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RESEARCH ARTICLE

The effects of language learning and math mindsets on academic success in an engineering program

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Abstract

Background: Mindsets are based on two basic assumptions: some people think that their intellectual abilities can be developed through hard work and instruction (i.e., a growth mindset), whereas others believe that nothing can change their level of intellectual ability (i.e., a fixed mindset). The association between mindsets and academic achievement has been examined in different academic subjects, such as biology and math. However, no previous study has examined the effects of language learning mindsets (LLMs) and math mindsets (MMs) on academic success in an English medium instruction (EMI) setting in which English, rather than the first language of the students, is used for teaching content (e.g., mechatronics engineering).

Purpose/Hypothesis: This study explores the relationship between Turkish mechatronics engineering undergraduate students' domain-specific mindsets, LLMs and MMs, and their academic success.

Design/Method: Student test scores for English medium and first-language medium courses were collected from fourth-year students studying mechatronics engineering ($n = 68$) at a public university in Turkey. Students also completed the LLM and MM inventories.

Results: Regression analyses revealed that growth LLM and MM were positive predictors of EMI and Turkish medium of instruction (TMI) academic success, whereas fixed LLM and MM were negative predictors of EMI and TMI academic success.

Conclusions: In both EMI and TMI courses, a growth mindset in math and language learning can profoundly predict students' academic achievement in a mechatronics engineering program. We argue that domain-specific mindsets can effectively explain the self-theories of intelligence and achievement.

KEYWORDS

academic achievement, engineering, English medium of instruction, higher education, language learning mindsets, math learning mindsets

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1 | INTRODUCTION

Engineering is considered to be a difficult field, and cognitive abilities are necessary to be successful; however, the non-cognitive characteristics of students, defined as “behaviours, skills, attitudes, and strategies crucial to students' academic performance and persistence” (Nagaoka et al., 2013, p. 46), are also critical for success. For instance, when cognitive measures are controlled for, non-cognitive measures, such as confidence in math and science and classroom engagement, can determine engineering students' persistence in the field (Sheppard et al., 2010). Although non-cognitive factors, such as student's sense of belonging, assessment of personal attributes, subject-matter confidence, and self-efficacy, among others, have been investigated thoroughly in the field of engineering education (Al-Sheeb et al., 2019; Burtner, 2005; Loo & Choy, 2013), the previous literature on these factors is limited regarding English-taught engineering programs (Macaro et al., 2018). A critical non-cognitive factor that determines persistence and success in the field of engineering is mindsets (Heyman et al., 2002; Lottero-Perdue & Lachapelle, 2020), which are people's dispositions toward the belief that intelligence is either fixed or subject to change (Dweck, 1999; Dweck, 2006). However, to our knowledge, mindsets have not been investigated in English-taught engineering programs.

English medium instruction (EMI), in this study, is defined as “the use of the English language to teach academic subjects other than English itself in countries or jurisdictions where the first language of the majority of the population is not English” (Macaro, 2018, p. 19). Pecorari and Malmström (2018) argued that in EMI learning situations, “language development is not a primary intended outcome” (p. 499). While some scholars agree (Aguilar, 2017; Paulsrud, 2014), students still expect a dual focus in EMI programs (i.e., to learn both content and English simultaneously; Galloway & Ruegg, 2020). This implies that both content and language are at stake when studying through EMI. Previous research has investigated whether this expectation can be fulfilled in terms of the development of language (Lei & Hu, 2014; Yang, 2015; Yuksel, Soruç, et al., 2021) and content (Dafouz et al., 2014; Hernandez-Nanclares & Jimenez-Munoz, 2017).

Engineering students in EMI programs have the onus to perform well in both English and content courses because English is used as the medium of instruction to deliver content (Macaro, 2018). Mathematics is central to engineering (Harris et al., 2014; Scanlan, 1985), and mathematical knowledge plays a substantial role in the engineering curriculum (Harris et al., 2014). Even though engineering programs attract students with an interest in designing, constructing, and developing machines, they require a basic mathematical foundation before delving into real-world problems (Rooch et al., 2016). The significance of these two areas (i.e., English and math) in EMI engineering programs motivated us to examine the impact of two domain-specific mindsets, language learning mindsets (LLMs), and math mindsets (MMs), on academic success in English-taught and first-language mediums of instruction (i.e., Turkish Medium of Instruction, TMI) courses for undergraduate engineering students.

2 | LITERATURE REVIEW

2.1 | Mindsets in engineering education

Engineering educators are expected to prepare persistent, lifelong learners who find creative solutions to societal issues (National Academy of Engineering, 2005). Concerned with lower graduation rates and larger achievement gaps compared to other majors, engineering educators and researchers pursue possible ways to improve students' academic success (Stump et al., 2014). Beliefs about intelligence have been identified as key components linked to persistence, effort, achievement, and, eventually, becoming lifelong learners (Blackwell et al., 2007). Growth and fixed mindsets have also attracted the attention of researchers in engineering education. For example, Heyman et al. (2002) reported that students who drop out of a difficult course in an engineering program are more likely to have a fixed mindset about engineering aptitude. In another study, Alpay and Ireson (2006) investigated the relationships between growth and fixed mindsets, views on group work/learning, and the creativity of undergraduate chemical engineering students at a UK university. Their results revealed that a growth mindset was correlated with improved creativity and the ability to participate in group work.

Creating and implementing the engineering mindset for the first time, Lottero-Perdue and Lachapelle (2020) modified Dweck's (1999) inventory of general mindsets. They used the engineering mindset inventory with fifth graders in an elementary school setting. Their findings revealed that a general growth mindset was a strong predictor of a growth engineering mindset, which they defined as a disposition toward obtaining engineering skills and becoming a successful engineer. Lottero-Perdue and Lachapelle (2020) emphasized that adopting a growth engineering mindset is crucial to being productive in engineering design.

A couple of studies did not find significant associations between mindsets and achievement in engineering. For example, Magno (2012) explored how individuals' orientations toward growth and fixed mindsets affect their achievement goal orientation and academic achievement among engineering students in Manila, Philippines. They found that neither type of mindset significantly predicted academic achievement. Stump et al. (2014) also examined the relationship between fixed and growth mindsets and the academic achievement of engineering students. Their findings revealed that neither mindset type predicted participants' academic attainment.

Another research area focused on developing growth mindsets among engineering students through interventions (see Campbell et al. (2021) for a systematic review). For the method of intervention, readings (Broda et al., 2018; Dringenberg & Kramer, 2019), videos (Frary, 2018; Robinson, 2019), lectures (Dringenberg & Kramer, 2019; Simon et al., 2008), and interactions with tutors (Choi, 2018; Schubert, 2017) were used. The results of the systematic review revealed that growth mindsets could be developed in engineering students. However, some interventions, such as interactions with tutors, were more effective than others, such as readings. Reid and Ferguson (2014) examined whether design experiences in the field of engineering helped students build a growth mindset. Their findings revealed that introducing open-ended problems positively impacted mindset changes among engineering students.

All of the studies in the field of engineering used a measure of general mindsets (a notable exception is Lottero-Perdue and Lachapelle (2020)) instead of domain-specific mindsets. This study uses two mindset inventories, LLM and MM, considering the medium of instruction (i.e., English) in the courses and the significance of mathematical knowledge in engineering programs (Harris et al., 2014). It has been argued that domain-specific beliefs can be better predictors of goals, attributions, and academic performance in engineering programs compared to general beliefs (Lottero-Perdue & Lachapelle, 2020). Engineering is viewed as “the application of mathematics and sciences to the building and design of projects for the use of society” (Kirschenman & Brenner, 2010, p. 54). Therefore, MMs have crucial functions in engineering success. In addition to mathematics, LLMs are also critical, as they determine students' success in English, which influences their content learning. Therefore, these domain-specific mindsets are used in this study to better conceptualize our participants' theories of intelligence and to examine the relationship between mindsets and academic success. We also acknowledge that there might be other domain-specific mindsets, such as the engineering mindset used by Lottero-Perdue and Lachapelle (2020) that should be considered in future studies.

2.2 | Mindset theory

Mindset theory was first proposed and developed by Dweck and her colleagues (Dweck, 1999, 2006; Dweck & Leggett, 1988; Muller & Dweck, 1998). It is usually examined in conjunction with other non-cognitive variables, such as motivation, self-efficacy, and goal orientation, under the umbrella of self-theories. Regarding intellectual abilities, Dweck (1999) argued that people either think that their intellectual capabilities are fixed, and it is very difficult (if not impossible) to develop their level of intellectual capability (i.e., fixed mindset), or they think that their intellectual capabilities can be developed by working hard and practicing (i.e., growth mindset). It has also been argued that mindsets can be domain-specific and that participants can independently hold different mindsets in different domains (Ryan & Mercer, 2012). Specifically, a person can be growth mindset-oriented in one field but fixed mindset-oriented in another (Dweck et al., 1995; Lottero-Perdue & Lachapelle, 2020). For example, a person can hold a growth mindset in terms of creativity but a fixed mindset about entrepreneurship.

Previous research has shown that a growth mindset can be developed through interventions that bolster academic achievement (Blackwell et al., 2007; Debacker et al., 2018; Paunesku et al., 2015; Rattan et al., 2015). In these interventions, students were informed about the malleability of intelligence and how the brain grows with exercise and effort. They were also informed that intellectual capacity is not fixed and that trying new strategies or seeking help when needed helps boost their intellectual abilities (Blackwell et al., 2007; Dweck & Yeager, 2021; Hwang et al., 2019; Paunesku et al., 2015).

2.3 | Mindsets and academic success

A main assumption of the mindset theory is that mindsets perform a key function in academic success (Rattan et al., 2015). Cury et al. (2006) argued that having a fixed mindset can negatively predict achievement, whereas having a growth mindset can positively predict academic success. Previous studies on mindsets, however, have shown mixed

results. On the one hand, a line of study has reported that mindsets predict achievement directly (Hong et al., 1999; Müllensiefen et al., 2015; Muller & Dweck, 1998; Paunesku et al., 2015; Zhao & Wang, 2014). These studies mostly compared the self-theories of their participants and their academic success scores in college and high school settings. They found that a growth orientation, compared to a fixed mindset, predicted higher final grades in specific courses. Mindsets have also been shown to be a mediating factor in predicting personal characteristics, such as beliefs about effort, goal orientations and self-regulation strategies (Blackwell et al., 2007; Dweck & Leggett, 1988). For example, in Blackwell and colleagues' study, students' learning goals mediated the relationship between mindsets and academic success.

Another line of studies reported that mindsets do not predict achievement (Bahník & Vranka, 2017; Li & Bates, 2019; Magno, 2012; Stump et al., 2014). For example, using a very large dataset of university applications and comparing mindsets with achievement in a scholastic aptitude test, Bahník and Vranka (2017) reported no relationship between growth mindset and test scores. Recent meta-analyses of mindsets have also revealed that mindsets might be weak predictors of academic success (Sisk et al., 2018).

2.4 | Language learning mindsets

LLM concept is a recently developed concept. Early studies examined learners' beliefs about the role of natural talent in language learning (Mercer & Ryan, 2009) and how language ability determined students' approach to learning (Ryan & Mercer, 2012). These studies examined how cross-cultural issues impacted and shaped the beliefs of their participants. Few studies have “specifically addressed fixed versus malleable beliefs about language ability” (Lou & Noels, 2017, p. 215). Recent research on LLMs has examined the interplay between LLMs and reading strategies (Molway & Mutton, 2020) and responses to failure and goal orientation (Lou & Noels, 2017). To the best of our knowledge, the relationship between LLMs and academic success has not been adequately explored. This study aims to address this gap in an EMI engineering program by using a commonly used tool – Lou and Noels' (2019) Language Mindsets Inventory, which involves nine growth language mindset items (e.g., No matter who you are, you can significantly improve your language intelligence level) and nine fixed language mindset items (e.g., To be honest, you cannot really change your language intelligence) to determine the LLMs of students. Each of these mindset categories was examined under three themes, namely general verbal intelligence, L2 aptitude, and age sensitivity; our inventory included three fixed language mindset items and three growth language mindset items for each theme.

2.5 | Math mindsets

Similar to LLMs, MMs are based on two dispositions about math intelligence: a growth mindset indicates people's beliefs about developing their math skills through instruction and practice, and a fixed mindset indicates a belief about having a fixed and innate math capability (Daly et al., 2019). Dweck (2014) stated that students tend to have a fixed mindset in math skills compared to other intellectual skills. Previous research that examined MMs found that having a growth mindset was positively related to students' math outcomes at the secondary school level, both cross-sectionally and over time (Bostwick et al., 2017, 2019). On the other hand, holding a fixed mindset about math learning has led to weak attainment outcomes for middle and high school students (Blackwell et al., 2007; Hwang et al., 2019). Bernardo (2021) found that a growth mindset was positively associated with math achievement in Programme for International Student Assessment (PISA) 2018. However, this was only among students with higher socioeconomic status and not among students with lower socioeconomic status. Therefore, it is not easy to generalize the positive relationship between a growth mindset and achievement. In our study, we utilized the MM inventory developed by Cury et al. (2006) based on Dweck's (1999) general mindset inventory. With this inventory, Cury et al. (2006) found a strong relationship between MMs and performance attainment.

2.6 | Mindsets in EMI settings

The implementation of EMI programs has resulted in unprecedented growth over the past two decades (Dearden, 2015; Kirkpatrick, 2014; Macaro et al., 2018; Yuksel et al., 2022). Several studies have examined the possible reasons for this expansion and have suggested that factors such as finding better jobs, future mobility opportunities, and better

educational opportunities, among others, have motivated students to choose EMI programs (Altay & Yuksel, 2021; Turhan & Kırkgoz, 2018). Universities have opted to offer EMI programs to internationalize and establish global reputations and standings (Dearden & Macaro, 2016; Soruç & Griffiths, 2018).

In terms of EMI academic success, previous studies have focused on the interplay between linguistic aspects, such as general English proficiency, use of students' first language, and academic success in EMI courses in engineering and social science subjects (Altay et al., 2022; Curle et al., 2020; Yuksel, Soruç, et al., 2021). Non-linguistic factors, such as the challenges students face when studying through EMI (Kamasak et al., 2021; Soruç et al., 2021), their motivations to study through EMI (Macaro & Akıncioğlu, 2018; Turhan & Kırkgoz, 2018), self-regulation skills and sense of self-efficacy (Soruç et al., 2022), and self-theories they possess (Yuksel, Curle, & Kaya, 2021), have been reported in some Turkish university setting studies. However, few studies have examined the relationship between non-cognitive factors (e.g., motivation, self-efficacy, and mindsets) and academic success in the Turkish EMI context.

As we have tried to portray in this section, previous research on the impact of MMs and LLMs in the field of engineering is scarce. Moreover, previous studies have revealed mixed results regarding the relationship between mindsets and academic achievement. These issues indicate the need for further examination of the relationship between mindsets and academic achievement, especially in the field of engineering. Finally, Costa and Faria's (2018) meta-analysis revealed that domain-specific and contextual factors also influence the relationship between mindsets and academic achievement. This study aims to add to the current knowledge by expanding this line of research by focusing specifically on the mathematical and language learning domains and how MMs and LLMs predict academic EMI and TMI achievement.

This study will therefore answer the following two research questions:

1. To what extent do LLMs predict:
 - a. EMI academic achievement in mechatronics engineering?
 - b. TMI academic achievement in mechatronics engineering?
2. To what extent do MMs predict:
 - a. EMI academic achievement in mechatronics engineering?
 - b. TMI academic achievement in mechatronics engineering?

3 | METHODOLOGY

3.1 | Setting

EMI higher education programs in Turkey began with the opening of engineering programs in the 1950s after the founding of Middle East Technical University (Selvi, 2014). In 1999, two technical universities offering predominantly engineering programs had the highest number of EMI programs in Turkey (Yuksel et al., 2022). EMI is offered in two models in Turkey, either full or partial, depending on the language(s) offered for instruction. In the full model, all courses are offered in English, whereas in the partial EMI model (i.e., the model used in this study), at least 30% of the curriculum is provided in English, and the rest is provided in Turkish. In the courses taught in English, all classroom instruction, assignments, projects, and exams are provided in English. Even though there is no explicit language focus, students' language proficiency might have an impact on their academic success (Yuksel, Soruç, et al., 2021). According to the most recent reports and reviews, EMI programs in Turkey have grown exponentially over the last 20 years. For instance, as of 2019, among the 10,396 undergraduate programs offered by 193 universities in Turkey, a total of 2920 programs (28%) offered full or partial EMI (OSYM, 2019).

This study was conducted at a Turkish public university that offers a partial EMI (Macaro, 2018) mechatronics engineering program. In this specific setting, which adopted a partial EMI model, students are required to take a minimum of two EMI courses per semester. The rest of the courses (approximately four or five) are offered in Turkish. This university is one of the major public universities in Turkey and has approximately 60,000 students. EMI courses are offered in 13 different academic programs across the economics, engineering, and science faculties.

In the mechatronics engineering program, 21 courses are offered in English, including Engineering Mathematics and Numerical Methods in Mechatronics Engineering. According to the university's course catalog system, these courses' assignments and assessment tools vary, but almost all courses have both mathematical and essay/project-based assessment modules. There are 42 courses instructed in Turkish, such as Elements of Mechatronics and

Fluid Mechanics. This academic subject included courses taught using EMI and TMI. This allowed us to examine the effects of LLMs and MMs on EMI and TMI academic achievement in the same context.

3.2 | Participants

Data were collected from fourth-year students in the mechatronics engineering program ($n = 68$; 72% male, 28% female) in the spring semester of 2021, with the support of their instructors. As of 2021, 22% of mechatronics engineering students in public universities in Turkey were female (Council of Higher Education, 2022). In this respect, our participants were somewhat representative of the overall population. The participants were provided a non-binary gender choice, although no students selected it during the data collection stage, which took place at the end of the semester. All students in the fourth year of the program ($N = 109$) were contacted via email and asked to voluntarily participate in the study. Sixty-eight responded positively to this call and completed the online questionnaire (62%). All participants were native Turkish speakers who studied English as a foreign language in a compulsory intensive English program before starting their academic degree programs. The intensive English program offered general English courses in all four skills (i.e., reading, writing, listening, and speaking) for two semesters. The participants were between the ages of 21 and 26 years ($M = 22.6$). All students had been learning English for an average of 9 years at the time of this study.

3.3 | Instruments and procedures

Students' exam scores from the EMI and TMI courses were obtained from the University's Registrar's Office after ethical permission was granted. Each semester, students took a minimum of two EMI courses and five or six TMI courses over 4 years. The correlation between TMI and EMI academic success was fairly strong ($r = .67$). According to the university guidelines and course catalog information provided to the students, students' end-of-semester scores included midterm and final exams for each course, as well as projects, presentations, assignments, and quizzes in various courses. The final exam grade usually constitutes 60% of the course grade, whereas other means of evaluation (e.g., midterm exams, projects, presentations, assignments, and quizzes) compromise the rest of the grade, thus providing a comprehensive assessment of the course goals and outcomes, as required by university regulations. For the midterm and final exams, the students were asked to respond using short answers, solve mathematical problems, choose the correct answer based on the given options, or apply formulas to given scenarios, reflecting a wide range of assessment tools. However, since there were a variety of courses and lecturers who taught each of these courses, specific classroom applications for assessment varied, and we do not know if each of the courses followed exactly the same assessment and grading procedures. Data were collected using the following measures and research instruments:

- An average score on the mechatronics engineering content courses taught in English was used to measure EMI academic success.
- An average score on the mechatronics engineering content courses taught in Turkish was used to measure TMI academic success.
- Lou and Noels's (2019) LLM Inventory was used to measure the participants' language mindsets (see Appendix A).
- Cury et al.' (2006) MM Inventory was used to measure the participants' MMs (see Appendix B).

Both inventories (LLM and MM) were translated into Turkish by two native speakers. A specialist who holds a Ph.D. in translation reviewed the translations and edited them as necessary. The Turkish versions of the questionnaires were then back-translated into English and checked by the researchers for any differences. After all necessary steps were carried out, a pilot study was conducted with 10 fourth-year students studying in the mechatronics engineering program to test the LLM Inventory. The MM inventory was piloted with 10 different students from the same year and program. Neither pilot group participated in the main study. For both inventories, the students did not report any issues related to the items, and the researchers did not make any changes to the questionnaires. The first section of the questionnaire explained the ethical issues and requested the students' consent. The next sections of the questionnaire included the LLM items, followed by the MM items. For LLM growth and fixed mindsets, the Cronbach alpha reliability

measures were $\alpha = .91$ and $\alpha = .84$ respectively. For MM growth and fixed mindsets, the reliability measures were $\alpha = .86$ and $\alpha = .88$ respectively. These values are above .7; therefore, the questionnaires are considered reliable.

3.3.1 | Scoring of instruments

As in Dweck's (1999) general intelligence theory, in both the LLM and MM inventories, there are two sets of items: fixed mindset and growth mindset items. Therefore, each participant had two separate scores on the inventories, one for each type of mindset. The LLM Inventory includes 18 items across the three aspects of language mindsets, including general language intelligence beliefs, second-language aptitude beliefs, and age sensitivity/critical period hypothesis beliefs. Each dimension included three fixed and three growth mindset items. The average scores of these three dimensions were used for the analyses. Similarly, the MM Inventory includes six items, three of which were fixed (e.g., Some people do well at math and others do not, no matter how hard they try), and three were growth mindset items (e.g., People can change how well they perform in math). Participants responded to both inventories on a six-point Likert scale (1: Strongly Disagree, 2: Moderately Disagree, 3: Slightly Disagree, 4: Slightly Agree, 5: Moderately Agree, 6: Strongly Agree), and all items were positively coded.

3.4 | Data analysis

Once all questionnaire data had been collected, the statistical computing software R was used to run multiple linear regression models on the data to answer all the research questions. There were no missing data, and all assumptions were met. EMI and TMI academic success scores were treated as outcome variables. LLMs and MMs were the main latent predictor variables divided into the sub-categories of fixed and growth mindset (Cury et al., 2006; Lou & Noels, 2017).

First, the assumptions for the regression were checked. Descriptive statistics (refer to Table 1) showed that students achieved an average of 67.85% in their EMI content courses (SD = 9.28; range = 47) and an average of 61.44% in their TMI content courses (SD = 9.81; range = 41). These averages indicate that students were slightly more successful in their EMI content courses compared to their TMI content courses. Regarding LLMs and MMs, all averages were between three and four on the six-point Likert scale, indicating that students did not have very strong dispositions toward fixed or growth mindsets. No variables were significantly skewed or kurtotic, and the data met all the remaining assumptions of regression.

To answer the research questions of this study, multiple linear regressions were carried out to investigate the relationships between LLMs, MMs, EMI, and TMI academic achievement in mechatronics engineering. Below are the regression model equations for each research question:

1. **RQ1a:** $EMI\ Academic\ Achievement_i = \beta_0 + \beta_1 GrowthLLM_i + \beta_2 FixedLLM_i + e_i$.
2. **RQ1b:** $TMI\ Academic\ Achievement_i = \beta_0 + \beta_1 GrowthLLM_i + \beta_2 FixedLLM_i + e_i$.
3. **RQ2a:** $EMI\ Academic\ Achievement_i = \beta_0 + \beta_1 GrowthMM_i + \beta_2 FixedMM_i + e_i$.
4. **RQ2b:** $TMI\ Academic\ Achievement_i = \beta_0 + \beta_1 GrowthMM_i + \beta_2 FixedMM_i + e_i$.

TABLE 1 Descriptive statistics of academic achievement and mindsets

Variable	N	Mean	SD	Min	Max	Skew	Kurtosis	SE
EMI academic achievement	68	67.85	9.28	41	88	.09	.10	1.12
TMI academic achievement	68	61.44	9.81	44	85	.46	-.26	1.19
Growth language learning mindset	68	3.28	1.16	1	6	-.32	-.91	.14
Fixed language learning mindset	68	3.25	1.21	1	6	.06	-1.34	.15
Growth math mindset	68	3	1.38	1	6	.49	-.89	.17
Fixed math mindset	68	3.24	1.16	1	6	.11	-.98	.15

Note: Academic achievement measures are on a scale of 0–100; mindset measures are on a scale of 1–6.

Abbreviations: EMI, English medium instruction; TMI, Turkish medium of instruction.

4 | RESULTS

4.1 | LLMs—EMI Academic achievement (RQ1a)

Both growth and fixed LLMs were statistically significant predictors of EMI academic achievement in mechatronics engineering. Growth LLM predicted EMI achievement positively ($F = 37.00, p < .001$) and explained 35% (adjusted R^2) of the variance in EMI test scores ($\beta = .60, t = 6.08, p < .001$). Results of a zero-order Pearson correlation confirmed this significant positive association ($r = .6, p < .001$). Fixed LLM predicted EMI achievement negatively ($F = 66.56, p < .001$), and explained 49.5% (adjusted R^2) of the variance in EMI test scores ($\beta = -.71, t = -8.16, p < .001$). Results of a zero-order Pearson correlation confirmed this significant negative association ($r = -.71, p < .001$). The stronger the students' belief that language learning ability can be improved and the weaker their belief that language learning ability is fixed (i.e., pre-determined, cannot change), the higher they achieve in their EMI mechatronics engineering courses. These relationships are illustrated in Figure 1.

4.2 | LLMs—TMI Academic achievement (RQ1b)

Similar to EMI achievement, both growth and fixed LLMs were statistically significant predictors of TMI academic achievement in mechatronic engineering but with smaller explained variances. Growth LLM predicted TMI achievement positively ($F = 15.92, p < .001$) and explained 18% (adjusted R^2) of the variance in TMI test scores ($\beta = .44, t = 3.99, p < .001$). Results of a zero-order Pearson correlation confirmed this significant positive association ($r = .44, p < .001$). Fixed LLM predicted TMI achievement negatively ($F = 19.19, p < .001$), and explained 21% (adjusted R^2) of the variance in EMI test scores ($\beta = -.48, t = -4.38, p < .001$). Results of a zero-order Pearson correlation confirmed this significant negative association ($r = -.48, p < .001$). In other words, TMI achievement moderately increased for growth LLM and moderately decreased for fixed LLM. These moderate relationships are displayed in Figure 2.

4.3 | MMs—EMI Academic achievement (RQ2a)

Both growth and fixed MMs were statistically significant predictors of mechatronics engineering EMI academic achievement. Growth MM predicted achievement positively ($F = 169.94, p < .001$), and explained 71.6% (adjusted R^2) of the variance in EMI achievement ($\beta = .85, t = 13.04, p < .001$). Results of a zero-order Pearson correlation confirmed this significant positive association ($r = .85, p < .001$). Fixed MM predicted achievement negatively ($F = 45.07,$

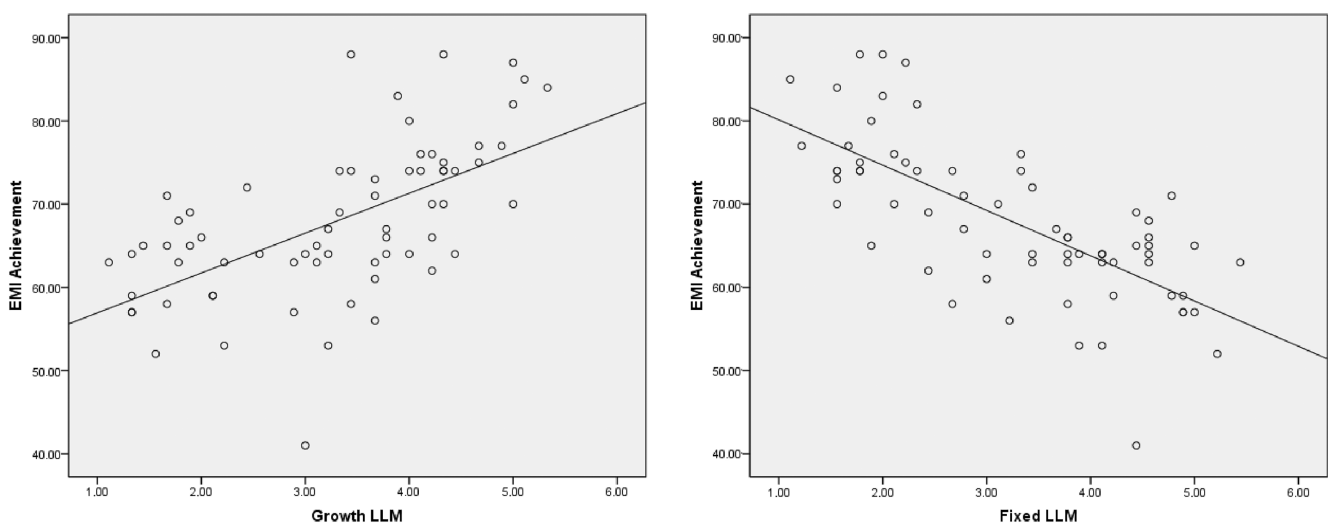


FIGURE 1 Scatterplot of EMI academic achievement in mechatronic engineering and LLMs. EMI, English medium instruction; LLMs, language learning mindsets

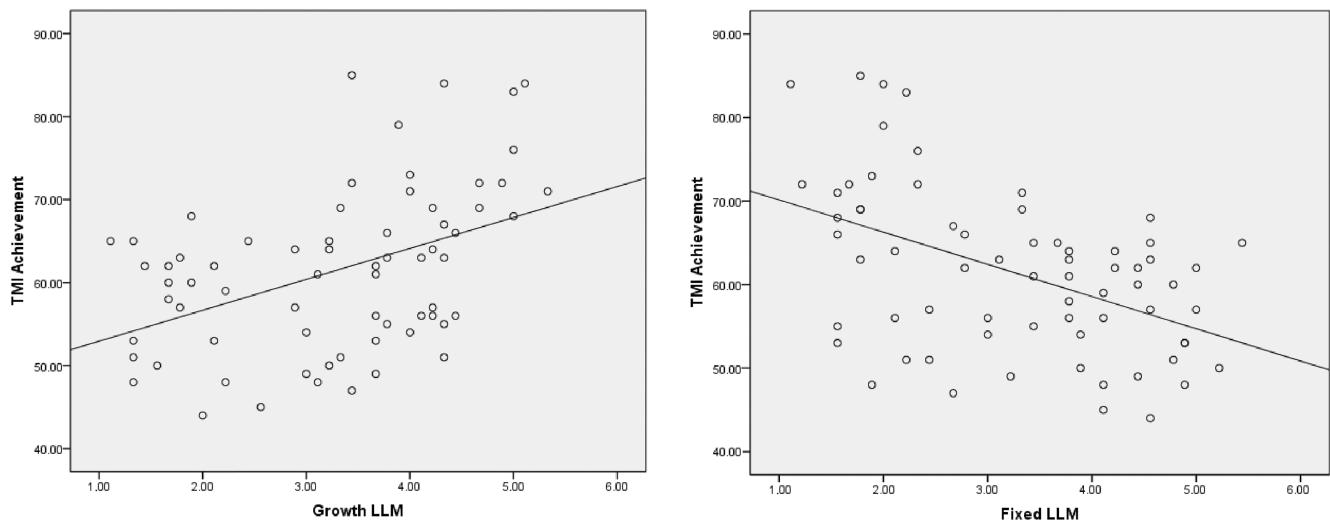


FIGURE 2 Scatterplot of TMI academic achievement in mechatronic engineering and LLMs. LLMs, language learning mindsets; TMI, Turkish medium of instruction

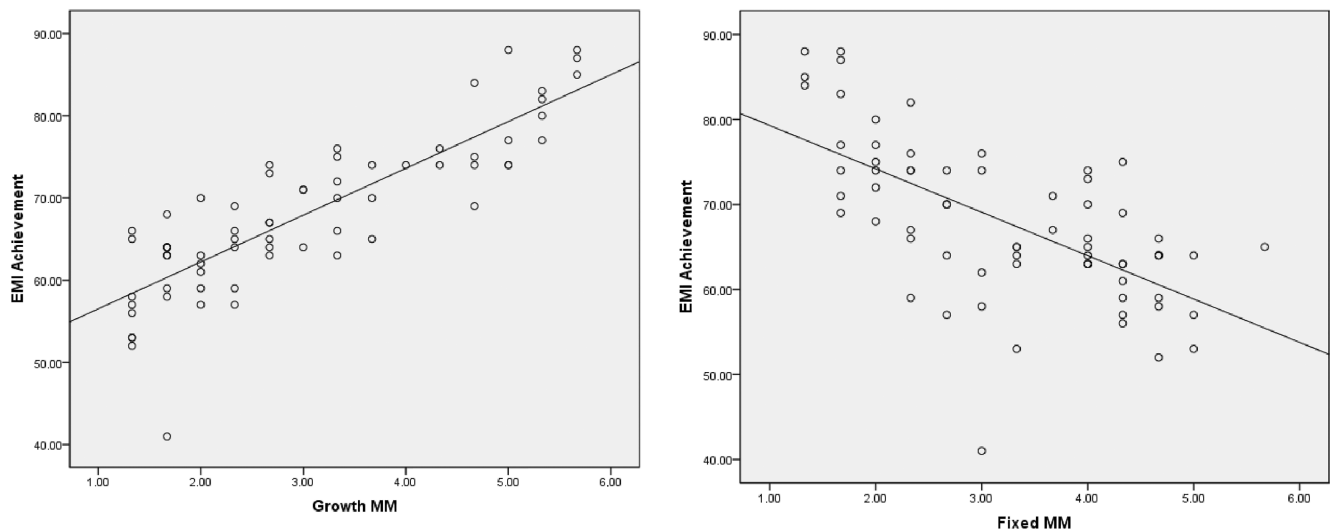


FIGURE 3 Scatterplot of EMI academic achievement in mechatronic engineering and MMs. EMI, English medium instruction; MMs, math mindsets

$p < .001$), and explained 39.7% (adjusted R^2) of the variance in EMI achievement ($\beta = -.64$, $t = -6.71$, $p < .001$). Results of a zero-order Pearson correlation confirmed this significant negative association ($r = -.64$, $p < .001$). The stronger the students' belief that math can be developed through practice or instruction, the higher their EMI academic achievement. On the other hand, the stronger the students' belief that math ability is fixed, the lower their EMI academic achievement. These strong relationships are illustrated in Figure 3.

4.4 | MMs—TMI Academic achievement (RQ2b)

Both growth and fixed MMs were statistically significant predictors of EMI academic achievement. Growth MM predicted achievement positively ($F = 141.47$, $p < .001$), and explained 67.7% (adjusted R^2) of the variance in TMI achievement ($\beta = .83$, $t = 11.89$, $p < .001$). Fixed MM predicted TMI achievement negatively ($F = 65.93$, $p < .001$), and explained 49.2% (adjusted R^2) of the variance ($\beta = -.71$, $t = -8.12$, $p < .001$). Zero-order Pearson correlation coefficients were $r = .83$ for growth MM and $r = -.71$ for fixed MM ($p < .001$). Similar to EMI achievement, growth MMs

had a major impact on TMI achievement. The stronger the students' belief that math can be developed through practice or instruction, the higher their TMI academic achievement; the stronger the students' belief that math ability is fixed, the lower their TMI academic achievement. These strong relationships are illustrated in Figure 4.

4.5 | Summary of our overall results

Our results showed that growth MMs explained a very large portion of the variance (70%) in achievement in both the EMI and TMI contexts. Fixed MMs affected achievement negatively in both mediums of instruction and explained a notable portion of the variance (40%–49%) in achievement. LLMs explained a much larger portion of the variance (35%–50%) in EMI achievement compared to TMI achievement (18%–21%; refer to Table 2).

5 | DISCUSSION

This study focused on the effects of two domain-specific mindsets (i.e., LLMs and MMs) on academic success in EMI and TMI courses. The findings showed that students' LLMs were significantly associated with their academic achievement in EMI courses. More specifically, growth language mindsets predicted achievement positively, while fixed language mindsets predicted achievement negatively. As Dalton-Puffer (2011) pointed out, students unfamiliar with second-language mediums may not be confident about their ability to understand academic content through their second language. Therefore, when students have a fixed mindset about language learning, this may hinder their understanding and achievement in EMI courses. Surprisingly, LLMs were also significantly associated with TMI achievement but with a smaller effect size compared to EMI achievement. An explanation might be that students who endorse growth LLMs might also endorse growth mindsets in other domains, which positively impacts their success. Although

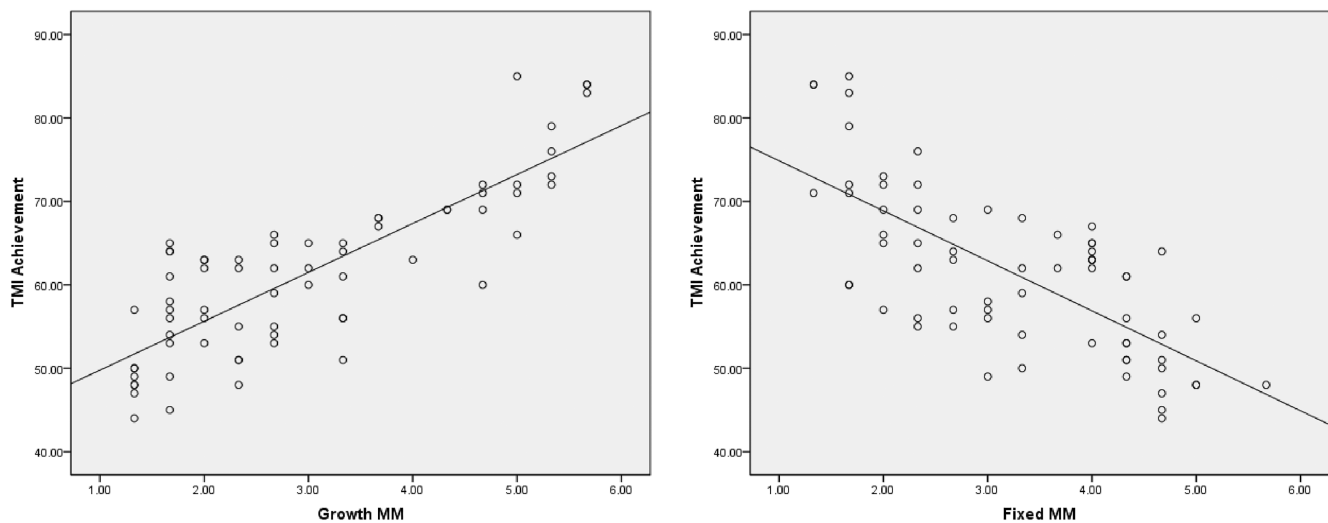


FIGURE 4 Scatterplot of TMI academic achievement in mechatronic engineering and MMs. TMI, Turkish medium of instruction; MMs, math mindsets

TABLE 2 Summary of the effects of mindsets on achievement through multiple linear regression models

Variable	Growth LLM		Fixed LLM		Growth MM		Fixed MM	
	β	R^2	β	R^2	β	R^2	β	R^2
EMI academic achievement	.60	.350	-.71	.495	.85	.716	-.64	.397
TMI academic achievement	.44	.180	-.48	.210	.83	.677	-.71	.492

Abbreviations: EMI, English medium instruction; LLMs, language learning mindsets; MMs, math mindsets; TMI, Turkish medium of instruction.

previous research introduced engineering mindsets and found that elementary school students with higher general mindset scores had higher engineering post-assessment scores (Lottero-Perdue & Lachapelle, 2020), the most notable finding of this study is the strong influence of MMs on undergraduate mechatronics engineering students' academic achievement in both EMI and TMI contexts.

Similarly, Bostwick et al. (2017, 2019) and Bernardo (2021) found significant effects of a growth mindset on the math achievement of large groups of middle and high school students. The current study extends similar findings to university students. Considering university students are adult learners, our study's findings contradict Sisk et al.' (2018) meta-analysis, in which they found no relationship between a growth mindset and the achievement of adult learners. Moreover, our results contradict two other studies involving participants from engineering programs (Magno, 2012; Stump et al., 2014). In both correlational studies, no relationships were found between intelligence beliefs and course grades or GPA. In those studies, however, general mindset inventories were used, which may not reflect the domain-specific beliefs of the participants, as is the case in this study. Therefore, the statistically significant relationship between mindsets and academic achievement in this study may be attributed to the utilization of more nuanced inventories.

This finding is especially noteworthy for engineering education because it highlights the significance of math in engineering (Flegg et al., 2012; Rooch et al., 2016). Math courses are typically prerequisites for engineering degrees, and performance in these courses is significantly correlated with subsequent performance in engineering courses (Kamal et al., 2015). Considering that several engineering programs have student attrition due to failure in math courses (Faulkner et al., 2020), it is important to highlight success components in math courses.

In terms of a fixed mindset, our findings echo the findings of Hwang et al. (2019), who predicted lower gains in academic achievement for students who endorsed a fixed mindset. Research suggests that students with a fixed mindset do not put much effort into learning when faced with difficulties, which often results in failure (Hong et al., 1999; Yeager & Dweck, 2012). Students with fixed mindsets believe that mistakes and failures are signs of inability. Rather than working hard on the subjects they struggle with and correcting their mistakes, they prefer to avoid the subject altogether, influencing their future success and careers (Dweck, 2007).

5.1 | Implications for educational practice

Based on these findings, student-and institutional-level implementations that can facilitate improvement in different domains of growth mindsets are suggested. Engineering math courses can provide a forum for the discussion and application of mathematical ways of thinking (Faulkner et al., 2020), and the discussion of growth MM can be part of it. At the student level, learning about mindsets can transform how students perceive their abilities and ways to improve them (Debacker et al., 2018; Paunesku et al., 2015; Rattan et al., 2015). Previous research has demonstrated positive results of interventions in developing a growth mindset (Debacker et al., 2018; Paunesku et al., 2015; Rattan et al., 2015). In general, these interventions included reading activities and discussions that conveyed the message of "malleable intelligence" to students. Growth mindset interventions not only improve students' achievement but also increase their enrollment in advanced math courses (Rege et al., 2021; Yeager et al., 2019).

Brez et al. (2020) warned against one-time interventions for college-level students. With close to 3000 university students, their experimental study did not find a significant impact of one-time growth interventions on college students' math and psychology course grades and end-of-term GPAs. Elective courses can be designed for engineering students in which math and English learning growth mindsets are highlighted. There are some examples of such long-term interventions specifically designed for engineering students. For example, in Choi's (2018) study, an 8-week course was designed for engineering students to help them adopt growth mindsets. As part of the course content, students watched TED talks on human behavior, cognition, and neuroscience presented with scientific evidence; they read book chapters on these issues, conducted group discussions, and wrote reflection papers. Based on pre-and post-survey data, students' growth mindset scores increased, and their fixed mindset scores decreased.

Student-level interventions may not be enough to sustain a growth mindset. Instructors' practices can be instrumental in developing students' mindsets, which in turn impact their success (OECD, 2021). At the institutional level, researchers emphasize the importance of creating a growth mindset culture (Bryan et al., 2021; Dweck & Yeager, 2021). Institutions should pave the way for the development of inclusive classrooms, which can facilitate the understanding and progress of students, and students can benefit from the mistakes they make when they see that they are a sign of improvement and development (Dweck & Yeager, 2021; Murphy et al., 2021). Interventions that train educators to create a growth mindset in their classroom culture may enhance students' long-term academic motivation and performance (Murphy et al., 2021).

Reid and Ferguson (2014) reported that engineering students tend to drift toward a more fixed mindset in their first year of study. Without any intervention, these students will likely show less persistence and effort when faced with challenges. Developing a growth mindset will help these students maintain motivation and remain in their chosen fields.

Bryan et al. (2021) pointed out that creating a growth mindset classroom culture would be less expensive and more effective in improving educational outcomes than conventional programs and policies. In their meta-analysis of studies examining factors related to student retention in engineering programs, Geisinger and Raman (2013) highlighted classroom climate as a determining factor. Instructors can aim to craft collaborative classroom groups in which students support each other. In this way, growth mindset feedback becomes a sign of progress and development. It is very important to benefit from the language of a classroom in which the teacher holds the assumption that every student has the potential to progress. Instructors should motivate students to look for alternative strategies when they make mistakes (Murphy et al., 2021).

Another pedagogical implication of this study might be changing instructors' approaches to assessment and feedback. Rather than giving only a final exam, instructors can provide multiple assessments of growth and allow opportunities for revision (Murphy et al., 2021). When grading homework assignments, instructors can value effort and correctness (Jaffe, 2020). Students may become reluctant to put in much effort when they equate talent with correctness; and this may result in a reduction in students' confidence in their own talents (Duckworth, 2016). Instructors can also help students question their effort-based strategies, such as how long they prepare for an exam/quiz or what kinds of learning strategies they use. By attributing these effort-based strategies to their performance, students can monitor their own learning (Stump et al., 2014). For students to succeed, instructors need to deliver messages that emphasize the importance of effort rather than intelligence, the power of mistakes, and the process of struggling (Boaler, 2016; Dweck, 2006). These implications will help learners recognize the power of their mindsets and evolve them for a better learning experience at the university level.

5.2 | Implications for educational research

In recent years, researchers have suggested using a domain-specific mindset (i.e., MM) rather than Dweck's generic mindset for explaining school learning (Boaler, 2016; Boyd & Ash, 2018; Lottero-Perdue & Lachapelle, 2020). The current study pursued this recommendation and found a strong influence of LLMs and MMs on achievement in engineering. The finding of a much stronger association between LLMs and EMI achievement compared to LLMs and TMI achievement further confirms the power of domain-specific mindsets and builds upon previous engineering research (Lottero-Perdue & Lachapelle, 2020). Future studies may consider this shift from a generic mindset to a domain-specific mindset for different subjects and settings.

Tempelaar et al. (2015) claimed that effort beliefs might mediate the effects of mindsets on achievement, such as believing that working hard allows one to learn better (positive effort beliefs). Similarly, Chen and Pajares (2010) demonstrated that a growth mindset's relationship with science achievement is mediated by motivational factors, such as learning achievement goals. Therefore, future research might focus on self-theories, such as effort, motivation, self-efficacy, and self-regulation, alongside mindsets, and how these interact with academic achievement. These relationships can be analyzed through more complex mediation models, such as structural equation modeling.

5.3 | Limitations

Although our study has some important implications, it also has some limitations. First, the authors acknowledge the limitations regarding the sample: a single academic program from a single university in Western Turkey. Due to this limitation, our results might not be transferrable to very different cultural/geographical contexts. Second, the mechanisms of mindset–achievement relationships for subgroups were not explored mainly due to the small sample size.

Similar to the findings in Hwang et al.' (2019) study, having a fixed mindset might impact achievement groups differently. Consequently, in forthcoming studies, researchers might investigate whether there are any group differences in the mechanisms of mindset–achievement relationships at the university level. Third, this study used the average grade of EMI courses to measure engineering achievement, as reported in Section 3.3. How the students were assessed in each course was not documented. The type of assessment, such as intelligence-based or effort-based, might have influenced the mechanism of mindset–achievement relationships. This is an important consideration for future research.

6 | CONCLUSION

The findings of this study suggest that, regardless of the medium of instruction (i.e., both in EMI and TMI settings), a growth mindset in math profoundly influences students' academic achievement in a mechatronics engineering program. When engineering students have a growth-oriented mindset in math, they tend to be more successful in their program, which likely impacts their success in their careers and in solving real-world problems. Given the importance of math in engineering, this finding is particularly relevant to engineering education. Moreover, a growth mindset in language learning also considerably affects students' EMI achievement. Therefore, developing a growth mindset in math and language learning may significantly support EMI students in engineering programs.

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APPENDIX A

LANGUAGE LEARNING MINDSET INVENTORY

Instructions: Please rate how much you agree or disagree with these statements. There is no right or wrong answer. We are interested in your personal opinion.

1	2	3	4	5	6
Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree

General Language Beliefs (GLB):

1. To be honest, you cannot really change your language intelligence.
2. Your language intelligence is something about you that you cannot change very much.
3. You have a certain amount of language intelligence, and you cannot really do much to change it.
4. No matter who you are, you can significantly improve your language intelligence level.
5. No matter how much language intelligence you have, you can always improve it quite a bit.
6. You cannot change how capable you are at learning new languages.

Second Language Aptitude Beliefs (L2B):

7. To be honest, you cannot really change your basic ability to learn and use new languages.
8. To a large extent, your ability to learn new languages is innate and you cannot change much.
9. You can always improve how good you are at learning new languages.
10. No matter who you are, you can always improve your basic ability to learn new languages.
11. After a certain young age, you have very limited ability to learn new languages.
12. You do not really have the ability to learn new languages after a certain young age.

Age Sensitive/Critical Period Hypothesis Beliefs (ASB):

13. After a certain young age, you have very limited ability to learn new languages.
14. You do not really have the ability to learn new languages after a certain young age.
15. Your ability to learn new languages is restricted after a certain young age, and you cannot really change it.
16. No matter how old you are, you can always improve your ability to learn new languages.
17. Regardless of age, you can significantly improve how good you are at learning new languages.
18. Even after a certain young age, you can substantially improve your ability to learn new languages.

APPENDIX B**MATH MINDSET INVENTORY**

Instructions: Please rate how much you agree or disagree with these statements. There is no right or wrong answer. We are interested in your personal opinion.

1	2	3	4	5	6
Strongly disagree	Moderately disagree	Slightly disagree	Slightly agree	Moderately agree	Strongly agree

1. My math intelligence can be changed.
2. Some people do well at math and others do not, no matter how hard they try.
3. There is a limit to what I can learn in math.
4. Some people just get math and others do not and never will.
5. I can understand math concepts better if I keep exploring when I miss problems.
6. People can change how well they perform in math.