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The Moderating Effect of Mindset on the Relationship Between University Students' Critical Feedback-Seeking and Learning

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Abstract

Mindset is believed to influence students' learning outcomes, but there is a paucity of research examining its relationship to students' learning choices (e.g., critical feedback-seeking and revision choices) as a pathway to improving learning and performance. This study examines the relationships between mindset, critical feedback-seeking, and learning. Undergraduate students (n = 155) at a University in Western Canada completed a mindset pre-test, played an online assessment game in which they designed three posters, and completed a post-test measuring their learning of graphic design principles. For each poster, the game tracked students' choices to seek confirmatory or critical feedback and to revise their posters, as well as their poster performance. Findings show that the more the students seek critical feedback, the more they revise their posters and the better they perform across the game. Theoretical implications resulting from mediation analyses indicate that revision fully explains the link between critical feedback-seeking and performance. Moreover, moderation analyses of mindset revealed differential results on the relationship between critical feedback-seeking and learning, depending on the conceptualization of the mindset construct. Implications of these results with regards to the conceptualization of mindset are discussed.

Keywords: feedback-seeking; revising; growth mindset; performance; learning

Introduction

Feedback and Performance

The relationship between individuals' engagement with feedback and their learning performance is affected by several factors, including motivation and feedback valence (Earley, 1986; Sansone & Harackiewicz, 2000; Steelman, Levy, & Snell, 2004). Although both positive and negative feedback predict task performance in some cases, they do not always reinforce the intended behaviors (Scott, Swan, Wilson, & Roberts, 1986) and they can even hinder performance (Kluger & DeNisi, 1998). Moreover, the link between feedback and learning may also be affected by learners' willingness to revise their work. Specifically, the literature shows a positive relationship between feedback and revision, but there is little evidence that learners will apply their revising strategies on new tasks (Suzuki, Nassaji, & Sato, 2019).

Feedback-seeking and Mindset

In contrast to feedback that is assigned to the learner, a culture of feedback-seeking may partly moderate the relationship between feedback and performance (Evans & Dobrosielska, 2019). Indeed, individuals are comfortable exchanging critical (i.e., negative, but constructive) feedback for performance improvement in settings that foster a culture of feedback-seeking. Several psychological factors may also impact students' feedback-seeking choices and responses to these choices, such as individuals' endorsement of different mindsets or theories of intelligence. For instance, individuals may behave differently when facing challenges, depending on their mindsets (Blackwell, Trzesniewski, & Dweck, 2007; Dweck, 1999). When learners believe that their intelligence and abilities are malleable (i.e., growth mindset), they may take a mastery-oriented approach to their learning (Dweck & Leggett, 1988). This approach may lead them to focus on their learning process and become more resilient toward challenges and failure

with the goal of further developing their competencies rather than merely demonstrating their current level of competence (Lou & Noels, 2017; VandeWalle, 2003). For instance, learners who endorse a growth mindset may be more likely to seek constructive feedback or to apply this type of feedback in future similar situations. Also, it is believed that students who endorse a growth mindset are more likely to actively seek opportunities to learn and develop their abilities (Rattan, Savani, Chugh, & Dweck, 2015) and that a growth mindset gives rise to perseverance and resilience in the face of challenges (Burgoyne, Hambrick, & Macnamara, 2020; Yeager & Dweck, 2012). In contrast, when learners believe that their intelligence and abilities are fixed, they may adopt a performance-oriented approach (Dweck & Leggett, 1988). This approach may lead them to validate their abilities and, thus, to avoid challenging situations or opportunities that reveal their current level of competence (Lou & Noels, 2017; VandeWalle, 2003). For instance, learners who endorse a fixed mindset may be less likely to seek constructive feedback and to subsequently apply it to improve their learning. A recent study sampling English-language learners revealed that growth mindset contributed to students' resilience and mitigated the perceived rejection and contact avoidance of students with lower competency (Lou & Noels, 2020a). However, in most such studies, the relationship between mindset and feedback has been examined when feedback was assigned to the learner, not sought by the learner. Finally, it is thought that mindset may predict not only behaviors, but also performance following failure (Burgoyne et al., 2020). Thus, we would expect people who endorse an incremental view of intelligence to perform better than those who endorse an entity view of intelligence.

Research Questions

Despite recent efforts on elucidating the relationship of mindset and learning outcomes, few studies have examined how both mindsets and learners' choices (e.g., choosing to seek

critical feedback about one's work or choosing to revise one's work) systematically influence different learning outcomes. In the present study, we hypothesize that growth mindset has a positive impact on the relationship between critical feedback-seeking and learning outcomes, as learners who endorse a growth mindset are more likely to view critical feedback as a learning opportunity (Haimovitz & Dweck, 2017) or as constructive information they can use to fill gaps in their knowledge. Thus, this study aims to explore: 1) the mediating role of revising one's work on performance and 2) the moderating effect of growth mindset on the relationship between critical feedback-seeking and learning. The study poses the following research questions:

- *Does critical feedback-seeking exert a direct influence on learning outcomes or is this influence mediated or moderated, respectively, by the choice to revise one's work?*
- *Does mindset moderate the relationship between learning behaviors (critical feedback-seeking and revision) and learning outcomes?*

We propose a theoretical model, illustrated in Figure 1, to address these research questions. The model outlines the mechanism of how critical feedback-seeking enhances performance and learning, including the mediating and moderating role of revision, and the moderating role of mindset. First, we examine whether revision explains or moderates the effects of critical feedback-seeking on performance and learning. Then, we investigate whether the links among critical feedback-seeking, revision, and learning outcomes depend on students' mindsets by adding either the mindset continuum or both fixed and growth mindsets as moderators in the mediation model.

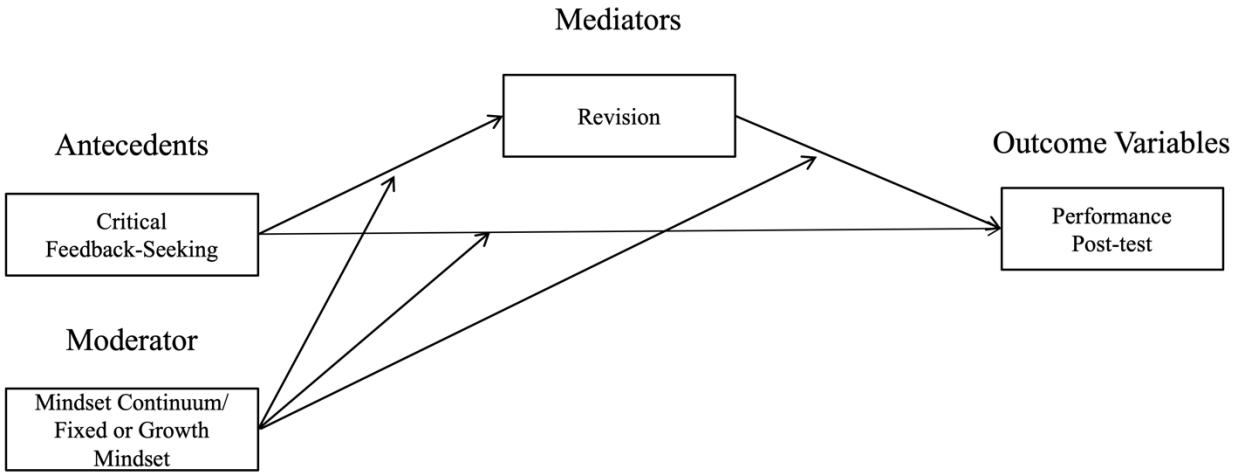

Figure 1. Theoretical model of the contribution of mindset to the relationship between learning choices and learning outcomes.

Theoretical Framework

Mindset has been given much attention recently due to its potential influence on individuals' motivation, responses to challenges, and achievements, as it is believed to be foundational to meaning-making systems (Burgoyne et al., 2020; Lou & Noels, 2019). Recent studies have challenged the efficacy of mindset in shaping individuals' behaviors and achievement. For instance, a study sampling 438 undergraduate students attempted to test several generally-believed mindset claims, but found little overall empirical support and, in one case, contradictory findings (Burgoyne et al., 2020). These results suggest that mindset theory needs to be revisited to reconcile contradicting claims revolving around mindset, especially as it holds implications for psychoeducational interventions.

The present study explores the role of mindset in influencing the relationship between learning behaviors and learning outcomes. It draws on Carol Dweck's (1999) theories of intelligence that differentiate between fixed mindset (i.e., the belief that intelligence or ability is stable – or an entity view) and growth mindset (i.e., the belief that intelligence or ability can be

improved with effort – or an incremental view). In the light of the current mindset discoveries, the present study explores two different theoretical mindset models. The first model is based on the mainstream mindset theory that considers a unidimensional mindset construct (i.e., an individual endorses one of the two opposing beliefs, a fixed or a growth mindset) with lower values representing the endorsement of a fixed mindset and higher values representing the endorsement of a growth mindset. The second model is based on empirical evidence from several studies distinguishing between a fixed mindset construct and a separate growth mindset construct (Chen & Tutwiler, 2017; Lüftenegger & Chen, 2017; Martin, 2015; Tempelaar, Rienties, Giesbers, & Gijselaers, 2015). The latter model allows for an individual to endorse a mixture of fixed and growth beliefs. The former assumes a complementary view: low agreement with fixed mindset means automatically high agreement with a growth mindset, which may not be universally valid, especially for those who endorse moderate beliefs (Khan, 2019). The recent literature on mindset suggests that individuals' views regarding changes in ability are more complex than a continuum from a fixed mindset to a growth mindset. For example, students may not believe that their ability is fixed or malleable, but they may believe that they can lose their ability (indicating neither a fixed nor a growth mindset; Lou, Masuda, & Li, 2017). As such, the opposite of fixed mindset is not necessarily a growth mindset.

Mindset and Learning Behaviors

It is thought that growth mindset leads to seeking challenges in favor of familiar tasks. For instance, in a study that measured event potentials using an electroencephalogram (EEG), participants who endorsed a growth mindset displayed heightened brain activity when receiving corrective feedback (Mangels, Butterfield, Lamb, Good, & Dweck, 2006). According to self-directed learning, seeking challenges is conducive to more effective learning (Lee, Heeter,

Magerko, & Medler, 2012). In fact, endorsing a growth mindset after encountering failure may better prepare individuals to manage challenging situations (Leith et al., 2014). Students who endorse a growth mindset are more likely to focus on learning and correcting mistakes, and less likely to focus on performance and to worry about failures (Dimotakis, Mitchell, & Maurer 2017; Lou & Noels, 2016). A study from organizational behavior research revealed that employees who endorsed a growth mindset were more likely to seek feedback when their abilities and job demands were misaligned (Devloo, Anseel, & De Beuckelaer, 2011). A second-language writing study, which sampled 128 foreign language writers from a US university, found that growth language mindset predicted the instrumentality of feedback in learners' goal pursuit. It also indirectly predicted the strategies of feedback monitoring and feedback inquiry, whereas fixed language mindset predicted the cost of feedback seeking (Papi, Bondarenko, Wawire, Jiang, & Zhou, 2019). For these reasons, students' incremental theories of intelligence would be hypothesized to predict their willingness to choose productive learning behaviors.

Conversely, students who endorse a fixed mindset are more likely to focus on performance feedback (i.e., how they were doing on a task) and discount corrective feedback for learning (i.e., whether their answers were correct; Mangels et al., 2006). As a result, students who endorsed a growth mindset made fewer mistakes on a follow-up test, whereas students who endorsed a fixed mindset continued to make the same mistakes (Mangels et al., 2006). Although mindset beliefs are considered important, a recent intervention study found that they are temporarily malleable and can revert to their pre-intervention state (Orosz, Péter-Szarka, Bőthe, Tóth-Király, & Berger, 2017), which practitioners need to consider when planning research interventions. Indeed, Dweck (2010, pp. 26-29) also suggested that theories of intelligence are not immutable.

Mindset and Learning Outcomes

The influence of mindset on students' learning outcomes is still a matter of debate, with the relevant literature yielding mixed results (Sisk, Burgoyne, Sun, Butler, & Macnamara, 2018). A recent study found that a growth mindset intervention improved high-school students' grades (Yeager et al., 2019), but the study only focused on performance and it did not examine students' learning. A previous study also showed that growth mindset buffered the negative effect of feedback disengagement on performance (Greene, Costa, Robertson, Pan, & Deekens, 2010). Also, growth mindset was found to moderate the relationship between the time elapsed since the latest training in neonatal resuscitation and performance (Cutumisu, Brown, Fray, & Schmölzer, 2018). Concomitantly, although mindsets are important in students' learning processes, university students often show a decline in growth mindsets over time, with negative implications on their learning (Dai & Cromley, 2014).

Mindset, Learning Behaviors, and Learning Outcomes

Mindset theory suggests that implicit theories of intelligence can predict achievement through their influence on self-regulatory processes activated as a result of failure (Dweck & Leggett, 1988). A recent meta-analytic review found that individuals who endorse an incremental view of intelligence are more likely to achieve higher grades in verbal and quantitative subjects and in overall achievement (Costa & Faria, 2018). Also, Greene et al. (2010) found that mindset moderated the link between self-regulated learning behaviors (e.g., help-seeking behavior) and post-test performance. Specifically, endorsing a growth mindset can mitigate the negative effect of feedback disengagement on learning. More recently, Yeager et al. (2019) found that a mindset intervention improved students' performance (as measured by their grades), especially when the classroom norms also encouraged students to seek challenges (e.g., negative feedback). That is,

students learn the most when they are encouraged to seek critical feedback and to endorse a growth mindset. Additionally, it was found that a stronger endorsement of college students' incremental theories of general intelligence at the beginning of the semester was associated with greater self-reporting of help-seeking behaviors during the semester, which may protect their academic achievement (Shively & Ryan, 2013). These studies suggest the important role of mindset when examining the effect of feedback on learning.

Method

Participants and Procedure

Participants were 155 undergraduate students (119 females and 36 males; M_{age} = 21.57, SD_{age} = 5.05) recruited from a large University in Western Canada. First, participants provided online informed consent. Second, they completed a pre-test that included a four-item mindset questionnaire about their general theories of intelligence shown in Table 1.

Table 1. The mindset questionnaire.

Item	How much do you agree with the following statements? (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree)
1	You cannot really change your abilities.
2	You can always change your abilities.
3	You can learn new things, but you cannot really change your abilities.
4	You can get better with practice.

Note. Items 1 and 3 represent fixed mindsets, and items 2 and 4 represent growth mindsets.

Third, they played Posterlet (Cutumisu, Blair, Chin, & Schwartz, 2015, 2017), an online game in which they designed three digital posters for booths at a Fun Fair. For each poster, they had three

options to seek either confirmatory (i.e., positive) or critical (i.e., negative) feedback from virtual game characters and one option to revise their poster. After each poster, the game displayed the number of tickets sold at the poster booth, as a measure of the player's poster performance. Finally, students completed an independent digital post-test measuring their learning of graphic design principles.

Materials

Pre-test: Mindset Questionnaire

Fixed Mindset represents the sum of items 1 and 3 in the mindset questionnaire shown in Table 1.

Growth Mindset represents the sum of items 2 and 4 in the mindset questionnaire shown in Table 1.

Posterlet Game

The game is a computer-based assessment of students' choices to 1) seek critical or confirmatory feedback about their posters and 2) revise their posters. It computes a poster performance measure per poster by comparing the poster against a set of 21 graphic design principles, ranging from -21 to 21.

Performance is a measure generated by the game and it represents a player's overall poster performance across the three posters. It sums the performance of the last poster (i.e., the revised version of a poster or the first draft, if the poster was not revised on that round) on each of the three rounds of the game.

Pre-test measures the performance of the first poster designed in the game, before any options to choose feedback or to revise the poster occurred.

Independent Post-test

Post-test measures students' learning of graphic design principles. Students were presented with two posters, the second poster being a variation of the first poster. One of the posters included a misused graphic design principle (e.g., the size of the text on the poster was too small). Then, they were asked to decide which poster had a better quality. Students were awarded one point for a correct answer and zero for an incorrect answer, thus, the measure ranged from zero to four. A detailed description of the post-test is included in previous research (Cutumisu, Chin, & Schwartz, 2019).

Data Analysis Plan

First, descriptive analyses were conducted for all the key variables, including means, standard deviations (SD), and assumption testing. Second, correlation analyses were conducted to test the associations among variables. Finally, path analyses were conducted to examine the hypothesized mediation (i.e., revision mediates the link between critical feedback-seeking and performance) and moderation (i.e., mindset moderates the link between critical feedback-seeking and the post-test).

Results

The descriptive statistics of the key variables included in Figure 1 are presented in Table 2. Between-subjects t-test and correlational analyses were conducted to examine gender and age differences on key variables. No significant gender and age effects were found on any of the key variables, so gender and age were not included in further analyses.

Table 2. Bivariate correlations and descriptive statistics: Mean (M), standard deviation (SD), skewness, and kurtosis.

	1	2	3	4	5	6	7	8
1. Fixed mindset	--	**-.60*****	**-.92*****	.02	.00	.12	.10	.11
2. Growth mindset		--	**.87*****	.08	.09	-.08	-.06	-.01
3. Mindset continuum			--	.01	.05	-.11	-.09	-.07
4. Critical feedback-seeking				--	**.47*****	**.18***	.05	**.21***
5. Revision					--	.12	-.08	.13
6. Post-test learning						--	**.26****	**.23****
7. Pre-test							--	**.75*****
8. Performance								--
M	4.10	8.62	16.52	5.62	1.70	1.97	11.74	41.42
SD	1.43	1.16	2.31	1.86	1.26	.96	4.47	8.74
Skewness	1.02	-0.84	-0.81	-0.46	-0.29	0.11	-1.06	-1.13
Kurtosis	1.83	0.21	0.93	0.09	-1.58	-0.65	1.79	2.06

Note. $^{***}p < .001$, $^{**}p < .01$, $^{*}p < .05$, two-tailed.

We estimated the internal consistency reliability of the mindset survey by computing Cronbach's alpha (Cronbach, 1951). The overall value for all four items, with the two fixed mindset items reversed, was α = .73, which exceeds the acceptable criterion threshold of .60 as well as the value of α = .63 obtained for the 8-item Mindset Assessment Profile (Burgoyne & Macnamara, 2020). The two-item scale for fixed mindset yielded α = .68 and the two-item scale for growth mindset yielded α = .41. Cronbach alpha is biased depending on the number of items, thus it is not surprising that the two-item scales often have low alpha values (see Eisinga, Te Grotenhuis, & Pelzer, 2013; McNeish, 2018). Therefore, we also reported the inter-item correlations to assess reliability. We found that the two growth-mindset items (r = .32) and the

two fixed mindset items (r = .51) were above the recommended level of .30 for inter-item correlation (Robinson, Shaver, & Wrightsman, 1991).

Confirmatory factor analyses conducted on the mindset items showed that both the two-factor model separating the mindset items into two constructs, fixed and growth (χ^2 = 1.53, df = 1, p = .22, CFI = .996, $RMSEA$ = .058, $SRMR$ = .02, AIC = 1248.93), and the one-factor model treating all the mindset items as one mindset construct (χ^2 = 2.63, df = 2, p = .27, CFI = .995, $RMSEA$ = .045, $SRMR$ = .026, AIC = 1248.03) fit the data equally well (Werner & Schermelleh-Engel, 2010), with no significant difference between the two models (χ^2_{diff} =1.10, p = .29). A decrease of the CFI by less than .01 and an increase of the RMSEA by less than .015 typically indicate that the models reflect the data structure equally well (Chen, 2007). Therefore, in the current study, we turned to mindset theory to choose a mindset model that explains our data. We compared the results of the two hypothesized mindset models: the one-factor model and the two-factor model, especially as there is mounting evidence in the mindset literature of two mindset constructs (fixed and growth mindset, respectively) rather than one mindset continuum (Chen & Tutwiler, 2017; Lüftenegger & Chen, 2017; Martin, 2015; Tempelaar et al., 2015). We reversed the two fixed mindset items and combined them with the two growth mindset items to form a mindset continuum variable. As such, a higher score on the mindset continuum represents a stronger growth mindset and a weaker fixed mindset.

The descriptive statistics and correlation coefficients among the key variables are reported in Table 2. The absolute values of skewness and kurtosis do not exceed the value of 3, showing that the data were normally distributed (George & Mallery, 2010; Kline, 2015). Findings showed that critical feedback-seeking and poster performance were significantly correlated with post-test learning. Also, mindsets (fixed, growth, and mindset continuum) were

not correlated with students' learning choices (critical feedback-seeking and revising) or learning outcomes (poster performance and post-test learning). Results also showed that the pre-test is significantly associated with both learning outcomes (post-test and performance). Thus, we subsequently controlled for the pre-test in the path models.

Path analyses in *MPlus 7.0* (Muthén & Muthén, 2017) were conducted to understand the mediation and moderation relationships depicted in Figure 1 more comprehensively. In all the figures, bold solid paths represent standardized significant coefficients ($p < .05$), whereas grey dashed lines represent standardized non-significant coefficients. The results of the path analyses shown in Tables 3–6, indicate that the models fit the data well. Tables 3-6 show the unstandardized coefficients of the models depicted in Figures 2 and 4-6, respectively. In these path models, the link between pre-test and revision was not specified, as these variables were not significantly associated with each other ($r = .13$). Nevertheless, we explored whether including this link would change the results (Tables S1–S4 in the *Supplementary Materials* document). The path model that includes the pre-test predicting revision is a saturated model ($df = 0$). The results suggest that the pre-test did not significantly predict participants' revising behavior ($\beta = -.09$ and $\beta = -.10$, $p > .05$, respectively). Moreover, other path coefficients were consistent with those obtained without controlling for the pre-test when predicting revision.

Does the choice to revise one's posters mediate or moderate the relationship between critical feedback-seeking and learning outcomes?

First, as shown in Table 3 and Figure 2, critical feedback-seeking significantly predicted revision and, in turn, revision predicted performance. This indirect effect showed that students' choice to revise their posters significantly mediated the link between critical feedback-seeking and performance ($b = .33$, $SE = .14$, 95% CI = [.096, .636], $\beta = .07$; 5,000 bootstrapping

samples). This is a full mediation given that the total effect of critical feedback-seeking on performance is significant (b = .85, SE = .24, β = .18, t = 3.51, p < .001), whereas the direct effect is no longer significant when revision is specified as a mediator in the model (b = .52, SE = .30, β = .11, t = 1.70, p = .09). In other words, students who sought critical feedback more often performed better *because* they revised their posters more often. However, revising did not mediate the link between critical feedback-seeking and post-test learning; the indirect effect was not significant (b = .02, SE = .02, 95% CI = [-.022, .062], β = .04; 5,000 bootstrapping samples), as shown in Table 3.

Table 3. Maximum likelihood estimates for the final path model on performance and post-test (controlling for pre-test on performance and post-test). Exploring the interactions between critical feedback-seeking and two-factor mindsets on revision and on the two learning outcomes.

Outcome variable	Predictor	*b*	*S.E.*	*t*	*p*	R^2
Revision						**.25*****
	Critical feedback-seeking	0.32	0.05	6.75	**<.001**	
	Growth mindset	0.11	0.09	1.18	.24	
	Fixed mindset	0.06	0.08	0.77	.44	
	Critical feedback-seeking × Growth mindset	0.05	0.06	0.78	.44	
	Critical feedback-seeking × Fixed mindset	0.07	0.04	1.71	.09	
Performance						**.63*****
	Revision	0.97	0.40	2.42	**.02**	
	Critical feedback-seeking	0.47	0.27	1.74	.08	
	Growth mindset	0.36	0.47	0.76	.45	
	Fixed mindset	0.44	0.38	1.14	.26	
	Critical feedback-seeking × Growth mindset	-0.25	0.30	-0.85	.40	
	Critical feedback-seeking × Fixed mindset	0.02	0.22	0.09	.93	

	Pre-test	1.47	0.10	14.88	**<.001**	
Post-test						**.15****
	Revision	0.06	0.07	0.88	.38	
	Critical feedback-seeking	0.07	0.04	1.53	.13	
	Growth mindset	-0.01	0.08	-0.08	.94	
	Fixed mindset	0.05	0.06	0.77	.44	
	Critical feedback-seeking × Growth mindset	0.12	0.05	2.50	**.01**	
	Critical feedback-seeking × Fixed mindset	0.05	0.04	1.46	.15	
	Pre-test	0.06	0.02	3.54	**<.001**	

Note. b = unstandardized path coefficient. The scores for critical feedback-seeking, fixed mindset, and growth mindset are mean centered.

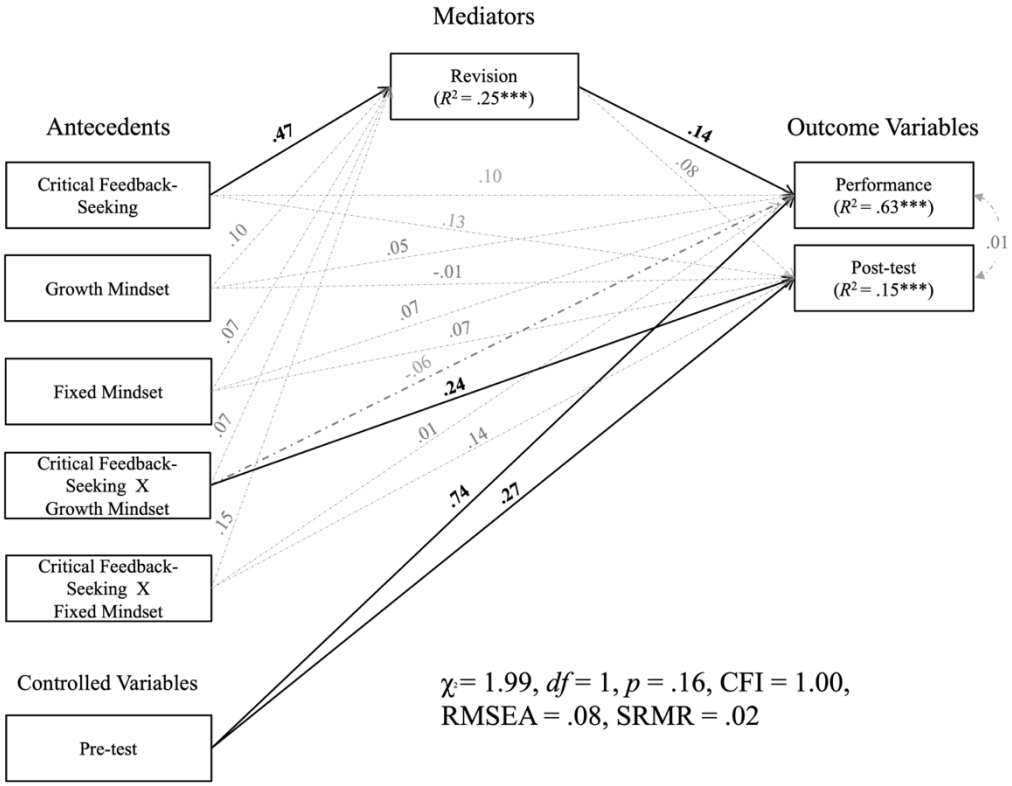

Figure 2. Path analysis model (n = 155). Numbers represent standardized path coefficients. Revision mediates the relationship between critical feedback-seeking and performance. Growth mindset moderates the link between critical feedback-seeking and the post-test.

Two moderation analyses were conducted to explore whether revision moderated the link between critical feedback-seeking and learning outcomes. The results suggested that revision did not moderate the effect of critical feedback-seeking on performance (b = 0.49, SE = .33, t = 1.48, p = .14) or on post-test (b = 0.01, SE = .04, t = 0.25, p = .81), even after controlling for the pre-test (performance: b = 0.05, SE = .22, t = 0.26, p = .81; post-test: b = -0.01, SE = .04, t = -0.20, p = .84).

Does mindset moderate the relationship between learning behaviors (critical feedback-seeking and revision) and learning outcomes?

Growth mindset

The interaction between critical feedback-seeking and growth mindset in the two-factor mindset model did not significantly predict performance, but it significantly predicted the post-test (i.e., the learning of graphic design principles measured independently of the assessment game environment), as shown in Table 3 and Figure 2. To explore this interaction effect, simple-slope analyses shown in Figure 3 were conducted using the PROCESS macro (Hayes, 2017) in SPSS.

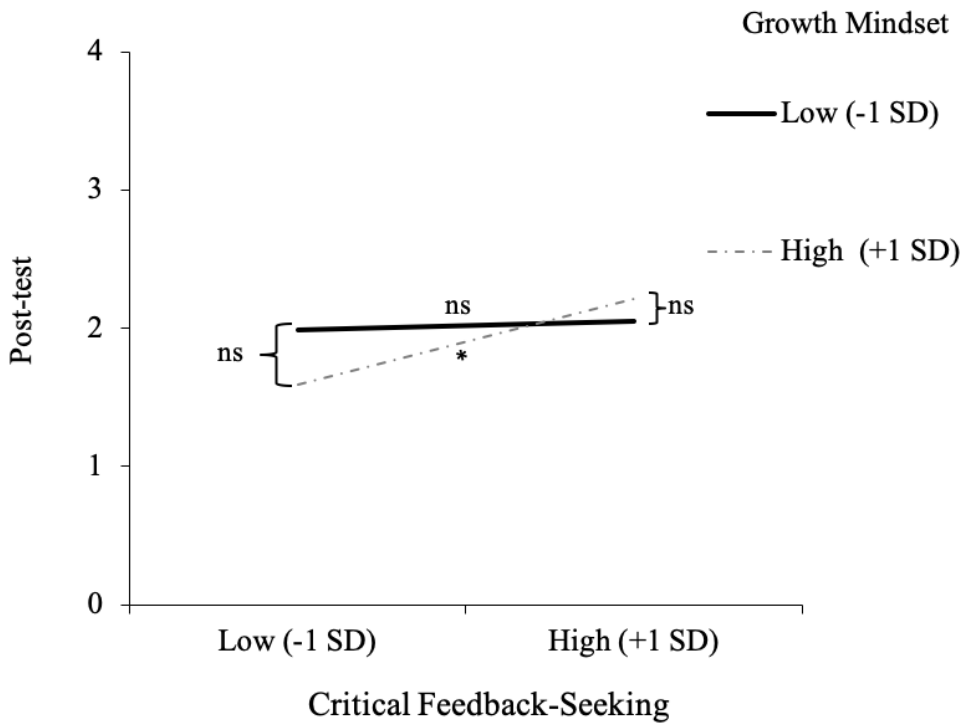

Figure 3. The visualization of the simple-slopes analysis (n = 155). Growth mindset moderates the link between critical feedback-seeking and post-test learning.

Results revealed that students' critical feedback-seeking was effective in predicting the post-test only when they endorsed a strong growth mindset (+1SD; $b = .17$, $SE = .06$, $t = 2.70$, $p = .008$); if they endorsed a weak growth mindset (-1SD), critical feedback-seeking did not predict their post-test learning outcome ($b = .02$, $SE = .06$, $t = 0.27$, $p = .79$). Specifically, the Johnson-Neyman technique (Johnson & Neyman, 1936) revealed that critical feedback-seeking predicted the post-test only when students' growth mindset was above 8.47 (out of 10), representing 63.23% of the participants in this sample. In contrast, critical feedback-seeking did not positively or negatively predict the post-test when students' growth mindset was below 8.47. Thus, students who endorse a stronger growth mindset (represented by the dashed black line in

Figure 3) learn significantly more graphic design principles when they choose higher rather than lower amounts of critical feedback in Posterlet. Concomitantly, students who endorse a weaker growth mindset (represented by the solid black line in Figure 3) learn at the same rate regardless of the amount of critical feedback they choose in Posterlet. Table 4 and Figure 4 show no significant interaction effect for revision.

Table 4. Model 2: Path analysis (n = 155): exploring the interactions between revision and two-factor mindsets on the two learning outcomes.

Outcome variable	Predictor	*b*	*S.E.*	*t*	*p*	R^2
Revision						**.22*****
	Critical feedback-seeking	.32	.05	6.67	**<.001**	
Performance						**.63*****
	Revision	0.97	0.39	2.47	**.01**	
	Critical feedback-seeking	0.49	0.27	1.86	**.06**	
	Growth mindset	0.46	0.47	0.98	.33	
	Fixed mindset	0.42	0.38	1.09	.27	
	Revision × Growth mindset	-0.52	0.38	-1.37	.17	
	Revision × Fixed mindset	-0.51	0.31	-1.66	.10	
	Pre-test	1.47	0.10	15.00	**<.001**	
Post-test						**.12***
	Revision	0.06	0.07	0.95	.34	
	Critical feedback-seeking	0.07	0.04	1.55	.12	
	Growth mindset	-0.01	0.08	-0.13	.90	

Fixed mindset	0.05	0.06	0.70	.48
Revision × Growth mindset	0.00	0.06	0.06	.95
Revision × Fixed mindset	-0.05	0.05	-1.06	.29
Pre-test	0.05	0.02	3.25	**.001**

Note: b = unstandardized path coefficient. The scores for feedback-seeking, fixed mindset, and growth mindset are mean centered.

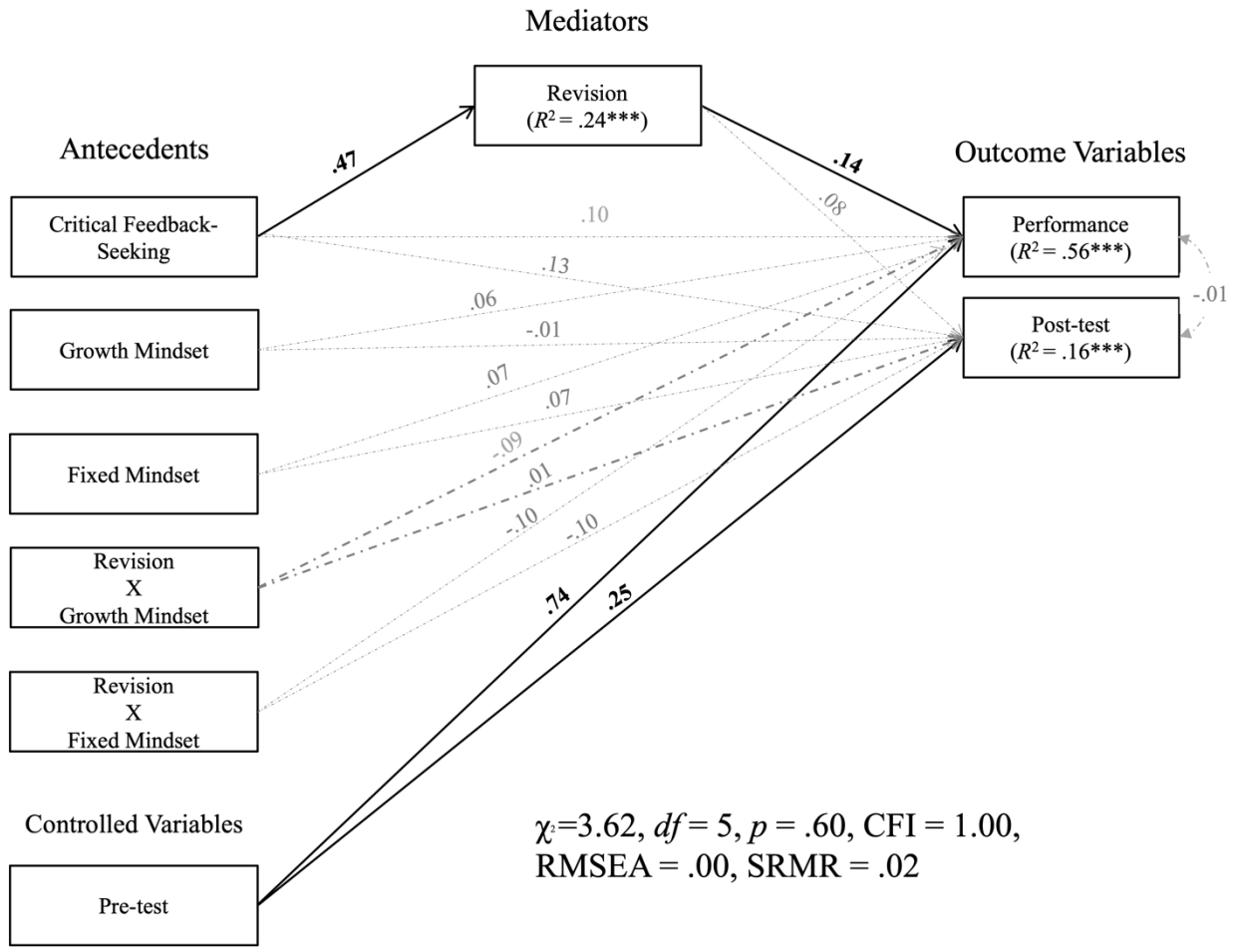

Figure 4. Path analysis model (n = 155). Numbers represent standardized path coefficients. Two-factor mindsets (fixed and growth) did not moderate the link between revision and learning outcomes (i.e., performance and post-test learning).

Fixed Mindset

In the path model for the two-factor mindset model (see Figure 2), findings revealed that the links between critical feedback-seeking and performance as well as between critical feedback-seeking and the post-test were not moderated by fixed mindset (see interaction effects between fixed mindset and critical feedback-seeking in Table 3, *p*s > .05). As shown in Table 3 and Figure 2, there was no main effect of fixed mindset on revision or learning outcomes. This supports the results of the correlation analyses showing that fixed mindset does not appear to affect students' learning choices or learning outcomes. Also, Table 4 and Figure 4 show no significant interaction effect for revision.

Mindset Continuum

In the path model of the one-factor mindset model (see Table 5 and Figure 5), findings revealed that the links between critical feedback-seeking and performance as well as between critical feedback-seeking and the post-test were not moderated by mindset (see interaction effects between mindset and critical feedback-seeking in Table 5, *p*s > .05).

Table 5. Maximum likelihood estimates for the final path model on performance and post-test (controlling for pre-test on performance and post-test). Exploring the interactions between critical feedback-seeking and the one-factor mindset on revising and on the two learning outcomes.

Outcome variable	Predictor	*b*	*S.E.*	*β*	*t*	*p*	R^2
							.23***
Revision	Critical feedback-seeking	0.33	0.05	.48	6.73	**<.001**	
	Mindset continuum	0.01	0.04	.01	0.16	.87	
	Critical feedback-seeking × Mindset	0.02	0.02	.07	0.94	.94	
Performance							**.63*****
	Revision	1.01	0.40	.14	2.56	**.01**	
	Critical feedback-seeking	0.52	0.27	.11	1.61	.053	
	Mindset continuum	-0.28	0.19	-.07	-1.49	.14	
	Critical feedback-seeking × Mindset	0.09	0.10	.04	0.87	.40	
	Pre-test	1.49	0.10	.75	15.27	**<.001**	
Post-test							**.11***
	Revision	0.06	0.07	.08	0.88	.38	
	Critical feedback-seeking	0.07	0.05	.14	1.55	.12	
	Mindset continuum	0.03	0.03	.06	0.78	.43	
	Critical feedback-seeking × Mindset	0.02	0.02	.08	0.98	.32	
	Pre-test	0.05	0.02	.26	3.37	**<.001**	

Note. b = unstandardized path coefficient. The scores for critical feedback-seeking and mindset are mean centered.

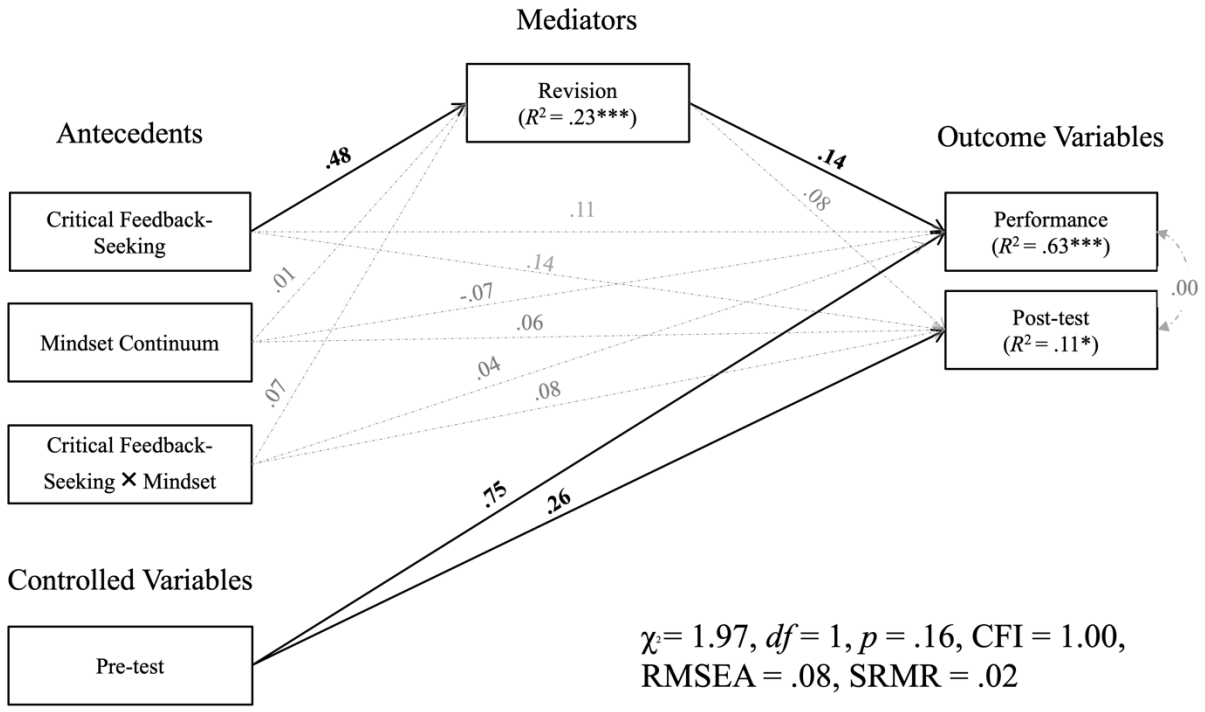

Figure 5. Path analysis model (n = 155). Numbers represent standardized path coefficients. Revision mediates the relationship between critical feedback-seeking and performance. The interaction effect of the one-factor mindset and critical feedback-seeking on the post-test was not significant.

Another path analysis was conducted to explore the moderating role of mindset on the relationship of revision with critical feedback-seeking and learning outcomes (performance and post-test, respectively). As shown in Table 6 and Figure 6, findings show that mindset did not moderate the link between these variables.

Table 6. Model 2: Path analysis (n = 155): exploring the interactions between revision and the one-factor mindset on the two learning outcomes.

Outcome variable	Predictor	*b*	*S.E.*	*t*	*p*	R^2
Revision						**.22*****
	Critical feedback-seeking	.32	0.05	6.67	**<.001**	
Performance						**.63*****
	Revision	1.02	0.39	2.60	**.01**	
	Critical feedback-seeking	0.48	0.27	1.86	**.07**	
	Mindset continuum	-0.28	0.19	-1.50	.13	
	Revision × Mindset	0.08	1.48	0.55	.58	
	Pre-test	1.49	0.10	15.21	**<.001**	
Post-test						**.11***
	Revision	0.06	0.07	0.89	.38	
	Critical feedback-seeking	0.06	0.04	1.44	.15	
	Mindset continuum	0.02	0.03	0.76	.45	
	Revision × Mindset	0.03	0.03	1.30	.20	
	Pre-test	0.05	0.02	3.33	**.001**	

Note: b = unstandardized path coefficient. The scores for feedback-seeking and mindset are mean centered.

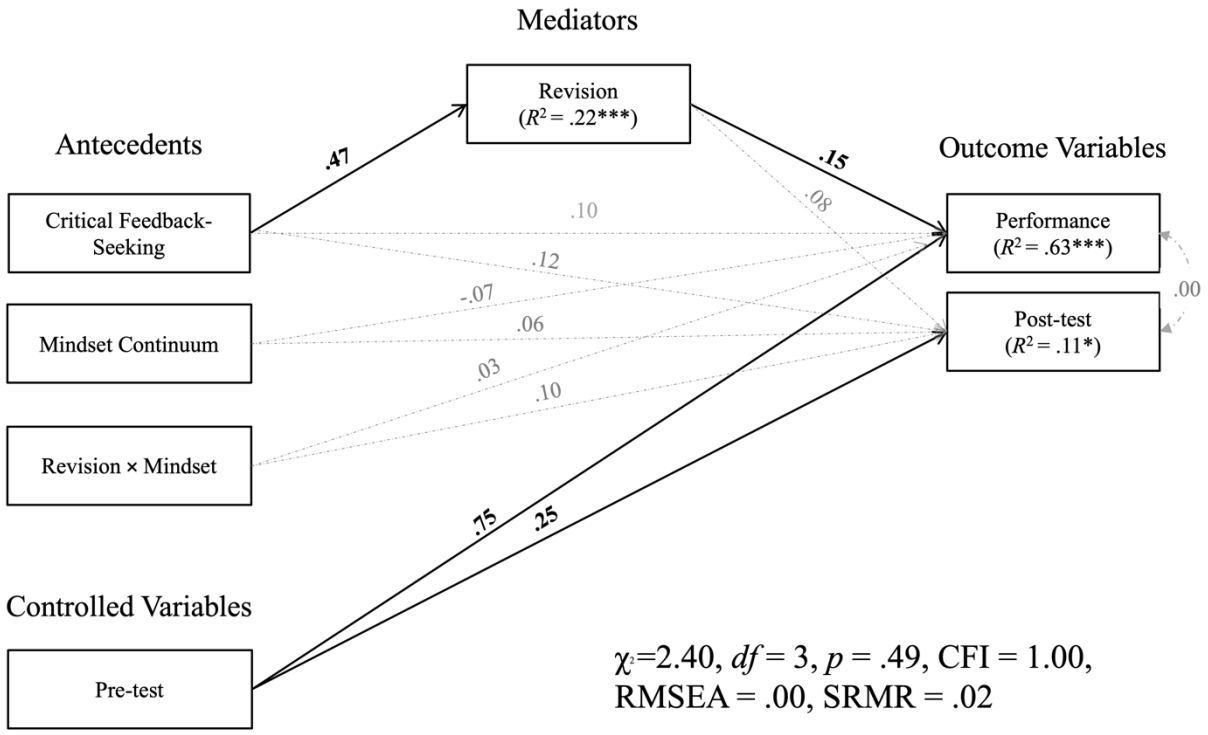

Figure 6. Path analysis model (n = 155). Numbers represent standardized path coefficients. The one-factor mindset did not significantly moderate the link between revision and learning outcomes (i.e., performance and post-test learning).

Analyses also explored whether including the pre-test in the model predicting revision would change the results. The results indicated that the pre-test did not significantly predict revision (*b*= -.03, *p* = .16) in the path model, as shown in Tables S3 and S4 in the *Supplementary Materials* document. This supports the results of the correlation analyses showing that mindset as one factor does not appear to affect students' learning choices or learning outcomes.

Discussion

Does the choice to revise one's posters mediate or moderate the relationship between critical feedback-seeking and learning outcomes?

The findings revealed that critical feedback-seeking and poster performance were significantly associated with learning, echoing prior research results (Cutumisu & Schwartz, 2018). Teasing out the relationship between critical feedback-seeking and learning outcomes showed that the impact of critical feedback-seeking on performance was fully mediated by the choice to revise one's work, even after controlling for students' pre-test performance (i.e., the performance of the first poster designed in the game, before any feedback and revision options). Also, regardless of students' initial poster performance (i.e., their performance when they started the game), revising posters explains their improved performance when they seek critical feedback more often in the game. Other research supports these results, as it has shown that individuals improve their performance when they revise their work using expert feedback (Ericsson, Krampe, & Tesch-Römer, 1993). Moreover, in the context of peer feedback, undergraduate students who responded actively to peers' critiques gained more from revising their video blogs (Yeh, Tseng, & Chen, 2019). Also, timely peer feedback enhanced students' revising behaviors and performance (Kulkarni, Bernstein, & Klemmer, 2015, pp. 75-84). More generally, in a recent study sampling 97 sixth-grade public-school students, it has been shown that critical feedback-seeking was positively associated with students' performance on the poster design task through revising, regardless of their prior academic achievement (Cutumisu, Schwartz, & Lou, 2020).

In sum, we found that revision mediated, rather than moderated, the link between critical feedback-seeking and performance. Thus, the answer to the first research question shows that

critical feedback-seeking predicted poster performance *through* revision. This is an important finding that constitutes a first step in identifying the mechanism that explains the effect of critical feedback-seeking on performance through revising one's work. Specifically, students who seek more critical feedback perform better on their posters *because* they revise their posters more often and not because they were better poster performers at the beginning of the game. Moreover, students' revising behavior was not correlated with their pre-test score, further suggesting that the learning mechanism of critical feedback-seeking on performance through revision has little to do with students' initial performance.

The current result has important implications for understanding students' learning processes. Although students' performance at the beginning of the game predicted their overall performance, students' initial performance did not impact the role of critical feedback-seeking and revision in improving performance. It is possible that students' initial performance was determined by numerous factors (e.g., prior achievement, learning experience, motivation, etc.). However, this study suggests that educators may encourage students, regardless of their initial performance, to seek critical feedback and to revise, which can in turn improve their performance. To our knowledge, this is the first time a mediating relationship was uncovered among learning choices (seeking critical feedback and revising) and performance.

However, the current study did not find any support for the mediating role of revision on the link between critical feedback-seeking and post-test learning. Instead, the present study suggests that post-test learning is driven by a different learning mechanism than the mechanism driving performance. A recent review has highlighted the distinction between these two types of learning outcomes, performance measured during instruction versus long-term learning, as one may happen without the other (Soderstrom & Bjork, 2015). This distinction suggests that certain

factors can have differential effects on performance and learning. Specifically, *learning* refers to lasting alterations of one's behavior or knowledge that also facilitate transfer (Chin et al., 2019), whereas *performance* refers to temporary observable and measurable variations in one's behavior or knowledge captured during or right after completing a task (Soderstrom & Bjork, 2015). The results presented in the current study may vary with different post-tests or with post-tests that are lengthier or administered across multiple timepoints, as research has shown those to be factors that influence learning (Lyle, Bego, Hopkins, Hieb, & Ralston, 2020). It has also been noted that conditions that are challenging early on in the learning process may be conducive to greater learning gains (Hayakawa, Bartolotti, van den Berg, & Marian, 2020). Thus, the role of mindset in untangling the relationship between performance and learning is still a matter of debate in the current literature.

Does mindset moderate the relationship between learning behaviors (critical feedback-seeking and revision) and learning outcomes?

To our knowledge, no other study has examined yet the link between mindset, prior achievement, and learning strategies such as feedback-seeking and revising choices. As we did not find a significant correlation between mindset and learning behaviors or outcomes, it is not clear why some students who endorse a growth mindset choose critical feedback-seeking more often than others. Thus, we hypothesized that mindset theory would explain why some students, perhaps those who endorse higher levels of a growth mindset, are more willing to improve their abilities (i.e., mastery-oriented), whereas others are more willing to prove their abilities (i.e., performance-oriented).

Critical Feedback-Seeking

The findings show that mindsets (fixed, growth, and the mindset continuum) were not correlated with students' learning choices (critical feedback-seeking and revising) or learning outcomes (poster performance and post-test learning). This result is echoed by an EEG study revealing that anticipation for verification feedback (correct vs. incorrect) on simple tasks produced the same increased brain activity regardless of participants' mindsets (Mangels et al., 2006). We expected that students who endorsed more of a fixed mindset would choose more positive feedback rather than criticism, due to their propensity to avoid engaging in activities where they may fail or not be portrayed in a favorable light (Dweck, 2002). This seems to suggest that there are other variables that determine some students to seek more constructive criticism than others and that mindset has little to do with this. An alternative explanation could be the difference in mindset operationalization, as the majority of the results in the mindset literature were obtained using a unidimensional mindset construct. More research in which mindset is operationalized as a two-factor construct is needed.

We also found differential results regarding the moderating role of mindsets on the relationship between learning behaviors and learning outcomes, depending on the mindset model considered. Although growth mindset moderated the relationship between critical feedback-seeking and learning in the two-factor model, the mindset continuum did not, when the one-factor mindset model was considered. Thus, in the two-factor model, critical feedback-seeking had a significant impact on learning when students endorsed a growth mindset, but in the one-factor model, critical feedback had a similar impact on post-test learning, regardless of students' mindsets. As such, growth mindset seems to benefit students' critical feedback-seeking with respect to their learning in the two-factor model. As there was no association between growth

mindset and critical feedback-seeking, this result suggests that growth mindset does not influence students' willingness to seek productive learning strategies, such as seeking constructive feedback, but that growth mindset influences how students respond to the critical feedback they choose to improve their learning. When the one-factor mindset model was considered, mindset continuum did not influence students' willingness to seek critical feedback or their response after choosing critical feedback. This result was confirmed by a recent study that found no association between mindset and performance after failure (Li & Bates, 2019).

The results of the two-factor model, but not those of the one-factor model, were consistent with previous research that the effect of self-regulated learning depends on students' growth mindset (Greene et al., 2010). In a similar population (i.e., university students), Lee et al. (2012) also found that students playing a serious game achieved better outcomes when endorsing a growth mindset rather than a fixed mindset, as they did not allow their failures to distract them from the task. They found that students also paid attention to feedback more than students endorsing a fixed mindset. Findings of the two-factor model are also supported by a recent study revealing that attention to mistakes, as measured by a brain signal using an electroencephalogram (EEG), mediates the relationship between growth mindset and higher post-error performance (Moser, Schroder, Heeter, Moran, & Lee, 2011). Finally, research shows that students who believe that they can develop their intellectual abilities tend to show higher achievement amid adversity and complete challenging math courses at a higher rate than those who believe that their intellectual abilities are fixed (Yeager & Dweck, 2012). In fact, in an experimental study that sampled high-school students, when students were provided with feedback that emphasized teachers' belief that they could raise to the challenge, students revised their essays more often, which improved the quality of their final drafts (Yeager et al., 2014). More research is needed to

elucidate the inconsistent findings when different factors were considered to operationalize the mindset construct. One possibility is that some of the previous research treated fixed and growth mindsets as separate constructs, whereas other research considered mindset as one construct, ranging from fixed to growth mindset.

Revision

A path analysis was conducted to explore the moderating role of fixed mindset, growth mindset, and the mindset continuum on the relationship between revision and learning outcomes (performance and post-test, respectively). The path analysis findings of both the one-factor and two-factor model showed that mindsets did not moderate the link between revision and learning outcomes, regardless of controlling for the pre-test. However, in other research, students who endorsed a growth mindset were more likely to learn from mistakes (Dimotakis, Mitchell, & Maurer 2017; Lou & Noels, 2016) and to correct their mistakes on a follow-up test, whereas students who endorsed a fixed mindset continued to make the same mistakes on a follow-up test (Mangels et al., 2006). It is believed that endorsing a growth mindset may better prepare individuals for dealing with failure (Leith et al., 2014), whereas endorsing a fixed mindset may lead students to focus on performance and to discount the feedback they encounter (Mangels et al., 2006). These conflicting results indicate that more research is needed to elucidate the role of mindsets in the relationship between revising and learning outcomes. Overall, the findings are supported by a recent study, which found that growth mindset was not associated with persisting to overcome a challenge (Burgoyne et al., 2020), as we did not find that students who endorsed a growth mindset also revised their posters more often. However, in contrast with our study, the former study used a self-reported measure to ascertain participants' persistence to overcome a challenge.

Limitations and Future Directions

We acknowledge several limitations of the current study. First, the relatively small sample size (n = 155) may decrease statistical power for the complex and numerous analyses included in the present study. Thus, it is important for future research to replicate the current findings. Second, the use of cross-sectional data does not allow us to draw a causal relationship of the mediation model. Future experiments that manipulate mindsets (e.g., Lou & Noels, 2016; Yeager et al., 2019) or longitudinal studies (e.g., Dai & Cromley, 2014) can be conducted to better understand whether promoting growth mindsets can explain the link between feedback-seeking and learning outcomes. Third, in addition to mindsets, future studies may include other motivational factors, such as the motivation to revise one's work, to better understand individual differences in feedback-seeking and performance. For example, it is possible that participants who are motivated to revise their work are more likely to seek critical feedback, which provides information that helps them revise their posters. Finally, the relation between mindset and learning outcomes may be influenced by individuals' generic or domain-specific type of mindset (Cutumisu & Lou, 2020).

Scientific Significance

Theoretical Implications

The findings indicate that performance and learning as measured by the post-test are distinct learning outcomes and they are driven by different learning mechanisms. Performance seems to be driven by critical feedback-seeking through revision, whereas learning seems to be driven by the combination of growth mindset and critical feedback-seeking. These findings provide important implications for understanding whether and how students learn graphic design principles and perform in an online assessment game that offers them learning choices (seeking

critical feedback and revising one's work). Additionally, the results enable us to understand how learning choices and individual differences interact to influence students' learning outcomes (performance and learning poster design principles). Critical feedback-seeking seems to be an important learning behavior that works differentially, through revision and growth mindset, respectively, to influence students' learning outcomes (performance and learning). This is in line with mindset theory, which suggests that individuals who endorse a growth mindset use mastery-oriented response patterns (Henderson & Dweck, 1990).

This study also provides more support for the conjecture that growth and fixed mindset constitute different mindset constructs, as their patterns of results differ, together with the participants' patterns of responses to critical feedback-seeking (Cutumisu, 2019a, 2019b). Specifically, although fixed and growth mindsets were correlated with each other moderately to strongly (r = .60), findings showed that only growth mindset moderated the link between critical feedback-seeking and learning. Students' fixed mindset, however, did not predict learning outcomes or moderate the link between learning choices and learning outcomes. Although some studies focus only on fixed mindset (e.g., Aronson, Fried, & Good, 2002; Hong, Chiu, Dweck, Lin, & Wan, 1999), our findings suggest that both fixed and growth mindsets are necessary to understand the mechanisms that link mindset to learning.

Moreover, the patterns of results differ between the one-factor and two-factor mindset models. Our results showed that the one-factor and two-factor models fit the data equally well. The lack of significant moderation found when mindset was considered as one factor, without differentiating between the fixed and growth mindset constructs, is not supported by the current mindset literature and it seems to provide more support for the two-factor model of mindset. Specifically, considering mindset as two distinct constructs may help to uncover relationships

that may have been missed when using a one-factor mindset construct. Much research suggests that growth and fixed mindsets are different constructs, as they have predicted different outcomes (e.g., Bråten & Strømsø, 2004; De Castella & Byrne, 2015; Diseth et al., 2014; Dupeyrat & Mariné, 2005; King, 2012; Lüftenegger & Chen, 2017). We further support this claim by showing that only growth mindset (but not fixed mindset or the mindset continuum) moderated the effect of critical feedback-seeking on learning. Therefore, separating fixed and growth mindsets can better contribute to this growing literature. Finally, another source of result discrepancy stems from the fact that many studies, in contrast with the present study, use self-reported data to measure non-mindset concepts (e.g., persistence, self-efficacy, etc.) and smaller sample sizes.

Practical Implications

The results suggest that revision needs to be emphasized through instruction or research interventions directed at enhancing students' learning. The results of the one-factor model suggest that mindset does not play an important role in students' learning choices or their learning outcomes resulting from their choices. However, suggestions emerging from considering the two-factor model include the development of learning and assessment environments that embed learning choices and that take into account learners' growth mindset to ensure that students improve their learning performance. The findings from the two-factor model suggest that growth mindset is the catalyst of the relation between critical feedback and learning. For instance, instructors may create feedback that is growth-mindset oriented, as it was also previously found that growth-oriented feedback leads to students' increased performance on a final exam (Cutts, Cutts, Draper, O'Donnell, & Saffrey, 2010). Importantly, although growth mindset is not correlated with learning choices nor learning outcomes, it seems to enhance the

effect of students' responses to their own learning choices (i.e., critical feedback-seeking) to improve learning. Therefore, when teachers encourage students to seek critical feedback and challenges, it is important to also encourage their students to believe in self-improvement and in learning from critique and challenges (Lou & Noels, 2020b; Yeager et al., 2019).

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Appendix A Supplementary Data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chb.2020.106445.

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