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The Paradox of Explaining: When Feeling Unknowledgeable Prevents Learners From Engaging in Effective Learning Strategies

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People often need to learn complex information as part of their daily lives. One of the most effective strategies for understanding information is to explain it, for instance to a hypothetical other (Pilots 1 and 2). Yet, we find that learners prefer equally effortful but less effective learning strategies, even when incentivized to perform well (Study 1). Critically, we propose and find that learners' reluctance to explain is tied to their subjective knowledge of the material; learners who feel less knowledgeable about what they learned are most reluctant to explain it, despite the strategy being as effective for them (Study 2). An intervention that increased subjective knowledge (by having learners answer a few easy questions) increased learners' choice to explain, which was mediated by learners believing that explaining would be more pleasant and effective (Study 3). Directly manipulating beliefs about how fun and effective explaining is also boosted learners' willingness to explain (Study 4). Finally, because Studies 1–4 incentivized performance financially, we replicated key results in the classroom with students, finding improved scores on a class quiz (Study 5). The paradoxical implication of these findings is that those who need effective learning strategies the most are the ones least likely to use them. Put together, we find that subjective knowledge plays a key role in learning decisions and that boosting subjective knowledge is a simple intervention that can improve learning-related choices.

Public Significance Statement
There is little overlap between the learning strategies that researchers have identified as effective and the strategies that people actually use. For example, explaining the material to a hypothetical audience is a highly effective but rarely used learning strategy. This set of studies highlights the importance of self-perceived knowledge for understanding people's reluctance to engage in explaining. Paradoxically, it is not only that people often adopt the wrong learning strategies but that people who feel the least knowledgeable and need effective learning strategies the most are the ones least likely to use them. This study also offers two low-cost interventions for increasing people's willingness to engage in explaining.

Keywords: learning strategies, subjective knowledge, self-explanation, explaining, self-perceptions

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All data (raw and processed), analysis scripts, and materials are available on the Open Science Framework at https://osf.io/9mkhj/?view_only=00fc5419994a41f59ed61fbad4108891. All studies except the Supplemental Pilots and Pilot 1a were preregistered. Pilot 1b is preregistered on AsPredicted. Org at https://aspredicted.org/znxw-53xf.pdf, Study 1 at https://aspredicted.org/ts35-jz8p.pdf, Study 2 at https://aspredicted.org/d6cq-ycdd.pdf, Study 3 at https://aspredicted.org/trkr-r898.pdf, Study 4 at https://aspredicted.org/vbjp-99k3.pdf, and Study 5 at https://aspredicted.org/pjft-njmm.pdf.

Findings from this research have been presented at the following conferences: Society for Personality and Social Psychology, Society for the Science of Motivation, Academy of Management, Southwest Academy of Management, Singapore Conference on Applied Psychology, BIG Difference BC, and the Self Preconference at Society for Personality and Social Psychology. The article has not been posted on a listserv or shared on a website.

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Sophie is a college student taking, say, a biology course. She has an upcoming quiz on glycolysis and wants to do well. How will Sophie prepare?

Research has identified effective learning strategies, one of the most effective of which is trying to explain the material (Crouch & Mazur, 2001; Fonseca & Chi, 2011; Smith et al., 2009). Explaining how glycolysis works would be effective for Sophie because it involves deep processing of the material, but although research has documented the effectiveness of explaining, it remains a strategy that learners use infrequently (Gurung et al., 2010; Pilot 1S). Instead, research shows that Sophie is likely to overrely on repetition-based learning strategies like rereading, highlighting, and copying (Blasiman et al., 2017; Karpicke et al., 2009; Tullis & Maddox, 2020) that are not strongly predictive of comprehension or test performance (Gettinger & Seibert, 2002; Gurung et al., 2010). We ask why this is, proposing that Sophie's subjective knowledge plays a key role. Specifically, we propose that low subjective knowledge steers learners away from explaining and toward learning strategies that involve less knowledge reflection because knowledge reflection can be self-threatening, especially for low-subjective-knowledge learners. This new understanding of learners' studying choices helps account for an important learning paradox. Namely, it is not only that people often adopt the wrong learning strategies but that learners who feel the least knowledgeable and need effective learning strategies the most are the ones least likely to use them.

This learning paradox is relevant for scholars across disciplines and builds on psychological processes from multiple areas of psychology. In particular, our findings bridge the traditional interests of educational psychology, cognitive psychology, and social psychology. We highlight the cognitive processes involved in self-assessment and learning strategy selection, while also addressing the social psychological implications of self-perception on behavior. The research not only provides insights into educational practices but also extends understanding of metacognitive and self-regulatory mechanisms, making it of broad interest to researchers studying learning, motivation, and self-perception.

Explaining Is an Effective Learning Strategy

Research shows that when trying to understand complex information, one of the most effective strategies one can use is to explain it to someone else, real or imagined, or even to oneself (e.g., Fonseca & Chi, 2011). Though different forms of explaining vary in their specifics, they generally involve the learner organizing information into a coherent explanation and articulating the explanation orally or in writing. Explaining involves reflecting on and making sense of the information. This process encourages being explicit about one's assumptions, which prompts deeper comprehension and reveals problem areas.

For example, consider the strategy often utilized in software engineering under the name "rubber duck debugging." When a software engineer struggles to find the problem ("bug") in a piece of code, they explain it line by line to an inanimate object, traditionally a rubber duck sitting on their desk. The process of explaining is thought to be effective for finding problems in the code because it encourages coders to spell out their steps, which exposes mistakes. Experimental work in the education domain bears out this notion; for example, learners who solved a geometry problem while explaining their steps to a computer-based tutor understood the material better, showing greater success on transfer problems (Aleven & Koedinger, 2002; see also work on computer-based "teachable agents" Biswas et al., 2005; Leelawong & Biswas, 2008). Similarly, learners who merely prepared to explain to someone else without actually doing so displayed better conceptual understanding than learners who prepared for a test (Benware & Deci, 1984), suggesting that explaining is effective even without the benefits from explaining to a real person (e.g., being questioned about the material) because it requires learners to organize the material clearly in their minds.

At its core, explaining is a knowledge reflection activity, such that it involves reflecting on what one does and does not know. It involves "deep" learning, contrasted with "surface-level" learning that is focused on mere reproduction (Nolen, 1988). Deep learning strategies like explaining are positively related to learning outcomes, whereas surface learning strategies are negatively related to them (Purdie & Hattie, 1999).

Learners' Studying Choices

Research has not only identified which learning strategies are more (vs. less) effective, but has also documented the descriptive learning choices that learners tend to make. Learners often have substantial flexibility in choosing how much to study and how to do so, making it particularly important to understand their learning choices. In educational settings, for example, students taught material in the classroom are then free to study this material outside class in whatever way and however much they like or think will prepare them to demonstrate comprehension, usually via exams or papers. In the workplace, which is becoming increasingly knowledge-centric (Bell & Kozlowski, 2008), employees choose how to learn job-relevant information (Greco et al., 2019; Maurer & Tarulli, 1994; Noe et al., 2010; Sitzmann et al., 2006). For example, a consultant researching information about an industry she is unfamiliar with can decide how to learn the information effectively for the assignment. A worker undergoing workplace training can choose how to learn the covered material for successful implementation on the job. Learners' choices of learning strategies have consequences for educational and professional performance (Dunlosky et al., 2013).

One choice that learners make that has received much research attention is how much effort to invest in studying. Previous work on self-regulation has focused on predicting when people increase their effort versus disengage from their goal (Brandtstädter & Rothermund, 2002; Carver & Scheier, 1990, 2000, 2001; Heckhausen, 1999; Poulin et al., 2005; Wrosch et al., 2003). For example, Carver and Scheier (2000) posited that goal pursuers assess the likelihood of their goal being achieved, leading them to either feel confident and increase their effort or feel doubtful and disengage from the goal. While this framework has been highly informative, the implied dichotomy does not capture the range of options available to learners, which include not only increased effort or disengagement but also ways of engaging. Learners not only decide whether to study but also how to do so.

Choosing Effective Versus Ineffective Learning Strategies

Past work has shown that students' learning mindsets and goals can lead them to choose more or less effective learning strategies (Ainley, 1993; Ames, 1984; Diener & Dweck, 1978; Dweck, 1986; Dweck & Leggett, 1988; Elliott & Dweck, 1988; Fisher & Ford, 1998; Meyer et al., 1997; Nolen, 1988; Schunk, 1990; Sujan et al., 1994). For example, Diener and Dweck (1978) found that learners who thought their capacity could grow (i.e., had a growth mindset) chose more effective problem-solving strategies than those who believed their capacity was fixed (i.e., had a fixed mindset). In another study, students who were learning for the sake of learning (i.e., had a mastery goal or task orientation) chose more effective learning strategies than those who were learning for the sake of performing well on a test (i.e., had a performance goal or an ego orientation; Nolen, 1988).

Although the work described above points to variability in learners' choices, previous research on learning strategies suggests that, overall, learners often fail to choose effective deep strategies, like elaborative interrogation (McDaniel & Donnelly, 1996; Seifert, 1993), interleaved practice (Kornell & Bjork, 2008), and other strategies that feel effortful (Karpicke et al., 2009). Instead, learners favor relatively ineffective surface-level learning strategies that do not predict exam performance well (Baars et al., 2020; Blasiman et al., 2017; Karpicke et al., 2009). Indeed, previous studies found that "many students—including some high achievers—do not engage in effective self-regulation during learning" (Schunk & Ertmer, 2000, p. 631; see also Nolen, 1988; Weinstein & Mayer, 1983; Zimmerman & Martinez-Pons, 1990). For example, middle and high school students report their most commonly used learning strategy is simply rereading the material, which is a surface-level strategy (Tullis & Maddox, 2020).

In the current article, we focus on one highly effective but rarely used learning strategy: explaining the material. To test our assumption that learners do not use this strategy often, in Pilot 1S (full details in the Supplemental Material), we asked current students who had studied for an exam or quiz in the past month to list all learning strategies they had used. Only 2% spontaneously mentioned explaining. Even when marking the strategies they have used from a list that included explaining (see Supplemental Table S1), only 34% indicated that they explained the material to someone else, and only 36% indicated that they explained it to themselves (with overlap in the responses).

Although no previous work has focused specifically on why learners are reluctant to explain, researchers have explored why learners fail to use other effective learning strategies. One answer is that learners default to ineffective learning strategies because they are unaware of more effective ones (Borkowski et al., 2014; McKeachie et al., 1985; Pressley, 1990). They also sometimes fail to recognize the value of effective strategies, either to the self (self-efficacy; Schunk, 1994; Zimmerman & Martinez-Pons, 1990) or in general (Bjork et al., 2013; Ertmer et al., 1996; Fabricius & Hagen, 1984; Roediger & Karpicke, 2006). When it comes to explaining, however, we suggest that learners may show reluctance even when they are aware of the strategy and despite recognizing that explaining is a highly effective learning strategy. To test whether learners are generally aware that explaining is an effective learning strategy, in a second Pilot 2S (full details in the Supplemental Material), we asked learners to imagine that they had just learned new information and to rate the effectiveness of 40 common learning strategies for preparing them for a test on the information. Learners indicated that explaining would be the most effective one (4.42 out of 5.00 on effectiveness). Being unaware of explaining as a learning strategy or not recognizing its value, then, cannot fully account for learners' reluctance to use explaining. We suggest that a key unexplored factor in learners' choices is their subjective feelings of knowledge about the material. Specifically, we examine whether learners are reluctant to explain because reflecting on one's knowledge can be threatening, especially when one feels particularly unknowledgeable.

Subjective Knowledge and Learning Strategies

Subjective knowledge is a metacognitive judgment that refers to people's beliefs about their level or quality of knowledge on a given topic. Research has demonstrated that subjective knowledge drives judgments in learning-related contexts (Atir et al., 2015; Hadar et al., 2013). For example, people who are made to feel more knowledgeable about a topic, without their objective knowledge changing, estimate that they scored higher on a subsequent test on the topic (Ehrlinger & Dunning, 2003), are more confident about their knowledge of specific topic-related terms (Atir et al., 2015), and are more willing to take action that requires topic knowledge (Hadar et al., 2013). Subjective knowledge has also been shown to influence learning-relevant behaviors, including information search (Brucks, 1985; Moorman et al., 2004; Raju et al., 1995; Tassiello & Tillotson, 2020), planning (Perry & Morris, 2005), and advice seeking (Brucks, 1985; Dodd et al., 2005; Lusardi & Mitchell, 2007; Robb et al., 2012).

Subjective knowledge is not a stable individual difference, but rather varies substantially based on topic and time. Thus, we examine whether subjective feelings of knowledge for a given topic (not as a general trait of the individual) will affect learners' willingness to employ explaining as a learning strategy. We consider two opposing predictions for how subjective knowledge will affect willingness to explain. On one hand, when learners feel less knowledgeable, they are most in need of effective learning strategies and might therefore be especially eager to explain. This is in line with past theorizing in control theory (Carver & Scheier, 1981, 1990, 2000) and the discrepancy reduction model (Dunlosky & Hertzog, 1998), according to which learners self-assess their knowledge to facilitate learning. Through a feedback loop, learners are expected to increase effort levels when there is a large discrepancy between the current state and the desired goal and to direct cognitive resources toward unfamiliar or less well understood material (Campion & Lord, 1982; Kanfer & Kanfer, 1991; Pintrich, 1990; Taylor et al., 1984; Winne, 1995). As Campbell and Lee (1988) explained in a review piece, "the theory implies that perceived discrepancies between current and predicted levels of performance not only trigger increased effort but they also trigger increased information search behavior. Individuals actively seek strategies for overcoming potential performance gaps" (p. 309). Thus, one possibility is that learners use their subjective knowledge assessment to study more effectively, choosing more effective learning strategies when their subjective knowledge is low.

On the other hand, learners' behavior often diverges from this ideal. For example, learners commonly overlearn easy material and underlearn difficult material (Bell & Kozlowski, 2008;

K. G. Brown, 2001). Furthermore, despite failure providing as much opportunity for learning as success does, research suggests that people often fail to learn from failure because it can be threatening, leading learners to tune out (Eskreis-Winkler & Fishbach, 2019, 2022). Similarly, people often refrain from learning information that would confer self-threatening knowledge (Kern et al., 2023).

Building on this work, we propose that when learners feel relatively unknowledgeable about the material, they will be especially reluctant to try to explain it, even to themselves. Explaining involves reflecting on one's knowledge, exposing gaps in understanding. Engaging in such knowledge reflection confronts the learner with what she does not understand well, which will be more unpleasant if she believes she does not understand the material well to begin with. Going back to Sophie and her glycolysis quiz, if Sophie feels she does not understand glycolysis well, explaining will seem especially unpleasant to her because it would confront her with her lack of knowledge about glycolysis as she struggles to explain it. Thus, we hypothesize that when students judge their knowledge of the material to be low, they will be less likely to try to explain it and instead opt for learning strategies that involve less knowledge reflection. By choosing a learning strategy that does not require the same level of knowledge reflection, learners avoid the unpleasant prospect of facing their own knowledge deficits. Thus, those who feel unknowledgeable and in need of effective learning strategies may be paradoxically less likely to use them. The theoretical model is diagramed in Figure 1.

Written Reflection as a Form of Explaining

Explaining can take various forms: formal peer teaching, as when a study group or a work team divides information to be learned, each member explaining their part to the rest of the team (Aronson et al., 1978; Svinicki & Schallert, 2016); informal explanation of information in casual conversation (Bowyer & Shaw, 2021); and self-explanation (Fonseca & Chi, 2011; Pi et al., 2022), in which a learner reflects on the material and tries to make sense of it. It can take a written (Lachner et al., 2017; Lawson & Mayer, 2021; Pi et al., 2022) or oral form (Jacob et al., 2020). Explaining is effective in both its social and solo versions (Chi et al., 1989, 1994; Fiorella & Mayer, 2016; Lachner et al., 2021; McNamara & Magliano, 2009; Wylie & Chi, 2014), but there are conceivable advantages and disadvantages to explaining to someone else compared with self-explaining (Coleman et al., 1997). On one hand, explaining to someone else means taking the perspective of someone else who is naïve about the material and may prompt particularly thorough explanations. This would lead to deeper processing and understanding. It may also be effective in revealing gaps in one's understanding (VanLehn et al., 1992), increasing metaknowledge accuracy to inform later studying behaviors (Metcalfe & Kornell, 2005). At the same time, explaining to someone else presents challenges that self-explaining does not. First, one must find an audience willing to listen to one's explanation. Second, if the explanation is lacking or incorrect, the result may be the spread of misinformation, which will be especially consequential if the listener later relies on the information. Indeed, in explaining studies, the explainer sometimes shows greater gains on comprehension measures than the explainee (Annis, 1983; A. L. Brown & Kane, 1988; Webb, 1989).

A promising strategy that combines the benefits of explaining to an audience with the logistical simplicity and low risk of self-explanation is explaining to an imagined or nonhuman audience (Aleven & Koedinger, 2002; Jacob et al., 2020; although some studies have found that self-explanations are more effective; Lachner et al., 2021). One such example is the above-mentioned rubber duck debugging strategy, in which computer coders explain their code line by line to an inanimate object to find errors in the code. In this article, we use a written form of this strategy that we call "written reflection," in which learners write an explanation of what they have learned as if they are explaining it to another person. This strategy has the benefit of being less costly than teaching others and does not risk spreading confusion or misinformation, while capitalizing on the explanatory benefits of taking the perspective of an uninformed target.

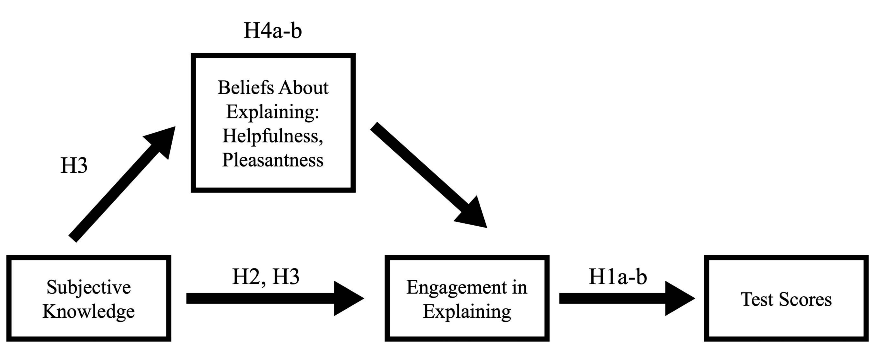
Hypotheses

Given previous research, we predicted that self-explaining would be effective for learning outcomes.

> *Hypothesis 1a:* Explaining (by engaging in written reflection) will improve test scores.

To build on this, we ask whether explaining is effective even for people who do not feel knowledgeable. One might wonder if

Figure 1
Theoretical Model



Note. H = Hypothesis.

low-subjective-knowledge learners are wise to avoid explaining; explaining may be ineffective for low-subjective-knowledge learners. Given the evidence that explaining is an effective learning strategy (Fonseca & Chi, 2011) and that learning interventions are often most effective for low-performing students (Yeager et al., 2019), we posited this to be unlikely. We predicted that explaining would be effective for low-subjective-knowledge learners and high-subjective-knowledge learners.

Hypothesis 1b: Explaining will improve test scores of both low-subjective-knowledge learners and high-subjective-knowledge learners.

Second, as described above, we suggest that learners disfavor explaining as a learning strategy, especially when subjective knowledge is low. Explaining involves reflecting on one's knowledge, revealing weak areas and confronting the learner with her own lack of knowledge. Though this feature may make explaining particularly effective, it also makes it self-threatening (Blascovich, 2013; A. J. Elliot, 1999), and when people feel less knowledgeable about a topic, the prospect of reflecting on their subjectively meager knowledge to generate an explanation should be particularly threatening. Thus, we predicted that learners who feel relatively unknowledgeable on the topic will be most reluctant to explain. Consistent with this notion, past work has found that when people feel they do not understand, for example, finance well, they are more reluctant to make investment decisions (Hadar et al., 2013). In the academic domain, when learners feel less confident in their ability to learn, they are more likely to disengage from an academic task (Liem et al., 2008). For learners who feel relatively knowledgeable on the topic, on the other hand, the prospect of reflecting on their own (subjectively substantial) knowledge would not be seen as self-threatening to the same extent. Instead, they would be more likely to see it as a challenge that they could take on and conquer. Thus, we expected them to be more likely to welcome the opportunity to explain the material.

Hypothesis 2: Subjective knowledge will be positively correlated with willingness to engage in explaining.

Note that we were agnostic about whether people's feelings of subjective knowledge are accurate in our context. Previous work has found that subjective knowledge is often positively correlated with objective measures of knowledge (with the specific correlations varying from essentially 0 to .5; Carlson et al., 2009; Chesebro & McCroskey, 2000; Falchikov & Boud, 1989; Park et al., 1994; Sitzmann et al., 2010; Witt & Wheeless, 2001; Zell & Krizan, 2014). However, subjective knowledge is clearly dissociable from objective measures of knowledge (e.g., Atir et al., 2024; Dunning et al., 2004; Ellen, 1994). This means that people sometimes under- or overestimate how much they know and how well they know it relative to the ground truth.

Third, if subjective knowledge indeed plays a key role in learners' choices to avoid or engage in explaining, it should be possible to shift subjective knowledge and affect learning choices. Previous experimental work has demonstrated that subjective knowledge is malleable. For example, one can artificially increase people's subjective knowledge on a given topic by asking them a series of easy (vs. difficult) questions on the topic (Atir et al., 2015; Ehrlinger & Dunning, 2003; Hadar et al., 2013) or decrease subjective knowledge by giving people complicated information on the topic (Hadar et al., 2013). This work has demonstrated the causal role of subjective knowledge in influencing behavior. We therefore predicted that making people *feel* more knowledgeable (without changing their objective knowledge) will make them more open to explaining.

Hypothesis 3: Increasing subjective knowledge will increase willingness to engage in explaining.

Finally, we began to test why learners with low subjective knowledge shy away from explaining and why learners with high subjective knowledge are more likely to embrace it. We posited that when learners felt knowledgeable, the prospect of using explaining would be seen as relatively unthreatening. It would be viewed as an effective way of reaching one's goal and as a pleasant opportunity to test oneself. When the same learners felt relatively unknowledgeable, on the other hand, explaining would be seen as self-threatening and, therefore, as unpleasant and ineffective. As an upshot, making learners feel more knowledgeable would lead them to view explaining as more pleasant and effective.

Hypothesis 4a: The positive relationship between subjective knowledge and willingness to explain will be mediated by beliefs about the effectiveness of explaining.

Hypothesis 4b: The positive relationship between subjective knowledge and willingness to explain will be mediated by beliefs about the pleasantness of explaining.

Overview of Studies

First, in two pilot studies, we confirmed that our written reflection explaining strategy boosted objective performance in the online setting that we used for Studies 1–4. In Study 1, we explored the extent to which individuals were interested in employing various learning strategies after they had learned complex new information on which they would be tested. In particular, we tested for the role of subjective knowledge. We found that those low in subjective knowledge about the material were especially reluctant to engage in strategies that required knowledge reflection.

Of course, it is possible that those low in subjective knowledge avoid knowledge reflection strategies because these strategies benefit them less. Thus, in Study 2, after we asked participants which activity they wanted to do, we assigned them to explain or not, regardless of their stated preference. We found that explaining improved performance regardless of subjective knowledge and interest in explaining.

To determine whether low subjective knowledge *causes* people to avoid explaining and to test whether we could increase people's willingness to explain, we experimentally manipulated subjective knowledge in Study 3. We found that making people feel more knowledgeable increased their willingness to explain. Consistent with subjective knowledge lowering self-threat, a mediation analysis suggested that subjective knowledge increased beliefs that explaining would be pleasant and effective, which was correlated with enhanced willingness to explain. Next, building on the results of Study 3, we tested whether directly telling people that explaining was pleasant or effective would increase their willingness to explain. We found that both interventions were effective (Study 4).

Finally, because Studies 1–4 were all run online with performance incentivized through financial payment, in Study 5 we provided additional external validity by replicating key results in a classroom learning environment. Confirming the effectiveness of explaining, students assigned to explain (vs. review the material) scored higher on a class quiz. Again, students low in subjective knowledge were the ones least interested in explaining despite explaining being effective for them.

In addition to the seven studies described in the main text, we report four additional studies in the Supplemental Material. These studies are presented in the Supplemental Material to reduce the length and improve the clarity of the article. Specifically, we ran two additional non-pre-registered pilot studies (Pilots 1S and 2S) that measured the learning strategies that students use and their beliefs about the effectiveness of various learning strategies (already described briefly in the introduction). We also ran two additional preregistered classroom studies (described briefly in the General Discussion section). The results of the classroom studies are consistent with our other studies, but because the intended manipulations were not effective in the setting, they cannot provide causal evidence for our hypotheses.

Transparency and Openness (All Studies)

We describe our sampling plan, all data exclusions, all manipulations, and all measures in the relevant Method sections and/or in the Supplemental Materials. All data (raw and processed), analysis scripts, and materials are available on the Open Science Framework at https://osf.io/9mkhj/?view_only=00fc5419994a41f59ed61fbad4108891. Data were analyzed using R, Version 4.2.1 (R Core Team, 2023) and the packages psych 2.2.5 (Revelle, 2022), lme4 1.1.-30 (Bates et al., 2015), and lmerTest 3.1-3 (Kuznetsova et al., 2017). All studies except Pilot 1a and the Supplemental Pilots were preregistered. Preregistration links are included in the Method section of each study.

Pilots 1a and 1b

We designed a written-reflection explaining strategy, which involves learners taking a few minutes after learning material for the first time to write down an explanation of the material directed to a hypothetical explainee who is unfamiliar with the material. This strategy builds on previous work that has established the benefits of learning strategies that involve explaining the material, as discussed in the introduction. It uses instructions similar to those used in previous studies on self-explaining and explaining to a hypothetical other (e.g., Pi et al., 2022). Nevertheless, we conducted two pilot studies testing whether written reflection was an effective explaining learning strategy in our context. To that end, we taught participants novel information about how global positioning system (GPS) works, randomly assigned them to engage in written reflection or not, and then tested their comprehension using a quiz that was administered 1 week later.

Method

Pilot 1a was not preregistered. Pilot 1b's design and hypothesis were preregistered on AsPredicted.Org at https://aspredicted.org/znxw-53xf.pdf. In addition to the relevant hypothesis (i.e., that explaining will increase scores), we preregistered a second hypothesis about subjective knowledge for a different project, which we do not discuss further here.

Participants

Both samples were recruited from Amazon's Mechanical Turk via CloudResearch and were restricted to U.S.-based participants. The final samples of Pilots 1a and 1b comprised 367 participants (201 men, 164 women, and two did not report gender) and 450 participants (231 men, 215 women, one chose "other," and one did not report gender), respectively. To measure gender, in the two pilot studies, participants saw the prompt "Gender:" and the following options: "Man," "Woman," "Other," and "Do not wish to say." We did not collect information on race or ethnicity. See Supplemental Material for all details about exclusions and attrition in this and all the following studies.

Materials, Design, and Procedure

Session 1. After providing consent, participants completed a series of screening tasks to ensure that their devices could properly display images and videos, to confirm that they were competent in English, and to screen for bots. Next, participants were introduced to the main task: learning about how GPS works using text (Pilot 1a) or videos (Pilot 1b). They were informed that they would be tested on their knowledge later. For Pilot 1a, we created a detailed six-part explanation of how GPS helps devices, such as smartphones, determine their location on earth. The explanation combined text and illustrating images. For Pilot 1b, we prepared seven video clips that taught the same information presented in textual form in Pilot 1a. The videos combined audio recordings of a narrator providing information about how GPS works and accompanying images that illustrated the information. Each video was between 30 s and 2.5 min long, for a total duration of a little over 10 min.

Participants read the six text sections (Pilot 1a) or watched the seven videos (Pilot 1b), presented on the screen one at a time. To encourage maximum understanding and retention, we asked participants to read each section or watch each video carefully and emphasized that the information may be complex and that participants would be tested on their understanding.

By random assignment, participants then completed the Written Reflection Task (written reflection condition) or not (control condition). For participants in the control condition, Session 1 concluded here. Participants in the written reflection condition were asked to write an explanation of how GPS works for 5 min as if explaining it to someone else. Specifically, they were asked to think back to what they had learned and try to explain it "really well," assuming the other person would get tested on the material. At this point, they no longer had access to the educational materials. The full instructions are available in the Supplemental Material.

Session 2. Session 2 took place 1 week after Session 1. Participants took a test about GPS as a measure of objective knowledge. The test comprised 20 multiple-choice questions that tested participants' knowledge and understanding of GPS as explained in the learning task. Questions varied in difficulty and in the number of incorrect options. Questions were presented individually in a preset order that ensured that no question revealed the answer to a later question. Participants received one point for each correct answer, for a total score of zero to 20. They could not skip questions.

After, participants were asked to honestly report if they had looked up answers to any of the questions in the study, with the assurance that their compensation would be unaffected by their response. Finally, they completed an attention check, answered demographic questions, and filled out information for payment.[1]

Results and Discussion

Supporting Hypothesis 1a, participants who were assigned to explain how GPS worked using the Written Reflection Task scored higher on the quiz about GPS ($M_{\text{Pilot1a}} = 10.30$, $SD = 2.69$; $M_{\text{Pilot1b}} = 12.70$, $SD = 3.08$) than participants in the control condition ($M_{\text{Pilot1a}} = 9.64$, $SD = 2.85$; $M_{\text{Pilot1b}} = 12.1$, $SD = 3.31$); in Pilot 1a, $b = .66$, $t(367) = 2.27$, $p = .024$; and Pilot 1b, $b = .65$, $t(448) = 2.17$, $p = .03$. This suggests that even 5 min of explaining via written reflection improves comprehension of learned material a week later.

Study 1

Pilots 1a and 1b confirm that explaining via written reflection is an effective learning strategy in our context. In Study 1, we tested our prediction that learners are relatively reluctant to engage in explaining and other learning strategies that require knowledge reflection, especially when they feel unknowledgeable about the learned material. We taught participants novel information and then asked them to rate their interest in learning strategies that did and did not require knowledge reflection, as well as in control activities that were unrelated to learning. Because people may prefer activities that require less effort, we selected strategies across the three categories that were matched in the effort that they required, based on the results of Pilot 2S. After rating their interest in each one on a Likert scale, participants ranked three of the strategies—one from each category—based on their interest.

Because reflecting on one's knowledge can be threatening, we expected learners to be less interested in strategies that required knowledge reflection in favor of less threatening, nonreflection learning strategies. Further, because we suggest that explaining is particularly threatening when people feel unknowledgeable about the material, we predicted that low-subjective-knowledge learners would be especially likely to avoid the reflection learning strategies. We also tested an alternative explanation, namely that those who choose nonreflection strategies are simply less motivated to study the material.

Method

The study was preregistered on AsPredicted.Org at https://aspredicted.org/ts35-jz8p.pdf.

Participants

The sample was recruited through the crowdsourcing platform Prolific and was restricted to U.S.- and U.K.-based participants. Two hundred and eighty-two participants successfully completed the study and were included in the analyses (164 women, 115 men, one nonbinary, one identified as "transwoman," and one did not report gender; $M_{\text{age}} = 44.67$, $SD = 14.60$; the modal level of education was a bachelor's degree; 271 not Hispanic or Latino/Latina, five Hispanic or Latino/Latina, and six did not report ethnicity; 261 White, nine Asian, four Black or African American, one self-identified as Cornish, and one as mixed; five multiracial;). Gender, ethnicity, and race were captured with the following prompts, respectively: "I am:" with options: "A man," "A woman," "Nonbinary (neither, both, or something else)," "I prefer to self identify" (with a text entry box), and "Do not wish to say"; "Ethnicity" with options: "Hispanic or Latinx," "Not Hispanic or Latinx," and "Do not wish to say"; "Race (select all that apply)" with options: "American Indian or Alaska Native," "Asian," "Black or African-American," "Native Hawaiian or Other Pacific Islander," "White," "Other" (with text entry box), "Unknown," and "Do not wish to say."

Materials, Design, and Procedure

After providing consent and completing the screening tasks, participants were told that they would be learning about GPS. To motivate participants to learn the material well, we informed them that they may be eligible to participate in a follow-up study in 1 week, in which they would be tested on their knowledge of GPS by answering 20 test questions. We added a monetary incentive by informing participants that some of them, randomly chosen, may receive a bonus payment for each correct answer on the test. In reality, there was no follow-up to this study. Participants rated how motivated they were to do well on the test on a scale ranging from 1 (*not at all motivated*) to 7 (*very highly motivated*).

Participants learned about GPS by watching the videos from Pilot 1b. After the learning task, we measured participants' subjective knowledge by asking how knowledgeable they thought they were about GPS using six questions (e.g., "How knowledgeable do you feel about GPS?" "If you had to rate your feeling of knowledge about GPS, how would you rate it?"; see the Supplemental Material for the full list of items used in each study) rated on a 7-point scale with question-specific anchors (e.g., 1 = *do NOT feel knowledgeable at all* to 7 = *feel very knowledgeable*). We averaged their responses (Cronbach's $\alpha = .93$).

Next, participants were asked to rate their interest in nine different activities that they could potentially spend the next 5 min doing ("Please rate your interest in doing each of the following activities for 5 min.") on a 7-point scale ranging from 1 (*not at all interested*) to 7 (*very interested*). Three activities were learning strategies that involved knowledge reflection: writing an explanation from memory of how GPS works as if explaining it to someone else (i.e., explaining), writing what one understood from the video about how GPS works, and writing answers to essay questions about how GPS works; Cronbach's $\alpha = .88$; three were nonknowledge-reflection learning strategies (rewatching one of the video sections and typing

[1] In the pilots, we also measured participants' subjective knowledge of GPS and their confidence on the test, described in the Supplemental Material.

notes on it, rewatching one of the video sections and memorizing it, and rewatching one of the video sections and creating a visual representation of the information on the screen; Cronbach's α = .73), and three activities were unrelated to learning (writing about one's favorite season, writing about a TV show one likes, watching a video about mental health and taking notes on it; Cronbach's α = .88). These activities were chosen based on Pilot 2S in which participants rated 40 activities on effort and knowledge reflection. We selected a subset of activities that required similar levels of effort ($ps > .32$) but varied in knowledge reflection ($ps < .001$), as shown in Table 1.

We pointed out to participants that some of the activities were focused on helping them learn more about how GPS works, whereas others were unrelated to the topic of GPS, and that some activities encouraged them to reflect on their own understanding of how GPS works and other activities did not. We also reminded participants that, earlier in the study, they had indicated that they would be interested in a follow-up study with a test on GPS, with the possibility of a financial bonus based on performance.

After rating all nine activities, participants then ranked three of the activities, one from each category (knowledge-reflection learning strategy: explaining, i.e., writing an explanation from memory of how GPS works as if you were explaining it to someone else; nonknowledge-reflection learning strategy: rewatching one of the video sections and typing notes on it; unrelated, nonlearning activity: writing about one's favorite season). They ranked these activities based on interest, with "1" being the activity they were most interested in and "3" being the activity they were least interested in. All participants were then told they were assigned to spend up to 5 min writing about their favorite season. Finally, they answered an attention check and reported their demographic information.

Results and Discussion

Interest as a Function of Activity Type

Overall, participants indicated being highly motivated to do well on the test ($M = 6.49$ out of 7, $SD = 0.78$). In line with this, participants were less interested in activities unrelated to learning ($M = 2.94$, $SD = 1.86$) than in both knowledge reflection, $t(281) = -5.19$, $p < .001$, and nonknowledge-reflection learning strategies, $t(281) = -8.09$, $p < .001$ (paired t test, two-sided). Yet, as expected and as shown in Figure 2, they were more interested in the nonknowledge-reflection learning strategies ($M = 3.98$, $SD = 1.41$) than the knowledge-reflection learning strategies ($M = 3.65$, $SD = 1.58$), $t(281) = 3.65$, $p < .001$ (paired t test, two-sided)—despite both categories of strategies requiring similar levels of effort (Pilot 2S). Thus, participants were willing to study but preferred doing so using strategies that required little knowledge reflection.[2] This result is in line with our theorizing that reflecting on one's knowledge is a generally self-threatening prospect. The result is particularly striking given that, based on Pilot 2S, learners recognized that the knowledge reflection strategies would be significantly more effective for preparing for a test, $p < .001$.

As shown in Figure 2, the share of top-ranked choices was similar to the rating results, with the nonknowledge-reflection learning strategy being the most popular choice (54%), followed by the activity unrelated to learning (25%) and the knowledge-reflection activity, that is, explaining (21%).

Subjective Knowledge and Interest in Learning Versus Nonlearning Activities

We next tested whether feeling knowledgeable was related to learners' interest in engaging in learning versus nonlearning activities. Indeed, there was a significant interaction between activity type (learning vs. nonlearning) and subjective knowledge, $b = -.80$, $t(2247.89) = -13.85$, $p < .001$, using a mixed-effects model with random effects for participant and for activity. Specifically, the more knowledgeable participants felt about GPS, the more interested they were in engaging in any of the six learning strategies, $b = .36$, $t(280) = 5.46$, $p < .001$. In contrast, subjective knowledge was negatively related to interest in the nonlearning activities, $b = -.44$, $t(280) = -4.54$, $p < .001$, suggesting that feeling knowledgeable is specifically positively correlated with learners' willingness to engage in learning strategies, not in any activity. Participants who felt more knowledgeable about GPS were also more likely to rank one of the two learning strategies (vs. the learning-unrelated activity) as their top choice, $b = .56$, $z = 4.31$, $p < .001$.

We also tested the alternative explanation that participants' motivation to do well on the test could account for their interest in learning strategies. Although participants' motivation to do well on the test positively predicted interest in the learning strategies, $b = .29$, $t(276) = 3.00$, $p = .003$, all the effects of subjective knowledge reported above were substantively the same when controlling for motivation as a fixed effect, suggesting that differences in motivation cannot fully account for the effect of subjective knowledge on studying preferences.

Subjective Knowledge and Interest in Knowledge Reflection Versus Nonknowledge Reflection Activities

We next tested our key prediction that subjective knowledge is most associated with interest in learning strategies that require knowledge reflection (compared to those that do not). Indeed, as shown in Figure 3 and supporting Hypothesis 2, there was a significant interaction between learning strategy type (knowledge reflection vs. nonknowledge reflection) and subjective knowledge, $b = .34$, $t(1404.93) = 6.02$, $p < .001$, again using a mixed-effects model with random effects for participant and for activity, such that subjective knowledge was more statistically predictive of interest in the knowledge-reflection learning strategies, $b = .53$, $t(280) = 6.72$, $p < .001$, than the nonknowledge-reflection learning strategies, $b = .19$, $t(280) = 2.53$, $p = .01$. As shown in Figure 4, participants who felt more knowledgeable about GPS were also more likely to rank the knowledge-reflection learning strategy over the nonknowledge-reflection learning strategy as their top choice, $b = .50$, $z = 2.96$, $p = .003$ (see Supplemental Figure S1 for a depiction of results for all three ranks). Once again, we tested whether participants' motivation

[2] This preference was not limited to the online setting. When we examined students' interest in learning strategies in the classroom (Study 5 and Supplemental Studies S1 and S2), we found that the vast majority of students preferred the nonreflection strategy (reviewing their notes) to the reflection strategy (written reflection).

Table 1
Activities in Study 1: Ratings of Effort, Reflection, Effectiveness (Pilot 2S Participants), and Interest (Study 1 Participants)

	Pilot 2S			Study 1
	Effort	Reflection	Effectiveness	Interest
Activity	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Knowledge reflection				
Explain	3.68 (1.06)	4.53 (0.77)	4.42 (0.69)	3.67 (1.76)
Write based on understanding	2.89 (1.20)	4.47 (0.70)	4.11 (0.99)	3.91 (1.75)
Answer essay questions	3.63 (1.06)	4.37 (0.83)	3.84 (0.90)	3.38 (1.78)
Nonknowledge reflection				
Rewatch and take notes	2.84 (0.96)	2.37 (1.06)	3.37 (1.06)	4.44 (1.81)
Memorize	3.74 (1.10)	3.21 (1.31)	2.95 (0.91)	4.20 (1.68)
Rewatch and create visual representation	3.56 (0.92)	3.33 (1.45)	3.50 (0.98)	3.32 (1.76)
Nonlearning				
Write about favorite season	3.82 (1.18)	2.45 (1.71)	1.64 (1.25)	2.81 (2.05)
Write about TV show	3.85 (1.22)	2.55 (1.67)	1.70 (1.34)	3.01 (2.14)
Watch video on mental health and take notes	2.59 (1.00)	1.47 (0.94)	1.47 (0.94)	2.99 (2.01)

Note. The table shows ratings of Pilot 2S participants of how much effort each activity would take (Effort), how much knowledge reflection it would require (Reflection), and how effective it would be for preparing one for a test (Effectiveness); the last column shows ratings of Study 1 participants' interest in engaging in each activity.

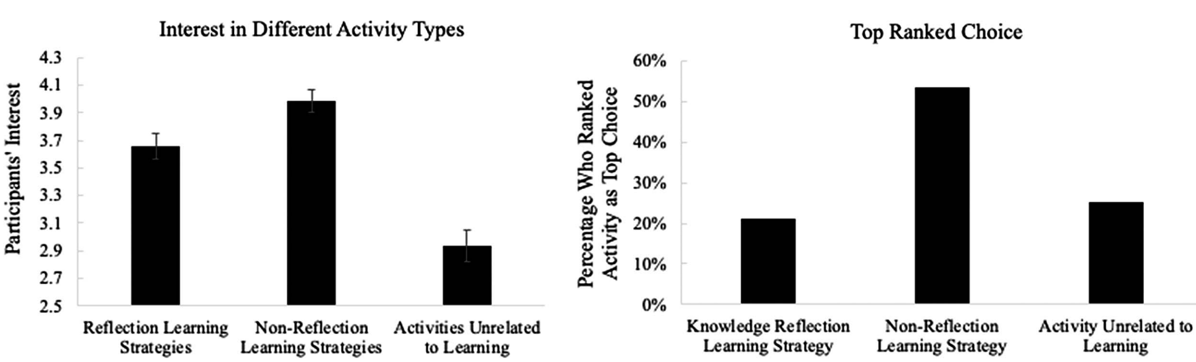
to do well on the test could account for these results. Although participants' motivation to do well on the test predicted interest in the knowledge-reflection learning strategies, $b = .34$, $t(276) = 2.81$, $p = .005$, all the above reported effects of subjective knowledge were essentially unchanged by including motivation in the model as a fixed effect, suggesting that differences in motivation cannot fully account for the effect of subjective knowledge on preference for knowledge-reflection learning strategies.

Study 2

Study 2 had three aims. First, we tested the robustness of the relationship between subjective knowledge and learners' choice to explain (vs. engage in a control task) by attempting to replicate it in a new study. Second, although explaining is an effective learning strategy in general, explaining could conceivably be ineffective for those who prefer to avoid it, that is, for those with low subjective knowledge. If that were the case, learners with lower subjective knowledge would be justified in their reluctance to engage in explaining. We therefore tested whether explaining (via written reflection) was beneficial even for those who preferred to avoid it and regardless of subjective knowledge. To do so, we employed a two-condition between-subjects design, in which participants indicated if they preferred to engage in explaining or a control activity and then were randomly assigned to one activity regardless of their indicated choice. By comparing participants' scores on a test, we could test whether explaining was also effective for participants who preferred to avoid it and whether its effect significantly depended on subjective knowledge.

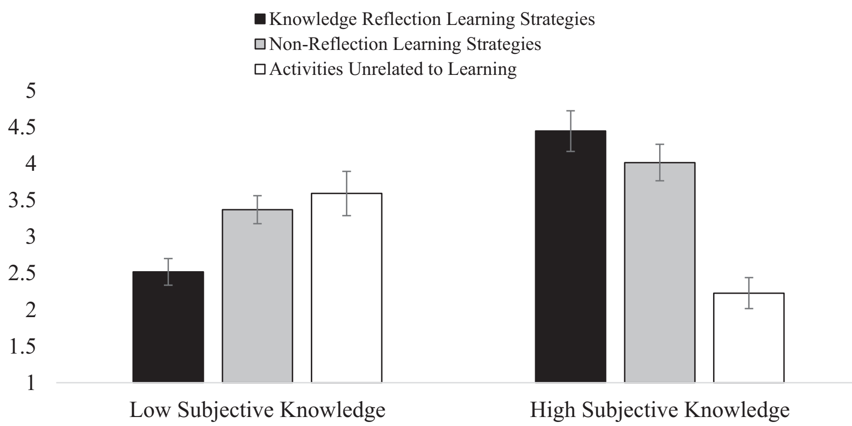
The study's third aim was to begin to probe why learners are reluctant to engage in explaining. To that end, we asked participants in this study to report their reasons for choosing as

Figure 2
Participants' Preferences for Reflection Learning Strategies, Nonreflection Learning Strategies, and Nonlearning Activities in Study 1



Note. Left: Participants' interest in engaging in each type of activity (learning strategies that involve knowledge reflection, learning strategies that do not involve knowledge reflection, and activities that are unrelated to learning; error bars show standard errors). Right: The percentage of participants who selected each activity as their top ranked choice.

Figure 3
Interest in Each Activity Type as a Function of Subjective Knowledge in Study 1



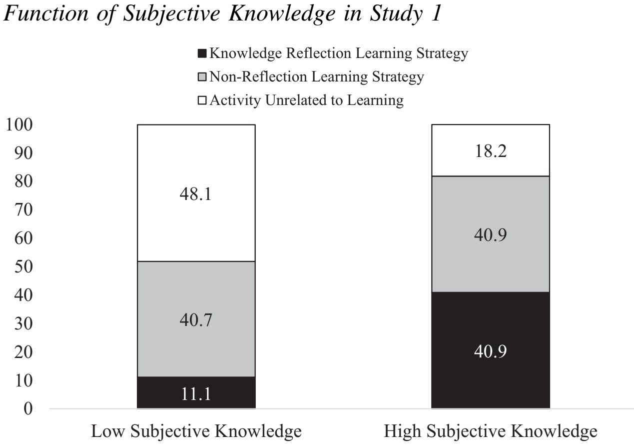
Note. Average interest of learners with low subjective knowledge (1 *SD* below the mean; left) and learners with high subjective knowledge (1 *SD* above the mean; right) in each of the three activity types (learning strategies that involve reflection, learning strategies that do not involve reflection, and activities that are unrelated to learning; error bars show standard errors).

they did. We expected reluctant participants to view explaining as especially unpleasant and difficult and therefore to choose an alternative activity. Conversely, we expected participants who were eager to engage in explaining to view it as relatively pleasant and easy.

Method

The study was preregistered on AsPredicted.Org at https://aspredicted.org/d6cq-ycdd.pdf.

Figure 4
Percent of Participants Ranking Each Activity Type as No. 1, as a Function of Subjective Knowledge in Study 1



Note. The percentage of low- and high-subjective-knowledge participants (1*SD* below and above the mean, respectively) choosing each activity type as their first ranked. Reflection-learning strategy was explaining, nonreflection learning strategy was rewatching one of the video sections and typing notes on it, and activity unrelated to learning was writing about one's favorite season.

Participants

The sample was recruited through Amazon's Mechanical Turk via CloudResearch and was restricted to U.S.-based participants. Eight hundred and thirty-four participants successfully completed Session 1, and 731 participants successfully completed both sessions and were included in the analyses (391 women, 336 men, four chose "other"; M_{age} = 37.67, *SD* = 10.95;[3] the modal level of education was a bachelor's degree; ethnicity and race were not measured in this study). Gender was measured the same way as in Study 1.

Materials, Design, and Procedure

Session 1. After completing two screening tasks, participants were informed that 1 week later, during Session 2, they would answer questions about the videos that they were about to watch. To motivate them to pay attention, they learned that some randomly selected participants would receive a bonus payment for each correct answer. Participants rated their motivation to do well on the test from 1 (*not at all motivated*) to 7 (*very highly motivated*). Participants then learned about GPS by watching the videos from Pilot 1b, afterward reporting their subjective knowledge of GPS using the same six items from Study 1. As in Study 1, we averaged the six items to create a single subjective knowledge measure (Cronbach's α = .92).[4]

Participants then chose the task they would like to perform for the next 5 min, presented in counterbalanced order: explaining via written reflection ("Spend 5 min writing an explanation from memory of how GPS works as if you were explaining it to someone else") or control ("Spend 5 min writing about how you celebrate

[3] One participant incorrectly reported age as 3 and was excluded from the age statistics.

[4] In this and the following studies, we also measured participants' subjective knowledge of GPS after the writing task (written reflection or holiday). These data were collected for a different project, and we do not discuss them here. See additional details in the Supplemental Material.

your favorite holiday"). After indicating their preference, participants were nevertheless assigned to one of the two tasks at random.

After working on their assigned task for 5 min, participants reported why they chose written reflection or the control task, first in an open-ended question and then by selecting their primary reason(s) from a list of eight options: because they thought it would be more fun, easier, more challenging, improve their performance on the upcoming test, help someone else, be more interesting, help them organize their thoughts, take less time, or a self-specified reason.

Finally, they completed an attention check, answered demographic questions, and filled out information for payment.

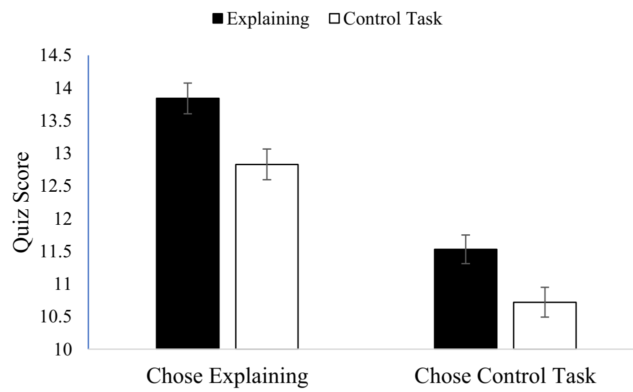
Session 2. Session 2 took place 1 week later. Participants completed the same objective knowledge test about GPS from Pilots 1a and 1b. As a reminder, before watching the GPS videos during Session 1, we motivated participants to pay attention by informing them that they may receive a bonus based on their responses. Before taking the quiz, however, we sought to reduce motivation to look up the answers, and therefore all but two participants (randomly chosen) were informed that they were not selected to receive a bonus based on their answers. We also stressed that participants should answer honestly using what they knew and that they should not switch away from the task's browser tab or window, as doing so may make them ineligible to participate in future studies. After the quiz, participants estimated the number of questions out of 20 that they had answered correctly. Finally, they reported whether they looked up any of the answers, completed an attention check, answered demographic questions, and filled out information for payment.

Results and Discussion

Fifty-five percent of participants chose the control activity and 45% chose to engage in written reflection, that is, to explain. Consistent with Hypothesis 2 and replicating the results in Study 1, this choice was statistically predicted by subjective knowledge; the more learners felt knowledgeable about GPS, the more likely they were to choose to explain, $b = .65$, $z = 8.01$, $p < .001$. Those who chose the control task felt less knowledgeable about the topic ($M = 4.32$, $SD = 1.11$) than those who chose to explain it ($M = 5.01$, $SD = 0.95$), $b = .69$, $t(729) = 8.85$, $p < .001$. This difference was not significantly driven by differences in motivation, as those who chose written reflection did not differ significantly in their motivation to do well on the quiz ($M = 6.60$, $SD = 0.80$) from those who chose the control task ($M = 6.61$, $SD = 0.76$), $b = -.01$, $t(729) = -.21$, $p = .83$.

Consistent with Hypothesis 1a and replicating the results of Pilots 1a and 1b, learners assigned to engage in written reflection scored higher on the quiz ($M = 12.60$, $SD = 3.29$) than those assigned to the control task ($M = 11.60$, $SD = 3.30$), $b = .95$, $t(729) = 3.29$, $p < .001$, demonstrating again that explaining the material enhances objective knowledge of it. Critically, as shown in Figure 5, explaining was effective at improving test performance for both learners who wanted to explain and those who did not, with a nonsignificant interaction between choice and condition, $b = .20$, $t(727) = .42$, $p = .67$. Each choice group benefited significantly from being assigned to explain (vs. control), $b_{\text{chose explain}} = 1.01$, $t(322) = 3.05$, $p = .002$, $b_{\text{chose control}} = .82$, $t(405) = 2.57$, $p = .010$. Similarly, there was no significant interaction between subjective knowledge and condition, $F(3, 727) = .024$, $p = .88$, suggesting that explaining boosted test scores relative to the control task regardless of how knowledgeable participants felt about the topic. Supporting Hypothesis 1b, even those who felt relatively unknowledgeable benefitted from engaging in explaining via written reflection.

Figure 5
Quiz Score as a Function of Chosen and Assigned Activity in Study 2



Note. Learners' scores on the quiz as a function of whether they chose explaining or the control task and whether they were assigned to engage in explaining or in the control task (error bars show standard errors). See the online article for the color version of this figure.

It is worth noting that subjective knowledge was positively associated with objective knowledge, $b = .84$, $t(729) = 7.75$, $p < .001$; learners who felt less knowledgeable were indeed less knowledgeable as reflected by their test score. In addition, regardless of the task they were ultimately assigned to, learners who *chose* written reflection (i.e., who chose to explain) ended up scoring higher on the quiz ($M = 13.40$, $SD = 3.02$) than those who chose the control task ($M = 11.10$, $SD = 3.23$), $b = 2.23$, $t(729) = 9.54$, $p < .001$. These results suggest that people are at least somewhat aware of how knowledgeable they are about a topic. At the same time, those who felt less knowledgeable were less likely to choose the task that would have improved their test performance.

In explaining their choices by selecting from a list of explanations, those who chose the control task primarily mentioned that it would be easier (78%), more fun (55%), and more interesting (32%). This suggests that, consistent with our theorizing, they may have been reluctant to engage in written reflection because they thought it would be less pleasant. Those who chose written reflection believed it would help them organize their thoughts (45%), be more interesting (44%), improve their performance (38%), and be more challenging (30%).

Study 3

In Studies 1 and 2, we found a positive correlation between subjective knowledge and learners' interest in explaining newly learned material via written reflection. This is in line with our theorizing that subjective knowledge plays an important role in determining whether learners are willing or reluctant to engage in explaining as a learning strategy. Of course, the correlation could also be explained by a third variable. For example, it is possible that individuals with low self-esteem report less subjective knowledge and are also reluctant to explain newly learned material. Therefore, in Study 3, we experimentally manipulated subjective knowledge (without changing objective knowledge) to determine whether low subjective knowledge about a topic *causes* people to avoid explaining and whether we can increase learners' willingness to explain by artificially increasing their subjective knowledge. Thus, we manipulated subjective knowledge by asking learners a series of easy or difficult questions about the material that they learned and then asked them to choose one activity in which to engage.

In addition, we continued to explore why low-subjective-knowledge learners are reluctant to engage in explaining. Specifically, building on the results of Study 2 in which participants reported their reasons for choosing explaining, we tested whether increasing subjective knowledge would lead participants to view explaining as a more pleasant and effective learning strategy.

Method

The study was preregistered on AsPredicted.Org at https://aspredicted.org/trkr-r898.pdf.

Participants

The sample was recruited through Amazon's Mechanical Turk via CloudResearch and was restricted to U.S.-based participants. Three hundred and forty-eight participants successfully completed the study and were included in the analyses (178 women, 166 men, one chose "other" gender, three did not report gender; $M_{age} = 36.11$, $SD = 11.11$; the modal level of education was a bachelor's degree; race and ethnicity information were not collected). Gender was measured the same way as in the pilot studies.

Materials, Design, and Procedure

The procedure and materials were the same as Session 1 of Study 2, with participants learning about GPS, reporting their subjecting knowledge, and then choosing their activity of interest. We made three changes to the design and procedures.

First, subjective knowledge was manipulated between subjects; after learning about GPS but before reporting their subjective knowledge, participants were randomly assigned to the high-subjective-knowledge condition or the low-subjective-knowledge condition. In the high-subjective-knowledge condition, participants were asked seven easy multiple-choice questions about the material they had learned (e.g., "Around what object do GPS satellites orbit?"). In the low-subjective-knowledge condition, participants were asked eight difficult multiple-choice questions about the material they had learned (e.g., "How does the GPS receiver receive the information necessary for its computations?"). As a manipulation check, participants then rated their subjective knowledge of GPS using the same items from Study 1 (Cronbach's $\alpha = .94$).

Second, after selecting which task they wished to perform (explaining via written reflection or the control task), we asked participants to rate their agreement with statements that explaining would help them understand GPS better, be pleasant, unpleasant, distressing, exciting, and would help someone else. Agreement was rated on a 7-point scale from 1 (*strongly disagree*) to 7 (*strongly agree*).

Finally, unlike in Study 2, participants were assigned to complete the task they chose. They explained their choice as in Study 2, completed attention checks, and reported their demographic information.

Results and Discussion

The manipulation of subjective knowledge was successful; participants in the high-subjective-knowledge condition rated their knowledge of GPS as higher ($M = 4.72$, $SD = 1.17$) than participants in the low-subjective-knowledge condition ($M = 3.85$, $SD = 1.24$), $b = .87$, $t(346) = 6.74$, $p < .001$.

As predicted and supporting Hypothesis 3, those who were made to feel subjectively knowledgeable about GPS were more likely to select to explain via written reflection (59.76%) than those who were made to feel less knowledgeable (44.13%), $b = .63$, $z = 2.90$, $p = .004$, suggesting that feeling more knowledgeable about a topic makes people more interested in explaining that topic.

Making people feel more versus less knowledge also changed what they thought about the explaining task. As shown in Table 2, those made to feel more knowledgeable thought explaining would help them understand the material better, $b = .45$, $t(346) = 2.72$, $p = .007$; be more pleasant, $b = .46$, $t(346) = 2.68$, $p = .008$; and be more helpful for someone else, $b = .49$, $t(346) = 3.15$, $p = .002$. They did not expect it to be significantly less distressing, $b = -.31$, $t(346) = 1.65$, $p = .099$; less unpleasant, $b = -.25$, $t(346) = 1.30$, $p = .19$; or more exciting, $b = .13$, $t(346) = .77$, $p = .44$.

Next, we tested whether each of the items that differed by subjective knowledge condition helped to explain participants' choice of activity. We used the mediation package in R (Tingley et al., 2014) to test whether participants' beliefs about written reflection (i.e., explaining) mediated the relationship between subjective

Table 2
Learners' Beliefs About Written Reflection in Studies 3 and 4

Belief about written reflection	Study 3		Study 4		
	High-subjective-knowledge condition	Low-subjective-knowledge condition	Effectiveness condition	Pleasantness condition	Control condition
	M (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Help me	4.85_a (1.47)	4.40_b (1.64)	4.86_a (1.17)	4.48_b (1.42)	4.33_b (1.46)
Pleasant	3.89_a (1.62)	3.43_b (1.56)	3.52_a (1.29)	3.92_b (1.41)	3.41_a (1.41)
Distressing	2.70_a (1.60)	3.01_a (1.85)	3.36_a (1.55)	3.30_a (1.62)	3.69_b (1.76)
Unpleasant	3.76_a (1.73)	4.01_a (1.82)	4.14_a (1.44)	3.90_a (1.57)	4.08_a (1.68)
Exciting	4.96_a (1.63)	4.83_a (1.54)	4.14_a (1.43)	4.21_a (1.40)	4.00_a (1.55)
Help someone else	4.41_a (1.42)	3.92_b (1.49)			

Note. Within a row, within a study, means without a common subscript letter differ ($p < .05$).

knowledge condition and their choice to engage in written reflection. Supporting Hypotheses 4a and 4b, the relationship was mediated by participants who were made to feel more (vs. less) knowledgeable believing that written reflection would be more effective for learning the material, indirect effect = .057 [10, .02], $p = .008$; more pleasant, indirect effect = .059 [.11, .02], $p = .004$; and more helpful for someone else, indirect effect = .07 [12, .02], $p = .004$.

Study 4

Study 3 provided evidence that increasing subjective knowledge increases willingness to explain and, specifically, that it increases learners' beliefs that explaining will be pleasant and effective. Building on these results, in Study 4, we manipulated these beliefs directly by having learners read a short paragraph arguing that explaining (by engaging in written reflection) will be either pleasant or effective. We tested if learners who read these paragraphs (compared to learners in a control condition who read nothing) were more likely to choose to explain rather than engage in a nonknowledge-reflection learning strategy or a nonlearning activity.

Method

The study was preregistered on AsPredicted.Org at https://aspredicted.org/vbjp-99k3.pdf.

Participants

The sample was recruited through Prolific and was restricted to U.S.- and U.K.-based participants. Six hundred and sixty-five participants completed the study successfully and were included in the analyses (404 women, 257 men, two preferred to self-identify as "female" and "NB masculine", and two did not report gender; $M_{age} = 34.41$, $SD = 12.58$; the modal level of education was a bachelor's degree; 602 not Hispanic or Latino/Latina, 18 Hispanic or Latino/Latina, and 45 did not report ethnicity; 564 White, 42 Asian, 20 Black or African American, 15 chose "other," 12 multiracial, and 12 did not report race). Gender was measured with the prompt "Gender:" with the options being: "Male," "Female," "I prefer to self-identify," and "Do not wish to say." Race and Ethnicity were measured the same way as in Study 1.

Materials, Design, and Procedure

As in Studies 1–3, participants learned about GPS and believed that they may be invited to a second session where they would be tested on the material. As in the previous studies, after learning about GPS, participants reported their subjective knowledge on the topic (Cronbach's $\alpha = .91$).

We manipulated what information participants read about explaining via written reflection. Participants either read several paragraphs suggesting that explaining via written reflection would be helpful for learning the material (effectiveness condition) or would be fun (pleasantness condition) or read nothing at all (control condition). The full texts are available in the Supplemental Material. As a manipulation check, we had participants rate their agreement that explaining (via written reflection) would be effective, pleasant, and so forth, using the statements from Study 3 (except we did not ask about the helpfulness of written reflection for someone else).

Participants chose which task to complete for the next 5 min: explaining via written reflection, an alternative learning strategy (listing what one can remember about GPS), or a nonlearning activity (writing about one's holiday). They then completed their selected task. Finally, participants explained their choice, completed attention checks, and reported their demographic information.

Results and Discussion

Replicating our previous results and providing additional support for Hypothesis 2, people who felt more knowledgeable about GPS were more likely to choose to explain via written reflection than choose the other activities, $b = .39$, $z = 4.89$, $p < .001$.

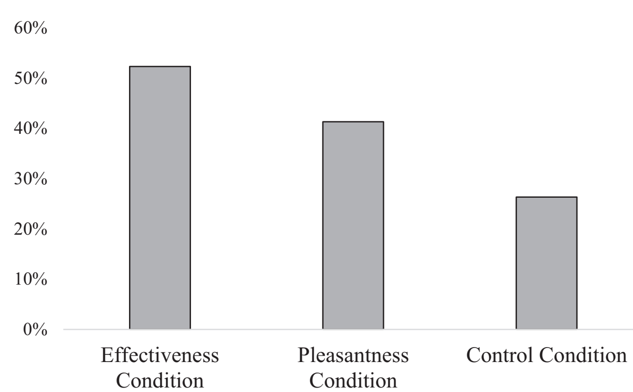
Reading That Explaining Is Effective

Verifying that the manipulation was successful, reading that explaining is effective led people to indicate that explaining would help them learn more than if they read that explaining was pleasant $b = .38$, $t(439) = 3.03$, $p = .003$, or read nothing, $b = .53$, $t(438) = 4.20$, $p < .001$. We also tested whether participants with different levels of subjective knowledge were differentially convinced by reading that explaining is indeed effective. There was no interaction between subjective knowledge and reading that written reflection is effective (vs. control) when predicting the belief that explaining is effective, $b = -.07$, $t(436) = -.60$, $p = .55$, suggesting that participants were convinced by the paragraph regardless of their subjective knowledge.

Importantly for our purposes, as shown in Figure 6, reading that explaining was effective (vs. reading nothing) made learners more likely to choose to explain (via written reflection) when given the choice (52.23% vs. 26.33%), $b = 1.12$, $z = 5.50$, $p < .001$. The manipulation also changed people's likelihood of choosing to list what they remember about GPS; specifically, reading that explaining was effective (vs. reading nothing) led to significantly *fewer* listing choices, $b = -.70$, $z = -3.63$, $p < .001$. Thus, reading about the effectiveness of explaining did not increase willingness to

Figure 6

Percentage of Participants Who Chose Written Reflection by Condition in Study 4



Note. The percentage of participants in each condition who chose to explain (via written reflection) over the two control activities, a nonknowledge-reflection learning strategy and a nonlearning activity.

engage in *any* learning strategy; rather, its effect was specific to explaining. There was no significant interaction between subjective knowledge and the effectiveness condition (vs. control), $b = -.33$, $z = -1.54$, $p = .12$, suggesting that the effectiveness manipulation was successful regardless of learners' subjective knowledge.

Reading That Explaining Is Pleasant

Consistent with a successful manipulation, people believed explaining to be more pleasant when they read a paragraph to that effect than if they read that explaining was effective, $b = .40$, $t(439) = 3.09$, $p = .002$, or read nothing, $b = .51$, $t(447) = 3.87$, $p < .001$. We next tested whether participants with low (vs. high) subjective knowledge were especially likely to change their views on explaining based on the manipulation. Indeed, there was a significant interaction between subjective knowledge and reading that written reflection was pleasant (vs. control) when predicting the belief that explaining was indeed pleasant, $b = -.39$, $t(445) = -3.35$, $p < .001$. We ran simple effects at $-1SD$ and $+1SD$ subjective knowledge and found that when people low in subjective knowledge read that written reflection was pleasant, they believed that it was indeed more pleasant than they would have otherwise, $b = .96$, $t(445) = 5.36$, $p < .001$. However, those with high subjective knowledge were already relatively high in this belief at baseline and did not increase when exposed to the manipulation, $b = .11$, $t(445) = .62$, $p = .53$.

As shown in Figure 6, reading that explaining was pleasant (vs. reading nothing) increased the likelihood that participants chose to explain (41.33% vs. 26.33%), $b = .68$, $z = 3.34$, $p < .001$. It led to marginally *fewer* listing choices, $b = -.35$, $z = -1.84$, $p = .066$, suggesting that this manipulation, like the effectiveness manipulation, affected willingness to explain specifically and not willingness to engage in any learning strategy. The manipulation was effective regardless of participants' subjective knowledge about GPS, $b = -.17$, $z = -.79$, $p = .43$.

Study 5

Finally, because Studies 1–4 were all run online with performance incentivized through financial payment, we sought to provide additional external validity by testing for a replication of key results in a real-world learning setting with real stakes: the college classroom. To that end, we recruited undergraduate students in an introductory biology course and randomly assigned them to explain (by engaging in written reflection) or to a control learning strategy (reviewing their notes). First, we tested whether using our written-reflection explaining strategy improved learning comprehension on a real stakes class quiz. Second, by measuring subjective knowledge, we sought to replicate the relationship that we observed in earlier studies between subjective knowledge and interest in explaining. Finally, we tested the replicability of our finding that subjective knowledge is associated with believing that explaining is pleasant and effective.

Method

The study was preregistered on AsPredicted.Org at https://aspredicted.org/pjft-njmm.pdf.

Participants

The sample comprised students enrolled in the class Introductory Biology at a large Midwestern university in the United States. Four hundred and sixty-eight students successfully completed the study (301 women, 151 men, three nonbinary, 13 did not report gender; 413 not Hispanic or Latino/Latina, 25 Hispanic or Latino/Latina, and 30 did not report ethnicity; 356 White, 61 Asian, 8 Black, 19 multiracial, five chose "other," 19 did not report race; modal year in college: second year), of whom 460 took the quiz. Gender was captured using the prompt "Gender" with the options "Male," "Female," "Nonbinary (neither, both, or something else)," "Prefer to self-identify" (with a space to write in), and "Do not wish to say." Race and ethnicity were captured the same way as in Study 1.

Materials, Design, and Procedure

In the fall semester of 2021, we recruited undergraduate students enrolled in the class Introductory Biology, offered at a large Midwestern university in the United States. In consultation with the instructors, we chose glycolysis as the topic of interest because it was covered in a single lecture, students could explain it in the given study time, and it was scheduled to be covered on an upcoming quiz.

We invited students to participate in the study during the last 15 min of the class session on glycolysis in exchange for candy. The study was conducted in both sections of the class. So that condition would not be confounded with seating location in the classroom, we interleaved the experimental and control condition study packets before distributing them.

As in the previous studies, we first measured participants' subjective knowledge by averaging their responses to several questions about how knowledgeable they thought they were on the topic of glycolysis (e.g., "How well do you feel you understand glycolysis?"; Cronbach's $\alpha = .94$). Students also rated how motivated they were to do well on the quizzes in the class on a scale ranging from 1 (*not at all motivated*) to 7 (*very highly motivated*).

Students then reported their beliefs that explaining (by engaging in written reflection) would be effective ("If I wrote an explanation about glycolysis as if I were explaining it to a student who missed today's class, it would *really help me* understand glycolysis better.") and pleasant ("It would be *fun* to write an explanation about glycolysis as if I were explaining it to a student who missed today's class") by rating their agreement with each statement on a 7-point scale ranging from 1 (*completely disagree*) to 7 (*completely agree*).

They then rated their interest in (a) explaining (via written reflection), (b) in a nonknowledge-reflection studying activity (reviewing their notes from the class), and (c) in a nonlearning activity (writing about one's favorite holiday) on 7-point scales ranging from 1 (*not at all interested*) to 7 (*very interested*). Students read that their responses would not affect what they were asked to do next.

By random assignment, students then explained glycolysis (i.e., engaged in written reflection) or reviewed their notes on glycolysis. If they were assigned to explain, they read that their goal was to explain glycolysis to a hypothetical student who could not make it to class that day. To focus participants on the contents of that day's lecture, we asked them to assume that the hypothetical student had the same level of knowledge that the student did before that day's lecture. To encourage students to be comprehensive and clear, we added that

> The student is relying on you to explain what they need to know about glycolysis. The student will use your explanation to study for the quizzes and exams, so try to explain glycolysis the best way you can and be as clear as possible so the student understands it as well as possible.

Students read that they could consult their notes if they got stuck in their explanation but to do their best to recall all the information they could before looking at their notes. Students assigned to review their notes read that their goal was to review what they had learned about glycolysis using the notes that they had taken in class that day. Regardless of their assignment, students were asked to continue working on their activity until class time was up and then to turn over to the next page. On this page, they indicated if they consulted their notes when writing their explanation (in the written reflection condition) and reported their demographic information.

The class instructors made the quiz available online to students 8 days after the study session through the class website. The quiz included four questions related to glycolysis and six questions unrelated to glycolysis (the instructors reported to the experimenters which questions were and were not related), with each question worth 1 point. The quiz made up about 0.75% of students' final grade in the class.

Results and Discussion

Consistent with successful random assignment, there were no significant differences between conditions in students' subjective knowledge, $b = -.004$, $t(466) = -0.04$, $p = .97$; interest in engaging in explaining (via written reflection), $b = -.19$, $t(465) = -1.53$, $p = .13$; and beliefs that explaining would be fun, $b = -.03$, $t(466) = -.25$, $p = .80$, or effective, $b = -.20$, $t(465) = -1.79$, $p = .07$.

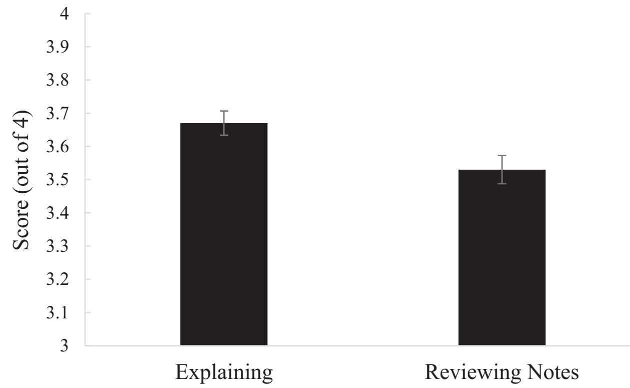
Replicating the previous studies and supporting Hypothesis 2, subjective knowledge predicted students' interest in engaging in explaining (via written reflection), $b = .28$, $t(465) = 4.94$, $p < .001$, even controlling for motivation to do well on the quiz, $b = .28$, $t(463) = 4.89$, $p < .001$; in fact, students' motivation did not significantly predict interest in explaining, $b = .06$, $t(464) = .83$, $p = .41$. In contrast, subjective knowledge did not significantly predict interest in reviewing one's notes about the material, $b = -.06$, $t(465) = -.10$, $p = .32$, again consistent with the hypothesis that people's willingness to engage in explaining is distinct from their willingness to engage in learning strategies more broadly.

People's beliefs about explaining also predicted their interest in explaining, with people being more interested in explaining the more they believed it would be fun, $b = .58$, $t(465) = 16.75$, $p < .001$, and helpful, $b = .36$, $t(465) = 7.17$, $p < .001$.

As shown in Figure 7 and supporting Hypothesis 1a, students who were randomly assigned to explain (via written reflection) scored higher on the quiz questions about glycolysis than students assigned to review their notes on glycolysis, $b = .14$, $t(458) = 2.45$, $p = .015$.[5] The same was true when controlling for students' subjective knowledge, $b = .14$, $t(457) = 2.46$, $p = .014$; controlling for their interest in written reflection, $b = .14$, $t(456) = 2.44$, $p = .015$; or controlling for their motivation to do well on the quiz, $b = .14$, $t(457) = 2.44$, $p = .015$. As shown in Figure 8 and further supporting Hypothesis 1b, explaining improved scores for students with different levels of subjective knowledge, $b_{\text{interaction}} = .07$, $t(456) = 1.32$, $p = .19$. Interestingly, the direction of results suggests that, in anything, explaining may be *more* effective for students who feel less knowledgeable. Explaining also improved scores for students with different levels of interest in explaining, $b_{\text{interaction}} = .04$, $t(455) = .93$, $p = .35$, and different levels of motivation, $b_{\text{interaction}} = .01$, $t(456) = .17$, $p = .87$. Students in the explaining condition ($M = 6.32$, $SD = 1.07$) versus review condition ($M = 6.25$, $SD = 1.13$) scored similarly on questions unrelated to glycolysis, $b = .07$, $t(458) = .72$, $p = .47$, suggesting that explaining produces benefits specific to the object of the explanation—in this case, glycolysis.

Figure 7

Score on Glycolysis Quiz Questions by Condition in Study 5



Note. Students' scores on the four quiz questions that required knowledge of glycolysis by condition in Study 5.

General Discussion

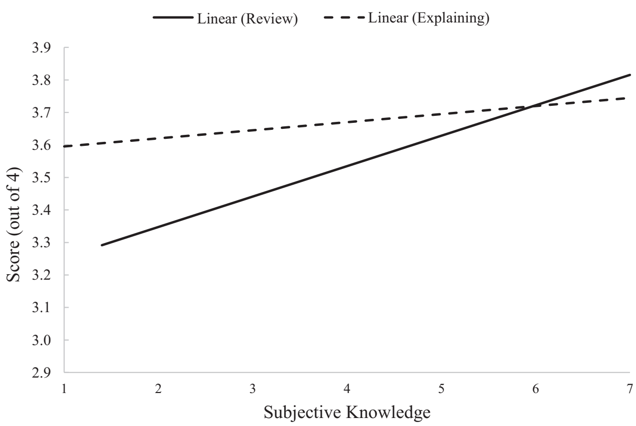
Although learning is a core feature of education, work, and daily life, research suggests that learners habitually use surface-level learning strategies that are poorly predictive of comprehension (Gettinger & Seibert, 2002; Gurung et al., 2010). Herein, we focused on an underused learning strategy: explaining the material. Though it is an effective learning strategy (Pilots 1a and 1b), learners commonly opt for other less effective learning strategies (Pilot 1S; Blasiman et al., 2017; Karpicke et al., 2009) and are reluctant to use it even when given the option (Study 1).

We posited and found that subjective knowledge plays a key role in accounting for learners' studying choices. Learners are more reluctant to engage in explaining when they feel less knowledgeable about the material; when learners feel unknowledgeable, they tend to choose learning strategies that involve less knowledge reflection or activities that are unrelated to studying (Study 1). This is to their detriment, given that when they are assigned to engage in explaining, they understand the material better and score higher on quizzes (Study 2), including in a classroom setting where quizzes count toward grades (Study 5). These findings contribute to the field's understanding of learning behavior. Previous work has prescriptively developed effective learning strategies and

[5] We report the results of a regression. The preregistered two-tailed t test produced effectively the same results, $t(455.26) = 2.49$, $p = .013$.

Figure 8

Score on Glycolysis Quiz Questions by Subjective Knowledge in Each Condition in Study 5



Note. Students' scores on the glycolysis quiz by subjective knowledge in the written reflection (explaining) condition and the review (control) condition in Study 5.

descriptively taken stock of which learning strategies students actually use. We add to our understanding of the detrimental disconnect between the two by identifying subjective knowledge as a driver of learning choices.

An equally important practical question is how to narrow the gap between prescription and description of learners' choices. One implication of our findings is that learners can be encouraged to engage in explaining by being made to feel more knowledgeable. Indeed, we were able to increase leaners' choice to explain by artificially boosting their subjective knowledge, which we accomplished by asking them a series of easy questions on the material (Study 3). Boosting subjective knowledge, in turn, increased learners' beliefs that explaining would be pleasant and effective, which statistically mediated the effect of subjective knowledge on the choice to explain. Directly increasing learners' beliefs about the pleasantness and effectiveness of explaining was also an effective route for encouraging learners to choose more effective learning strategies (Study 4).

A second implication is the paradox referenced in the title of this article: that those who need effective learning strategies the most are the ones least likely to use them. Learners who do well are likely to feel knowledgeable and therefore be ready to adopt effective learning strategies like explaining. This will help them continue to do well. Learners who struggle, on the other hand, are likely to feel less knowledgeable and, therefore, be reluctant to engage in effective but self-threatening learning strategies like explaining. This may cause them to fall even further behind, creating a vicious cycle of underperformance.

Note that the paradox we are highlighting is not an instance of the Dunning–Kruger Effect, which is a different paradox documented in the literature (Kruger & Dunning, 1999). The Dunning Kruger Effect is concerned with people's ignorance of their own incompetence, finding that those who are most unskilled are most overconfident about their skill. Our investigation is instead concerned with learners who *do* see themselves as incompetent or unknowledgeable—justifiably or not—being reluctant to engage in explaining.

We also make a practical contribution by developing *written reflection*, a specific explaining strategy that involves writing an explanation of the material as if one were explaining it to a naïve learner. This strategy takes advantage of the benefits of explaining while drastically reducing the barriers, risks, and costs associated with explaining to others (i.e., teaching). Specifically, it eliminates the barrier of having to seek out a willing explainee, the risk of propagating falsehoods if one's explanation contains inaccuracies, and the cost of appearing ignorant or foolish in front of another person. We suggest that written reflection may be a particularly useful strategy outside of school contexts, where people are often not surrounded by peers. It can be used independently and flexibly in daily life.

We suggest that the theoretical and practical implications described above are relevant for scholars from across several areas of psychology (educational, social, and cognitive) as well as for those from neighboring disciplines. The research is particularly significant for educational psychology, as it highlights the discrepancy between effective learning strategies identified by research and the strategies learners actually use. By demonstrating that learners' reluctance to engage in explaining is tied to their subjective knowledge, the study provides actionable insights for educators on how to design interventions that can boost subjective knowledge and thereby encourage the use of more effective learning strategies. From a cognitive psychology perspective, the research sheds light on the metacognitive processes involved in learning. It emphasizes how learners' perceptions of their own knowledge influence their engagement with learning strategies, contributing to the broader understanding of both metacognition and self-regulation. In the realm of social psychology, the reluctance to engage in explaining, especially among those who feel less knowledgeable, underscores the role of self-perception and self-threat in learning contexts.

Constraints on Generality

One limitation of the reported work is its use of primarily Western, educated, industrial, rich, and democratic participants. Scholars have theorized that learners in collectivistic cultures (vs. individualistic ones, more common in the West) are more likely to prefer learning through reflective observation (Aktaş, 2012), which may make them more open to written reflection overall and may weaken the relationship between subjective knowledge and interest in explaining. Research suggests that students from a collectivistic (vs. individualistic) culture are more likely to engage in socially oriented learning behaviors when working in dyads, including sharing understanding of relevant knowledge (Shi et al., 2013). Further, having a collectivistic orientation is positively associated with intention to share knowledge in a workplace setting (Yu, 2014). Thus, learners from a more collectivistic culture may also be more motivated to engage in the social version of explaining. The role of subjective knowledge may also shift when learners balance concerns regarding appearing helpful on one hand and providing a reliable and correct explanation on the other.

Another limitation is our use of online and student samples. We hypothesize that in a workplace setting, explaining will be equally effective and similarly predicted by subjective knowledge. Future research is needed to test these hypotheses and explore potential moderators, such as the degree of time constraints placed on employees and the organizational culture's emphasis on learning. The effectiveness of explaining may also vary depending on the topic and type of information. For example, learners may benefit more from explaining a process or mechanism (how GPS works, glycolysis) than disparate pieces of information that are not logically related (e.g., a list of product attributes). Along those same lines, we note that the documented effect sizes for the effectiveness of explaining in our studies are reliable but small, which may be the result of using a relatively weak version of explaining. In implementing the intervention outside the lab, learners may benefit from having time to prepare their explanation (Benware & Deci, 1984), explaining the material to another person who could ask questions that would prompt deeper consideration (Roscoe & Chi, 2004), being allowed longer to explain than the 5 min we allotted, and/or engaging in multiple rounds of explaining to deepen and solidify comprehension.

Future Directions

We identified several interventions for increasing learners' interest in knowledge-reflection learning strategies. Increasing subjective knowledge boosted learners' willingness to explain by making it seem more effective and fun, as did directly telling people that explaining is an effective and fun strategy. We note that these interventions were more complicated to introduce in a classroom setting than our online setting. In Study 1S, reported in the Supplemental Material, an attempt to boost subjective knowledge in the classroom by having students answer easy questions about the material was unsuccessful because the "easy" questions turned out to be too difficult (only 57% of students answered them correctly) and did not lead students to feel more knowledgeable compared to a control condition. In Study 2S, having students read a brief text claiming that explaining is effective and fun proved unconvincing in this setting (see Supplemental Material for a full description).[6] Thus, instructors and other practitioners will need to carefully test interventions to tailor them to the learning context. Future research should also test other potential interventions for reducing the threat from low subjective knowledge (e.g., self-affirmation) and continue to explore the most effective ways to introduce our interventions in real-world learning contexts.

Another question for future research is how long our subjective knowledge intervention lasts in encouraging learners to engage in written reflection. It may be self-weakening, with learners confirming their initial belief that explaining is self-threatening—a difficult and unpleasant activity that does not yield immediate noticeable benefit. On the other hand, it may be self-reinforcing, with learners discovering that explaining is a challenge they are able to surmount—a useful strategy they can successfully employ.

Finally, though we focused on explaining as a learning strategy, the findings can potentially be applied to other effective learning strategies that learners are reluctant to use, especially those requiring knowledge reflection. Subjective knowledge may underlie learners' reluctance to, for instance, engage in self-testing (testing one's own knowledge by answering practice questions about the material) and elaboration (independently expanding on learned concepts). Future work should test whether interventions that successfully increase subjective knowledge embolden learners to adopt a myriad of effective but self-threatening learning strategies.

There is still much to learn about how learners learn. A better understanding of how and why people choose to study as they do is critical for improving learning outcomes for all—including those who need it most.

[6] Although the interventions were not successfully operationalized in the classroom setting, students' studying choices and the relationship between subjective knowledge and studying choices replicated our findings. First, students in both classes strongly preferred to review their notes (80% and 73% in Studies 1S and 2S, respectively) than explain the material (20% and 27%, respectively). Second, this preference was predicted by subjective knowledge, with students who reported less subjective knowledge being less willing to explain the material (ps $< .001$).

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