repeated measures ANOVA with midterm z-scores as a within-subject factor and treatment (meeting, e-mail, and usual low) as a between-subject factor. There is a marginally significant interaction between midterm z-scores and treatment, $F(2, 196) = 2.8, p = .06$. Repeating this analysis with two treatments at a time shows that the meeting intervention students significantly outperformed usual low students, $F(2, 169) = 5.5, p = .02$, effect size = 0.91, and likely outperformed the e-mail intervention group, $F(2, 33) = 3.3, p = .08$, effect size = 0.77 (Figure

2). However, the e-mail intervention group showed the same gain as the usual low group, $F(2, 190) = 0.34$, $p = .56$, effect size = 0.12. Receiving an e-mail from an instructor, in this case, produced the same increase in exam performance as simply knowing one failed the first exam, a typical "wake-up call" for students (Bonner & Holliday, 2006). The usual other group showed expected regression toward the mean, with negative average gains (Figure 2). The only treatment in this large introductory class that produced a greater gain than might be expected simply because of regression toward the mean was a meeting intervention. For Course A, we lack data from previous terms for a parallel analysis. Possible interpretations of our existing Course A data include either (a) the improvement shown by intervention students is not beyond regression to the mean, or (b) in this higher level class, e-mail and meeting interventions have approximately equivalent impacts. Additional data from future courses will help differentiate these options.

What did intervention students do differently?

Although these results establish that the meeting intervention had an effect, they do not determine why. Did students improve because they changed how they studied, changed how much time they studied, or were simply motivated to study harder because the instructor showed personal concern with their success?

Changing study habits in general

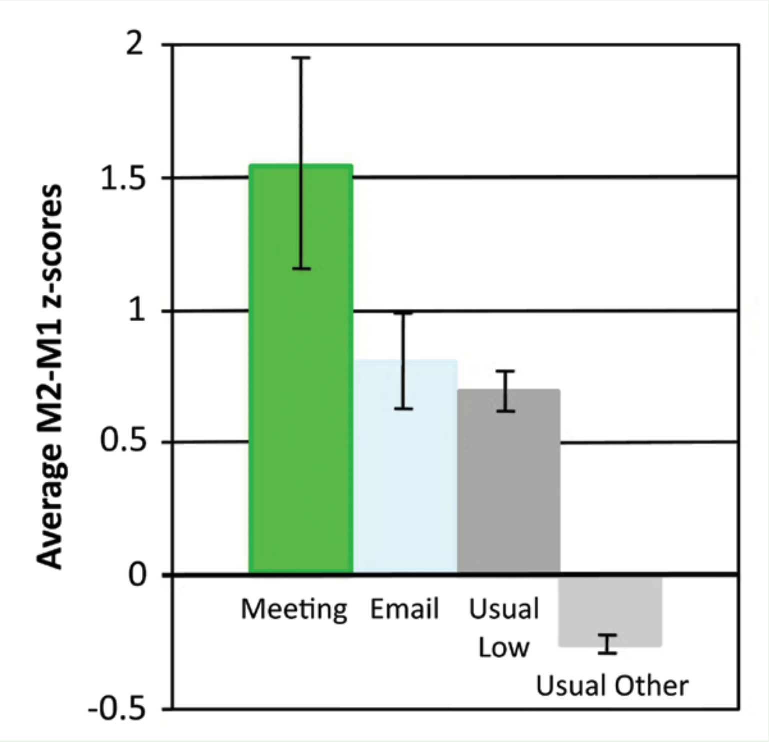
In Course B, in an online survey at the end of the term, students were asked, "Did you modify your study habits during the second half of the term?" Answer choices were (a) Yes, a lot, (b) Yes, a little, and (c) No. Of 102 students who responded, 80% of the meeting intervention students reported changing their study habits "a lot" during the second half of the term ($n = 5$), compared with only 25% of the e-mail intervention students ($n = 16$) and 15% of the nonintervention students ($n = 81$). Results from Fisher's Exact Test indicate that the distribution of answers from meeting intervention students is different from the responses from the other two groups ($p = .006$). These survey responses from Course B imply that the intervention (meeting in particular) may have encouraged students to change their study tactics, but for Course B, we lack information regarding specific changes they made.

Adopting recommended study strategies

For Course A, the formal verbal surveys of 23 students show that meeting intervention students adopt recommended study practices at much higher rates than nonintervention students. The two groups reported nearly identical rates for using recommended study practices to prepare for Midterm 1 (Figure 3, top). The meeting intervention verbal survey responses regarding Midterm 1 were consistent with what these students had said previously during the intervention

FIGURE 2

For Course B, comparison of M2–M1 z-scores among the meeting intervention group, e-mail intervention group, usual low performers who failed Midterm 1 during four other offerings of the course, and usual other performers who passed Midterm 1 in any of five terms, including the intervention term. Error bars represent standard error. M1 = Midterm 1; M2 = Midterm 2.



meetings. However, 7 of 10 meeting intervention students reported newly adopting recommended practices to study for Midterm 2 (e.g., testing themselves, targeting the learning goals, consulting the book, attending review sessions), whereas only 1 of 13 higher-performing nonintervention students reported a change in these categories (Figure 3, bottom). One additional nonintervention student reported a change in studying for Midterm 2, but that change was to "study more," rather than change tactics. This contrast between these two groups suggests that the meeting intervention influenced how these students studied later in the course.

No increase in study time

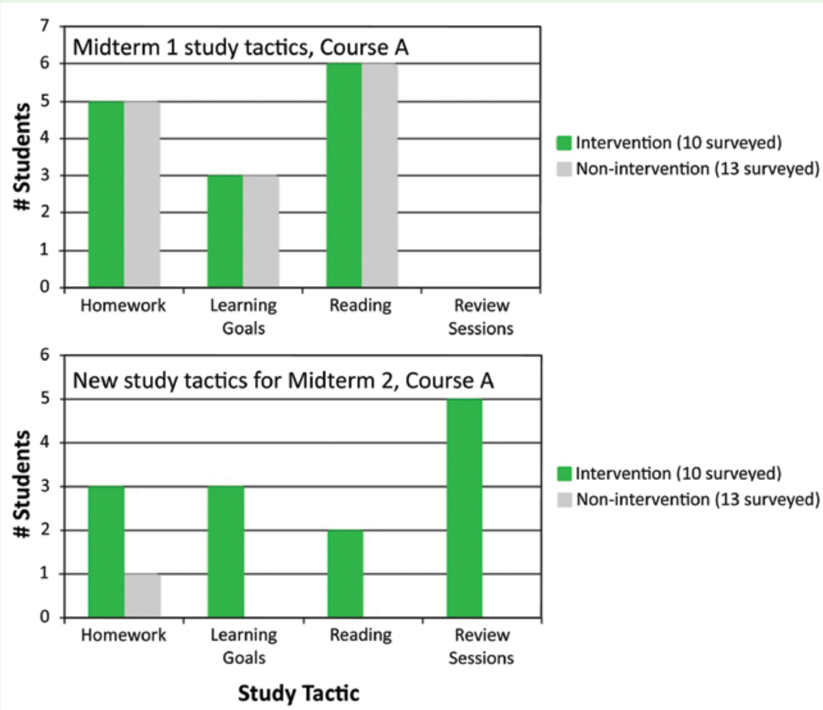
The meeting intervention students in Course B reported studying slightly less for Midterm 2 compared with Midterm 1 (decreased from a median of 11 hours to 10 hours), though they still remained above the class median (6 hours per exam). These results imply that "studying harder" was not generally responsible for the improvement shown by meeting intervention students. Both subsets of the e-mail intervention groups (those who studied more than 6 hours and those who studied less than 6 hours) moved toward the class median study time for Midterm 2. The first group's median study time decreased from 10 to 6 hours, whereas the latter group's median study time increased from 3 to 8 hours. The increase in study time by the latter group might be expected simply from learning that one has failed the first exam.

Why did intervention students change?

Did intervention students improve solely because an instructor expressed concern about their performance and willingness to help? Research in communication behaviors has indicated that students are more motivated when they receive high levels of out-of-class support (Jones, 2008). Student perceptions regarding whether instructors care about their learning positively correlate with student self-reports of learning (e.g., McCroskey, Valencic, & Richmond, 2004; Teven & McCroskey, 1997; these studies did not measure performance). In informal interviews with instructors in Course A, some students did mention instructor concern as a motivating factor. Figure 2 indicates that receiving an e-mail from an instructor may not motivate students more than merely receiving the information that they failed the first exam. Thus, an e-mail appears to be below the threshold for an effect of instructor concern on performance, at least in Course B. It's possible that the meeting intervention students were responding to instructor concern, but (a) they also reported changing their study habits (Figure 3), and (b) they slightly decreased their study time (Course B). If a student's primary motivation was to try harder simply because he or she was informed that the instructor was paying

FIGURE 3

For Course A, comparison of self-reported study tactics between the meeting intervention group (*n* = 10 surveyed) and nonintervention students in the second lowest quartile (based on Midterm 1 scores) of the class (*n* = 13 surveyed). The four categories shown here are the four codes that correspond to tactics discussed in the intervention meetings. Original codes "book" and "prereading" are combined in this figure into "reading." Top: Study tactics reported for Midterm 1. Bottom: New study tactics (not done for Midterm 1) reported for Midterm 2.



attention, we might expect increased study time with little change in study tactics to be the most common response. Although we cannot discount instructor concern as a motivating factor, our other data indicates that nearly all students who participated in intervention meetings made specific changes in study practices in response to the guidance given, allowing them to prepare more efficiently and effectively for assessments in these course contexts than other students.

Will recommended study strategies work in other courses?

Inventory surveys of student approaches to learning (Biggs 1978, 1987; Entwistle, 2000; Entwistle & Ramsden, 1983; Pintrich, Smith, Garcia, & McKeachie, 1993) would not predict a large effect for the intervention we used. These studies consistently identify a division between learning approaches primarily based on simple memorization ("surface," "rehearsal") and approaches involving deeper more extensive cognitive processing (Entwistle & McCune, 2004). Correlations between deeper learning approaches and course marks range from modest (*r* values 0.1–0.2) to nonexistent, and surface approaches show small anticorrelations with marks. In a setting similar to ours, a science course in a large North American public university, Zusho, Pintrich, and Coppola (2003) found a correlation of 0.13 between course mark and "rehearsal" (memorization) learning strategies, and an insignificant but negative correlation with deeper cognitive strategies of "organization," "elaboration," and "metacognition."

These approaches-to-learning results, particularly from Zusho et al. (2003), would appear to contradict cognitive psychology studies of memory showing how deeper, more extensive processing consistently leads to substantially better learning and would imply much smaller, or even opposite, effects on student exam performance from what we observed. This apparent contradiction between approaches to learning inventory results and our study can be understood by contrasting our students' perceptions of how to succeed in the courses studied here, compared with how to succeed in their other science courses.

Students verbally surveyed in Course A were specifically asked to articulate advice they would give to other students, both to succeed in Course A and to succeed in other science courses. The contrast in their responses to these two questions indicates that most courses do not have course components aligned. In advice regarding success in Course A, the meeting intervention students nearly always listed the items discussed during the intervention. However, their advice for succeeding in other science courses commonly focused on "figuring out the instructor" and what sort of exam questions he or she might ask, rather than mastering the course content. For example, we were initially surprised to learn during our intervention meetings that students didn't automatically review the homework, but in the formal verbal surveys, these students indicated that in many of their science courses, they did not see a connection between the exams and homework problems.

Our intervention advice was designed to help students pursue deeper, more metacognitive study strategies, guided by articulated learning goals that are clear to both students and instructors (Simon & Taylor, 2009). Many students have difficulty figuring out what's important to learn, particularly in an unfamiliar domain, and their interpretation of what's important differs from instructors' views (Bonner & Holliday, 2006; Hrepic, Zollman, & Rebello, 2007). We argue that the intervention described here worked largely because, in both these courses, serious effort (as described in Chasteen, Perkins, Beale, Pollock, & Wieman, 2011) was made to establish clear and explicit learning goals and to ensure that all course elements (class time, homework, exams) were well aligned with these goals. Specific study guidance "embedded within the teaching context itself" (Hattie et al., 1996, p. 131) does appear most effective in our cases. The large gains we observed may not be evident in other university course settings.

Recommended conditions for an intervention

Clearly, an intervention must offer advice that will actually help students study more effectively. An intervention in which an instructor recommends targeting the learning goals for study is likely to be effective only if the exam is also aligned with those learning goals and students perceive that alignment. Much of the variation observed in studies examining correlations between student approaches to learning and course performance may be due to variations in the degree of alignment in the different courses studied.

Implications

The most important result from this study is that it demonstrates specific ways that instructors can improve the performance of students at the bottom of the class distribution. From one exam to the next, this intervention moved the lowest-performing students to near or slightly above the class median, without increasing their reported study time. This result is all the more striking because of the quite basic nature of the study advice offered. This study skills intervention has features that psychologists note as important for behavioral change, namely a small number of quite specific actions embedded in the context in which they are to be used. Future application in other well-aligned courses of the intervention in the small-scale study described here will test whether our approach is broadly applicable.■

Acknowledgments

This work is supported by the University of British Columbia through the Carl Wieman Science Education Initiative. We are pleased to acknowledge the assistance of Grace Wood in carrying out surveys and of the students in our courses who volunteered to be surveyed. Thanks to Ido Roll for statistics advice and to Roger Francois and May Ver for providing comparative data. Comments from Wendy Adams and Sarah Gilbert greatly improved this work. This work does not necessarily represent the views of the Office of Science and Technology Policy or the U.S. Government.

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