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Divergent effects of mindsets on performance trajectories

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Recent initiatives worldwide have promoted the "growth mindset" to improve educational outcomes. However, the effectiveness of this approach remains controversial. This research presents novel perspectives by investigating the natural effects of growth mindsets on students' academic performance trajectories from university entrance to completion. Longitudinal analyses involving 915 students, 6,918 student-term, and 33,607 student-course observations, reveal previously unexplored relationships. Transcending the dichotomized debate of whether growth mindsets are effective, our findings reveal that students with stronger growth mindsets initially outperform their fixed mindset counterparts; however, this advantage diminishes over time. Additionally, students with growth mindsets are more adept at navigating unfamiliar academic territories. Importantly, both growth and fixed mindsets are associated with higher academic achievement, but a lack of clear mindset is linked to poorer outcomes. Our study underscores the importance of considering these factors in educational institutions that aim to foster growth mindsets to enhance human capital development.

The "growth mindset" refers to the belief that people's abilities are malleable and can be improved[1,2]. Although significant resources have been devoted to developing a growth mindset through education and training[3], there have been controversies about whether the growth mindset merits such attention[4–7]. This research aims to provide additional insights into this debate by investigating the natural effects of mindsets on academic achievement. Specifically, it examines the effects of growth mindset on performance trajectory over four years of college education, explores its effects on performance in specialized (vs. non-specialized) areas of education, and verifies whether the belief in a growth mindset has a linear effect on performance as assumed in the growth mindset literature.

The growth mindset is often contrasted with a fixed mindset, which suggests that people are born with certain abilities that cannot be changed. The fixed and growth mindsets are conceptualized as opposite ends of a continuum, ranging from a relatively rigid and immutable view of personal attributes to a dynamic view of change[8,9]. The growth mindset is built on a model of achievement motivation[10–12]. Its premise is that fundamental beliefs about personal attributes can shape how individuals respond to challenges and setbacks[1,2]. With the belief that people can change and improve with effort, a growth (vs. fixed) mindset should motivate people to persist in tackling obstacles across different contexts[13–15]. Consistent with this notion, research has shown that a growth mindset could enhance the performance satisfaction and actual performance of at-risk high school students[16], facilitate the transition to high school[17], raise first-time college enrollment and increase first-year college grade[15], and enhance receptiveness toward self-paced learning in college[18]. The effects of the growth mindset have also been found in other achievement settings, such as confronting prejudice at work[19], negotiating with challenging counterparts[20], and promoting peace in the midst of conflicts[21].

Due to its potential positive impact on human capital development, the growth mindset has drawn significant attention. The popularization of the growth mindset coincides with the priority of policymakers worldwide in developing human capital through training and education[22]. Developing human capital not only increases productivity and economic growth, but also improves social well-being and equality[3,23,24]. This vision is reflected in the goals of the United Nations 2030 Agenda for Sustainable Development, which promotes quality education and lifelong learning opportunities. Such an emphasis is not surprising, as educational attainment, an important indicator of human capital development, contributes positively to job performance and provides society with a high-quality labor supply[25–28]. Indeed, many global initiatives that aim to develop human capital, such as the Global Insights Initiative (GINI) launched by the World Bank[3], have focused on promoting a "growth mindset" among students and educators.

Although interventions aiming to promote the growth mindset in educational settings have been implemented around the world (e.g., Chile[29],

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China[30], Finland[31], Germany[32], India[14], Indonesia[33], Peru[34], South Africa[35], the Netherlands[36], and the US[37]), there is a vigorous debate about its merits[4]. Indeed, some researchers have questioned whether growth mindsets have any effect on human capital[5,6], whereas others maintain that its effects exist but are heterogeneous; that is, the effects vary in magnitude depending on the social and economic conditions of the intervention settings[7]. These discussions can help advance science and lead us to reconsider the fundamentals upon which such global psychological interventions are built[4,38].

The debate regarding growth mindsets tends to focus exclusively on intervention effects. However, intervention effectiveness and robustness are often confounded with other factors, such as the availability of resources[38]. In this research, we ask a more fundamental question: Do mindsets matter to academic performance in the absence of interventions? Everyone brings a mindset to the table, but there is relatively scant evidence regarding the possible long-term effects of mindsets on developmental trajectories. Studies that examine the effects of mindsets in the absence of interventions tend to capture performance outcomes only at one time point, with a single performance indicator (e.g., a standardized test score)[8,30,39]. Longitudinal studies that examine performance trajectory often involve interventions and focus on change of a single performance indicator at an aggregate level (e.g., overall GPA) within a relatively short time frame (e.g., two years of junior high school[13]; two semesters in high school[16], first year in college[15]). Our study examines the effects of growth mindsets throughout an important life stage -- from initial university entrance to program completion and graduation. It also investigates performance outcomes at multiple levels (i.e., individual-level, term-level, and course-level) to assess the robustness of the effects.

In this study, we focus on three potential areas where mindsets could exert influence. First, the growth mindset framework posits that belief in the malleability (vs. fixedness) of ability should motivate individuals to take a knowledge mastery approach and to persist. Thus, we examined whether growth mindsets are associated with better overall academic performance and improvements in performance over time as individuals progress across the four years of their university education. Second, the growth mindset framework argues that the effects of mindsets should be more pronounced when facing challenges[4]. Since taking classes in subject areas outside of (vs. within) one's expertise specialization would be more challenging, as it involves unfamiliar (vs. familiar) subject areas, we examined the relationship between mindsets and performance in specialized (i.e., major) versus non-specialized (i.e., non-major) areas. Third, the growth mindset and fixed mindset are conceptualized as opposite ends of a continuum[8,9]. Accordingly, training and interventions based on the growth mindset framework aspire to increase endorsement of beliefs in growth and change, because such beliefs are argued to be more conducive to performance. An implicit tenet in such growth mindset interventions is that there is a linear and positive association of growth mindsets with performance: That is, the stronger the beliefs in a growth mindset, the better the performance outcome would be. Therefore, a typical intervention aims to increase the endorsement of growth and change, such that those who weakly endorse these beliefs would show a relatively stronger endorsement, and those with a priori moderate beliefs would correspondingly shift further along the continuum. This linear assumption is central to the effectiveness of growth mindset interventions, but it has not been verified or challenged empirically. Therefore, we explore the linearity (or non-linearity) of the effect of growth mindsets on performance.

In sum, this research investigates the natural effects of mindsets on academic performance at university as measured by: (a) cumulative grade point averages and the trajectory of this performance across terms during the four years, (b) performance in specialized (vs. non-specialized) areas, and (c) whether the strength of belief in a growth mindset has a (non)linear effect on performance. This study consists of 915 students who consented to participate and completed the growth mindset measure[1,40] as part of an introductory orientation exercise. The final study includes 6918 student-terms and 33,607 student-courses. The growth mindset measure is scored such that a higher score indicates a stronger belief in change. Each of the four academic years consists of two main terms (Fall and Spring). Performance was assessed in terms of the Final Cumulative Grade Point Average (Final CGA), the Term Grade Point Average (Term GPA), and the course grade.

Results

Summary statistics for the key variables are presented in Supplementary Table 1.

Growth mindset and performance over time

As an initial test, we regressed students' final CGAs (i.e., upon graduation) on mindset, controlling for gender and intake cohort. Note that the growth mindset was measured and analyzed as a continuous variable. For ease of discussion, we refer to the relatively stronger [and weaker] endorsement of growth mindset as growth (+ 1 *SD*) [and fixed (-1*SD*)] mindsets. Overall, as shown in Table 1 and consistent with the canonical growth mindset predictions, students who endorsed stronger growth mindsets did indeed show better performance overall (Final CGA: $B = 0.023$, $SE = 0.013$, $p = 0.086$; Column 1). Furthermore, growth mindset was also positively associated with their performance at the term level (Term GPA: $B = 0.023$, $SE = 0.006$, $p < 0.001$; Column 2). This reflects a difference in Term GPA of 0.023 points per scale unit on the mindset measure.

Additionally, there was a quadratic effect of term over time ($B = -0.006$, $SE = 0.001$, $p < 0.001$; Column 3), such that students' grades generally increased from term to term, but leveled out towards the latter part of their university journeys. Interestingly, this quadratic effect of term had a significant interaction with growth mindset ($B = -0.003$, $SE = 0.001$, $p = 0.029$; Column 4), which held even after controlling for gender and cohort (Column 5). The negative coefficient of $Mindset_i \times Term_{it}^2$ implies that the concavity is greater for students with a stronger growth mindset. Our main specification is:

$$TermGPA_{it} = Term_{it} + Term_{it}^2 + Mindset_i + Mindset_i \times Term_{it} + Mindset_i \times Term_{it}^2 + Gender_i + \eta_i + e_{it}$$

Figure 1 visually presents the results. Each line reflects the predicted Term GPA for each Term. The red line represents the predicted Term GPA with a growth mindset, and the blue line represents the predicted Term GPA with a fixed mindset. The upper and lower bounds represent the 95% confidence intervals for each line. As shown in Fig. 1, the quadratic effect was both visually and statistically stronger for those with a growth mindset ($B = -0.008$, $SE = 0.002$, $p < 0.001$; Column 6), but weaker for those with a fixed mindset ($B = -0.003$, $SE = 0.002$, $p = 0.047$; Column 7). These estimated quadratic relationships are inverted U-shaped (i.e., negative coefficient on Term Squared). Assuming the same starting point, this suggests that students with growth mindsets outperform those with fixed mindsets in earlier terms, but the difference decreases over time in the later terms. The 95% confidence interval of the estimates of fixed and growth mindsets in Fig. 1 is shown in Supplementary Table 2. These statistics show that students with growth mindsets did not show significantly different performance compared with fixed mindsets in Term 1. The differences in performance started to emerge in Term 2. Specifically, those with growth mindsets started outperforming those with fixed mindsets. The difference became statistically significant from Term 3, was greatest in Term 4, and became weaker from Terms 5 and 6. Eventually, the performance of those with growth and fixed mindsets became statistically indistinguishable from Term 7 and converged at the end of their academic journey. We control for the differences in the courses (i.e., modules) that students take using course fixed effects, and the analyses at the course grade level showed similar interaction effects between mindset and the quadratic effect of term ($B = -0.003$, $SE = 0.001$, $p < 0.001$; Column 8). That is, the result is qualitatively unchanged after controlling for course fixed effects. The full results for course level analyses are shown in Supplementary Table 3.

The effect of $Mindset_i \times Term_{it}^2$ on academic performance is robust. It holds regardless of whether it is tested at the term level (Term GPA; Table 1) or course level (Course Grade; Supplementary Table 3), and regardless of whether gender and intake year are controlled for.

Table 1 | The effects of growth mindset on performance at individual level (Final CGA), term level (Term GPA), and course level (Course Grade)

Model:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Final CGA	Term GPA						Course Grade
Variables		Mean Centered				Growth Centered (+1 SD)	Fixed Centered (−1 SD)	
Term		0.040***	0.097***	0.098***	0.094***	0.115***	0.073***	0.041***
		(0.003)	(0.011)	(0.011)	(0.011)	(0.016)	(0.016)	(0.013)
Term Squared			−0.006***	−0.006***	−0.006***	−0.008***	−0.003**	−0.003***
			(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)
Mindset	0.023*	0.023***	0.023***	−0.004	−0.007	−0.007	−0.007	−0.011
	(0.013)	(0.006)	(0.006)	(0.023)	(0.023)	(0.023)	(0.023)	(0.014)
Mindset*Term				0.021*	0.021*	0.021*	0.021*	0.022***
				(0.011)	(0.011)	(0.011)	(0.011)	(0.007)
Mindset*Term Squared				−0.003**	−0.003**	−0.003**	−0.003**	−0.003***
				(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Gender (0=female, 1=male)	−0.081***				−0.088***	−0.088***	−0.088***	−0.087***
	(0.027)				(0.013)	(0.013)	(0.013)	(0.008)
Intake (0=Cohort 1, 1=Cohort 2)	0.028				0.038***	0.038***	0.038***	0.040***
	(0.027)				(0.013)	(0.013)	(0.013)	(0.008)
Constant	3.039***	2.820***	2.721***	2.720***	2.745***	2.738***	2.752***	2.907***
	(0.021)	(0.013)	(0.023)	(0.023)	(0.024)	(0.033)	(0.033)	(0.030)
Course fixed effect	-	-	-	-	-	-	-	Yes
Observations	915	6918	6918	6918	6918	6918	6918	33,519
R-squared	0.015	0.034	0.038	0.039	0.047	0.047	0.047	0.118

When controlling for course fixed effect, those with only one observation within a fixed effect group are dropped.
Note: Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level (two-sided) respectively.

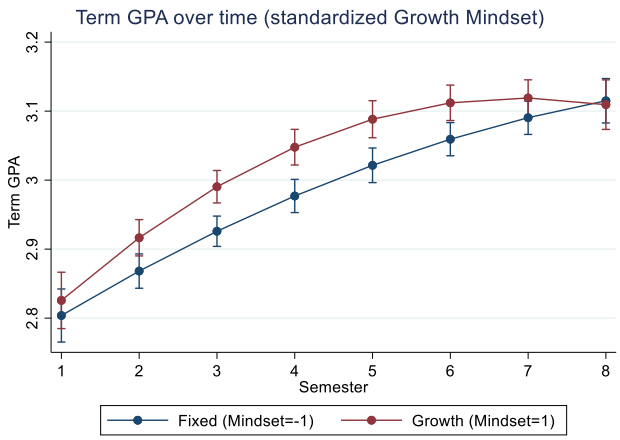

Fig. 1 | Predicted term GPA by growth mindset and term. This figure depicts the predicted term GPA by growth mindset and term. The regression model used is $Term\ GPA_{it} = Term_{it} + Term_{it}^2 + Mindset_i + Mindset_i \times Term_{it} + Mindset_i \times Term_{it}^2 + Gender_i + \eta_i + e_{it}$. Red line stands for the predicted term GPA with growth mindset ($Mindset_i = +1S.D.$), and blue line stands for the predicted term GPA with fixed mindset ($Mindset_i = -1S.D.$). The figure also shows 95% confidence intervals for each line.

Furthermore, for the course level analyses, the effect also holds with or without controlling for course fixed effects (Supplementary Table 3, Columns 3 to 6).

Growth mindset and expertise specialization

Our study does not include a direct measure of the subjective experience of challenges. However, we do have data that enable us to examine the relationship between mindsets and performance in specialized (i.e., major) versus non-specialized (i.e., non-major) areas. Specifically, students holding a growth mindset should perform better in courses outside of their specialized disciplinary majors, which tend to be more challenging as they are less familiar with the area. To test this intuition, we investigated whether the impact of mindset differed by course subject, depending on whether the subject fell within or outside of the students' area of specialization (i.e., major vs. non-major courses). In these analyses, we use course performance data and test the following specification:

$$Course\ Grade_{ijt} = Mindset_i + Gender_i + \eta_i + \theta_j + e_{ijt}$$

where η_i is the intake year fixed effect and θ_j is the course fixed effect.

As shown in Table 2, growth mindset was positively associated with academic performance on average ($B = 0.022$, $SE = 0.004$, $p < 0.001$; Column 1). More importantly, the impact was driven by courses outside of a student's major specialization ($B = 0.029$, $SE = 0.005$, $p < 0.001$; Column 2). For courses in their home discipline, there was no significant relationship between growth mindset and performance ($B = -0.005$, $SE = 0.009$, $p = 0.575$; Column 3). These results hold after controlling for course fixed effects (Columns 4 to 6).

Linearity of the Effect of Mindsets on Performance. Psychological interventions have focused on shifting individuals from a relatively fixed to a relatively growth mindset along a continuum, assuming that any increase from a more fixed mindset to a more growth mindset would be beneficial. Our data allow us to directly test this assumed positive linear association between growth mindset and performance. We regressed students' Final CGA on mindset and the squared term of mindset controlling for gender

Table 2 | Impact of growth mindset on course performance by subject

	(1)	(2)	(3)	(4)	(5)	(6)
				Course Grade		
Variables	All	Non-major courses	Major courses	All	Non-major courses	Major courses
Mindset	0.022***	0.029***	−0.005	0.019***	0.027***	-0.006
	(0.004)	(0.005)	(0.009)	(0.004)	(0.005)	(0.008)
Gender (0=female, 1=male)	−0.091***	−0.093***	−0.080***	−0.086***	−0.086***	−0.092***
	(0.009)	(0.010)	(0.017)	(0.008)	(0.009)	(0.017)
Intake (0=Cohort 1, 1=Cohort 2)	0.046***	0.050***	0.031*	0.041***	0.048***	0.014
	(0.008)	(0.010)	(0.017)	(0.008)	(0.009)	(0.017)
Constant	3.011***	3.007***	3.025***	3.010***	3.003***	3.038***
	(0.007)	(0.008)	(0.013)	(0.006)	(0.007)	(0.013)
Course Fixed Effect	No	No	No	Yes	Yes	Yes
Observations	33,607	26,619	6988	33,519	26,530	6976
R-squared	0.005	0.006	0.004	0.117	0.139	0.087

When controlling for course fixed effect, those with only one observation within a fixed effect group are dropped.
Note: Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% level (two-sided) respectively.

Table 3 | The non-linear effects of growth mindset on performance at individual level (Final CGA), term level (Term GPA), and course level (Course Grade)

Model:	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Final CGA			Term GPA		Course Grade
Mindset	0.022*	0.022***	0.023***	0.023***	0.020***	0.020***
	(0.013)	(0.006)	(0.006)	(0.006)	(0.006)	(0.004)
Mindset Squared	0.019*	0.015***	0.016***	0.015***	0.017***	0.016***
	(0.010)	(0.005)	(0.005)	(0.005)	(0.005)	(0.003)
Semester			0.040***	0.097***	0.093***	0.040***
			(0.003)	(0.011)	(0.011)	(0.013)
Semester Squared				−0.006***	−0.006***	−0.003**
				(0.001)	(0.001)	(0.001)
Gender (0=female, 1=male)	−0.084***				−0.091***	−0.090***
	(0.027)				(0.013)	(0.008)
Intake (0=Cohort 1, 1=Cohort 2)	0.026				0.036***	0.039***
	(0.027)				(0.013)	(0.008)
Constant	3.022***	2.985***	2.805***	2.706***	2.731***	2.893***
	(0.023)	(0.008)	(0.014)	(0.024)	(0.024)	(0.030)
Course fixed effect	-	-	-	-	-	Yes
Observations	915	6918	6918	6918	6918	33,519
R-squared	0.019	0.003	0.036	0.039	0.048	0.118

When controlling for course fixed effect, those with only one observation within a fixed effect group are dropped.
Note: Standard errors are reported in parentheses. ***, **, and * denotes significance at the 1%, 5%, and 10% level (two-sided) respectively.

and intake cohort. Our main specification is:

$$FinalCGA_{it} = Mindset_i + Mindset_i^2 + Term_{it} + Term_{it}^2 + Gender_i + \eta_i + e_{it}$$

Interestingly, the results (Table 3) are both consistent and inconsistent with the growth mindset framework. Consistent with the framework, as evidenced by the main effect of mindset ($B = 0.022$, $SE = 0.013$, $p = 0.089$; Column 1), students holding growth mindsets did indeed perform better than those with fixed mindsets. However, there is a U-shaped relationship between mindset and academic performance, as indicated by the positive coefficient of the mindset squared term ($B = 0.019$, $SE = 0.010$, $p = 0.061$; Column 1). The standardized estimated vertex is located around −0.586, slightly left of the mean. In other words, the vertex is located at 3.084 (3.695–0.586*1.042) on the raw growth mindset measure ($M = 3.695$; SD = 1.042). This U-shaped effect suggests that a stronger growth mindset was not necessarily associated with more positive performance outcomes. Not only is the effect of mindset nonlinear, it is also non-monotonic. Specifically, students with the strongest fixed mindset performed better than those who were moderate in their beliefs.

Using Term GPA instead of Final CGA shows qualitatively similar patterns. As shown in Table 3, Columns (2) to (5), there was a U-shaped relationship between mindset and students' academic performance. The results consistently showed statistically positive coefficients on the growth mindset squared term with or without controls ($B = 0.015$, $SE = 0.005$, $p = 0.002$, Column 2; $B = 0.016$, $SE = 0.005$, $p = 0.002$, Column 3; $B = 0.015$, $SE = 0.005$, $p = 0.002$, Column 4; $B = 0.017$, $SE = 0.005$, $p = 0.001$, Column 5). The estimated vertex is also located slightly left of the mean (standardized

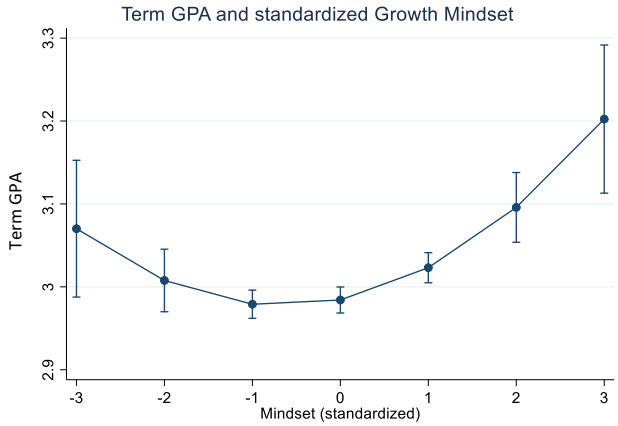

Fig. 2 | Predicted term GPA by growth mindset. This figure depicts the predicted term GPA by growth mindset. The regression model used is: $TermGPA_{it} = Mindset_i + Mindset_i^2 + Term_{it} + Term_{it}^2 + Gender_i + \eta_i + e_{it}$, The figure also shows 95% confidence intervals.

estimated vertices = −0.723, −0.753, −0.744, and −0.592, respectively for models in Columns 2 to 5).

Figure 2 visually presents the results based on the specification of Column 5 in Table 3. The U-shaped relationship is clearly depicted. The x-axis shows the standardized score of Mindset, from more fixed (−3) to more growth (+ 3). The y-axis represents the Term GPA. The line represents the predicted Term GPA at varying levels of mindset. The figure shows that those with a slightly fixed mindset (i.e., −1 on the mindset axis) show the lowest Term GPAs, whereas those with stronger growth mindset (i.e., +3) and stronger fixed mindset (i.e., −3) show higher Term GPAs. This implies that students with the most growth and the most fixed mindsets outperform those with neutral or slightly fixed (and even slightly growth) mindsets. This U-shaped relationship remains statistically significant even at the course level after controlling for course fixed effects ($B = 0.016$, $SE = 0.003$, $p < 0.001$, Column 6; estimated vertex = −0.604).

Discussion

Much effort has been directed towards understanding the personal characteristics that influence academic achievement[41,42]. This is because educational attainment is an important indicator of human capital development that can contribute to a high-quality labor supply[25–28]. The field has observed that as job demands shift from task-oriented competencies to those requiring both task-specific knowledge and social coordination skills, the influence of psychological factors on achievement has grown[43,44]. The growth mindset has emerged as one such factor, drawing significant attention due to its potential positive impact on human capital development.

The current research investigates how the mindsets students bring with them influence their academic achievement as they progress in their university education. Taking into consideration time, coursework specialization, and the nonlinear association between mindset and performance, our findings reveal important missing pieces in the growth mindset discourse. Growth mindsets have shown some potential in supporting the development of human capital through shaping achievement motivations; however, there are important boundary conditions that need to be considered. Results from the longitudinal analyses and expertise specialization analyses indicate that students who strongly believe in either the growth or the fixed mindset can both flourish in their own unique ways.

The longitudinal analyses reveal unexplored relationships between growth mindset and performance. Although students had similar starting points, the performance of those holding a growth mindset progressed more quickly and then flattened. Those with fixed mindsets tended to show slower initial acceleration; however, they became on par with those espousing growth mindsets toward the end of their education journey, ultimately leveling the playing field. That is, having growth mindsets seemed to matter more at initial life transition stage, but mattered less as time progressed. In retrospect, most of the longitudinal studies that examined the impacts of growth mindset tended to focus on a relatively short time frame that ranged from one to two years[13,16,39]. This means that depending on the specific time point the impacts were assessed, growth mindset does or does not appear to matter, contributing to the heterogeneity of the effects[4–7].

Why might students with different mindsets follow such different trajectories? One possibility is that people with a growth mindset tend to adjust more quickly in the face of challenges than those with a fixed mindset. The beginning of one's university career corresponds to a time featuring many challenges that arise from transitioning from high school to university. In addition, students in the specific academic program under consideration are exposed to different disciplines during the initial terms. They choose their "home" disciplines (i.e., majors) after three terms, and focus on the chosen majors during their later university years. This suggests that when the students needed to manage life transitions and handle subject areas that they were not familiar with, growth mindsets smoothened the adjustment process. Growth mindsets enabled the students to excel more quickly compared with fixed mindsets. However, evidently the benefit of having a growth mindset dissipated after students had settled in.

The expertise specialization analyses provide some support for this interpretation. The results reveal that the growth mindset was positively associated with academic performance on average. Such an effect was driven by courses outside of a student's major specialization. For courses in their home discipline, there was no significant relationship between growth mindset and performance. This suggests that individuals with a growth mindset are more comfortable exploring unfamiliar territories. Such an observation is consistent with recent findings that people with growth mindsets prefer diverse experiences that enrich their breadth of knowledge, whereas those with fixed mindsets are drawn to knowledge that refines their understanding in a given area to enrich their knowledge depth[45]. One potential implication of this finding is that students might benefit from having a growth mindset in emerging interdisciplinary areas that require open exploration (e.g., sustainability), but the benefit of a growth mindset might be less apparent for traditional disciplines that focus on technical skills and depth of understanding.

The putative benefits of having a growth mindset depend on the moment in time or the domain over which performance is assessed. Our findings revealed that both growth and fixed mindsets can flourish in their own way (domain specialization) and at their own pace (time). One might ask: Does the growth mindset matter to human capital development after all? On one hand, it might appear as if mindsets do not matter, as everyone could thrive in their own way regardless of their mindsets. On the other hand, the early performance benefit of growth mindsets may be fairly consequential. Higher performance at early stages of an academic pathway might present positive first impressions and open doors of opportunity[46], which often translates into meaningful effects on human capital. For instance, higher grades at an earlier stage of a developmental trajectory do improve career advancement opportunities due to better internship placements, more international exchange opportunities, a higher chance of receiving scholarships, and positive effects on self-esteem and well-being[47–49]. Whether the growth mindset merits the attention and resources it has drawn[4,5,38,50] might depend on the developmental time point that one focuses on and the value one puts on having a developmental head start that might help secure resources. Future theoretical and empirical work on growth mindsets should take the time dimension into consideration.

Our exploration regarding the linearity and nonlinearity of the growth mindset effects also merits attention. Implicit in promoting the growth mindset is the idea that a growth mindset would have a linear and positive association with performance. That is, increasing strength of belief in growth mindsets should be associated with better performance. The results reveal that the relationship between growth mindset and performance is not only nonlinear but also non-monotonic. These findings raise three concerns: First, the growth mindset literature has assumed a positive linear relationship between mindset and performance. It has focused on comparing

growth with fixed mindsets. Such discussions have neglected the majority who are moderate in their beliefs. In our study, 62.62% of the students fall between +/− 1 scale point of the vertex. Our findings reveal that it is exactly this neglected majority that might deserve more attention as they are the ones with the poorest performance regardless of whether performance is assessed at the individual level, term level, or course level. Neglecting the underperforming majority can be consequential to human capital development. Future theoretical and empirical work should consider factors that might contribute to the poorer performance among those with such moderate mindsets. Could their performance reflect their lack of motivation in exploring the unknown (i.e., growth mindset), or in having an in-depth understanding of the known (i.e., fixed mindset), or both? Could the moderate mindsets reflect a sense of uncertainty about what they would like to achieve, or do they simply care less about achieving? These questions merit further investigations.

Second, psychological interventions have focused on shifting individuals from a relatively fixed mindset to a relatively growth mindset along a continuum. Presumably, those who endorsed beliefs in growth beyond the moderate point (vertex) might have benefited from embracing a stronger growth mindset, as having a stronger belief in growth is associated with more positive performance. However, this may be counter-productive for those who strongly embraced a fixed mindset to begin with. Encouraging such individuals to embrace a more growth mindset might well have moved them into the trough, thereby ironically undermining their performance. Indeed, there could be variations in the extent to which individuals in different communities believe in growth and change due to structural and social constraints in their societies[14,51,52]. For communities in which there are high structural constraints, individuals' sense of growth and change might be limited to begin with. Promoting a sense of growth in these communities might inadvertently shift individuals into the trough and lead to worse performance. Future work on mindsets should carefully assess this linearity assumption and consider how the same interventions might work for some but potentially backfire for others.

Third, similar to most studies in the literature, the primary focus of this study is on performance in curricular pursuits. Arguably, mindsets could have significant impacts beyond academic performance[30,53]. For instance, a large-scale global study called the Programme for International Student Assessment (PISA), conducted by the Organisation for Economic Co-operation and Development (OECD) among students[54], found that growth mindsets are positively associated with beliefs in one's own ability to perform and accomplishing challenging tasks, and negatively associated with the fear of failure. The higher sense of competence and the lower fear of failure can potentially be translated into a more resilient and adaptive workforce in times of change[4]. By focusing on the growth (vs. fixed) mindsets dichotomy, is it possible that existing studies might have overlooked the psychological health and resilience of a majority holding a moderate mindset? Future work should consider the potential nonlinearity of mindset effects in developing a more resilient workforce.

This study reveals previously unexplored relationships between mindsets and performance. It points to potential directions for future work, but it has limitations just like other studies. For example, although the sample is quite diverse and the data are longitudinal, it is a single-site study. Hence, while it contributes to the literature in unique ways, the generalizability of the findings across different regions with different educational systems and institutional practices need to be examined further. To advance the science of learning, generalizability of any research findings should not be assumed, but should be tested regardless of whether the study is conducted among the 5% of the population that has been well-researched[55,56] (mostly American), or among the neglected 95% in the majority world[57]. Evaluating the generalizability of the findings can help identify potential boundary conditions that can inform theory and practices.

To conclude, a famous parable talks about five blind people trying to form an impression of an elephant by touching and describing it. One touched its tail and described it as thin and pliable, like a rope. One touched its tusk and described it as hard and sharp, like a spear. They were both telling the truth based on their subjective experiences without being aware of the limitations in their perspectives. One version of the parable depicts how the disagreement brews distrust among people, leading them to think that the others were not telling the truth. Another version notes that by listening to each other and recognizing the different viewpoints, the people worked together to pool their knowledge so that they could see a fuller picture. By taking time dimensions, expertise specialization, and (non)linearity into consideration, our study provides initial evidence to help reconcile the heated debate about whether growth mindsets are meaningful to human capital development. Our findings present a bigger picture of how specific mindsets might help but might also hurt. Psychological research in general and psychological intervention research in particular are in a process of continuous exploration and evolution. These results suggest that more work is still needed to understand when and how different psychological attributes contribute to developing human capital. They caution against one size fits all propositions that ignore underlying heterogeneity.

Methods

Participants

The sample consisted of two cohorts of students ($N = 915$; $N_{Cohort\ 1} = 517$; $N_{Cohort\ 2} = 398$; Age at intake: M = 18.20, SD = 0.559; 59.8% female) at a major Asian university over the four years from when they first joined the university to when they graduated. Our data set includes students admitted to the university's business school through the standard admissions process for a four-year (i.e., eight-term) undergraduate program. The study was approved by the Human Participants Research Panel of the Hong Kong University of Science and Technology (Protocol #221). Students who consented to take part in the study and completed an intake exercise were included in the sample. These students belonged to admission cohorts in two consecutive years. Students in the first intake year were denoted as Cohort 1, and those in the next intake year were denoted as Cohort 2. The sample consists of students from 18 different regions: 76.8% from the Hong Kong SAR, 8.5% from Mainland China, 3.8% from India, 3.2% from Indonesia, 2.1% from South Korea, and the remaining 5.6% from other regions such as Canada, Chile, France, Italy, Japan, Kazakhstan, Malaysia, Philippines, Singapore, Sweden, Taiwan, Thailand, and the US. The demographic is representative of the student population in the institution, which is relatively culturally diverse. The students were admitted without a specialization (i.e., major). They were required to choose a major by the end of their third term after taking required courses (i.e., modules) across business disciplines. They then specialized in their chosen major and took the required major courses in the subsequent terms. Our final data set includes 915 students, with 6918 student-terms and 33,607 student-courses. We excluded 80 students who were still active in the program and 29 students who had discontinued from the program at the time of data collection.

Measures

Mindset. We assessed growth mindset using an existing 3-item measure[1] that captures the extent to which individuals believe that their personal attributes can be changed or not. A sample item is, "Your intelligence is something about you that you can't change very much." This item was used in the Programme for International Student Assessment (PISA) study conducted by the Organisation for Economic Co-operation and Development (OECD) to assess growth mindset across countries[50]. Following established convention[1,8] the students in our study responded to the measure using a 6-point scale anchored at 1=Strongly Disagree and 6=Strongly Agree. The items were reverse-scored such that a higher score means a stronger endorsement of the belief in change, $\alpha = 0.861$.

Students completed the measure at the beginning of their first term as part of an introductory orientation exercise that helped them reflect on their learning goals and make plans for the coming years. The growth mindset

was normally distributed among students (M = 3.695, SD = 1.042). This distribution is similar to the distributions observed in other populations[13,58].

Term. Term indicates the calendar order of the two main terms (Fall and Spring) for a student. We excluded the Winter and Summer terms as they are not regular academic terms and few students opt for taking classes during these non-regular terms, which last approximately four weeks each. Most students (735, 80.3%) finished their program within eight terms. There were 114 (12.46%), 61 (6.67%), and 5 (0.55%) students who finished in 9, 10, and 11 terms respectively, due to factors such as military service, internships, etc.

Performance. Performance was assessed in terms of the Final CGA, Term GPA, and the course grade (i.e., grades in individual modules). Students in the university receive letter grades on a scale ranging from A+ to F. The university has an official numerical equivalent for each grade (e.g., A + = 4.3, A = 4.0, etc.), based on which the Registrar's Office aggregates letter grades from individual courses (modules) into a grade point average (GPA). All students have their GPA computed centrally on a term basis (Term GPA) and reported on their official transcripts. Simultaneously, a running cumulative grade average (CGA) is computed based on all courses (modules) the student has taken and is also reported on the transcript. Importantly, the university has detailed guidelines in place to limit grade inflation.

To assess students' performance within and outside of their area of specialization, we computed their grade point averages across major and non-major courses (modules) separately. The distributions of course grades for the major subjects and the non-major subjects were similar, which may be explained in part by the guidelines to restrict grade inflation.

Controls. We included three control variables: 1) Gender (0 = female, 1 = male), 2) Intake Year (0 = Cohort 1, 1 = Cohort 2), and 3) Course Fixed Effect to control for course characteristics. There were 592 unique courses (modules) in the final sample.

Data availability

The data can be downloaded from https://osf.io/5p3xn/?view_only=15046177faad4d4d992db76a293045b2.

Code availability

Codes are available in the supplementary document.

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Author contributions

M.M.C. and A.M. conceptualized the study. M.M.C., A.H.H., A.M., and J.S. designed the study. J.S. analyzed the data. M.M.C. and J.S. drafted the first version of the manuscript. All authors worked on the manuscript revision. All authors have read and approved the submission.

Competing interests

The authors declare no competing interests.

Additional information

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