

**Developing growth mindsets in engineering students:  
Work-in-progress on a systematic literature review**

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**Conference Key Areas:** Diversity in Engineering Education; Lifelong learning;  
Talent management

**Keywords:** Growth mindsets; beliefs; intervention; engineering students

**ABSTRACT**

Engineering programs can be very demanding, particularly in the first years where students often encounter challenging coursework. Dropout from engineering studies has been linked to ‘fixed mindset’ beliefs that make students more likely to give up when facing new challenges. Extensive research evidenced that students with a ‘fixed mindset’ believe that intelligence is an innate and fixed trait. In contrast, students with a ‘growth mindset’ believe that intelligence can be improved with effort and drive, and are then less likely to disengage when confronting difficult tasks. Interventions to develop ‘growth mindsets’ have been successfully implemented at primary and secondary schools. However, there seems to be a paucity of interventions with university students studying engineering. In this work-in-progress paper, we will present findings from a systematic literature review of engineering, education and psychology databases to answer the question, ‘What interventions to develop growth mindsets have been implemented with engineering students, and what measures have been used to assess the effectiveness of the interventions?’ Preliminary findings

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suggest that the number of interventions aimed at strengthening growth mindsets in engineering students is still small. We present a categorization of interventions together with the measures used to assess the effectiveness of the interventions. The findings will be useful for engineering educators who want to encourage students to have the benefits associated with a growth mindset, such as greater resilience after setbacks and willingness to take on challenges and stick with them when difficulties arise, and support their academic success.

## INTRODUCTION

To meet stakeholder expectations, engineering educators are expected to produce graduates with a broader range of skills and attributes than in the past. The extra demands on students in a rapidly changing learning environment, and increased diversity within engineering programmes, makes it more likely that some engineering students will encounter setbacks in their studies. Students with fixed mindsets believe that intelligence is a fixed trait [1] and may feel that they are not the 'type' for engineering if success does not come easily. Growth mindsets defend against disengagement from studies when encountering challenges, such as failed assignments, because success is believed to be a result of improving intelligence and ability through applying appropriate effort.

Since failure is part of the creative process, and growth mindsets promote learning from mistakes, developing growth mindsets in engineering students should be an aim of a modern university that wants to graduate engineering students capable of using creativity in their future careers. While many interventions to develop growth mindsets in schools have been reported [2, 3], there seems to be few interventions with university students studying engineering. In addition, while growth mindset beliefs in engineering students were found to be associated with active learning strategies [4], growth mindsets were not predictive of course marks, unlike studies involving school-aged students [5]. This systematic literature review addresses the research question: *What interventions to develop growth mindsets have been implemented with engineering students, and what measures have been used to assess the effectiveness of the interventions?* The results will help engineering educators plan growth mindsets interventions based on previous research that is specific to engineering students.

## METHOD

We followed the procedures for a systematic literature review involving engineering education research outlined in [6]. A comprehensive literature search of the following electronic databases was carried out before 2 April 2019. This work-in-progress paper reports on the findings from journal papers and conference papers.

Search terms were created to find studies that met the following conditions:

1. The research design involved an intervention aimed at developing growth mindsets.

2. The interpretation of ‘growth mindset’ aligned with Carol Dweck’s theory of mindsets.
3. The intervention involved engineering students in tertiary studies (college or university).

The exact search terms used are presented in Table 1.

*Table 1. Search Terms Used in Databases.*

("growth mindset" OR "incremental mindset" OR "malleable intelligence" OR "implicit theories of intelligence")	AND ("engineering student*" OR "engineering class")	AND (intervention* OR experiment* OR compar*)	NOT "middle school"
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Note: a suffix of \* allows for multiple endings, e.g. comparison, compare.

The inclusion and exclusion criteria, with rationales, are presented in Table 2.

*Table 2. Inclusion and exclusion criteria*

Category	Inclusion criteria	Exclusion criteria	Rationale
Publication type	Peer-reviewed journal and conference articles.	Not peer-reviewed.	Quality assurance of the research; more credible results.
Publication language	Publications in any language found from database searches with English search terms.	Article not able to be translated into English, or translation quality weak.	The number of translations required were small; including more studies increases the value of the review.
Participants	Engineering students and students sharing classes with engineering students.	Not involving engineering students as the group targeted for the intervention.	The research question targets engineering students.
Purpose of intervention	The intervention aims to develop growth mindsets, or changes in mindset are reported.	The intervention does not aim to develop growth mindsets, or there is no assessment of students' mindsets.	The research question focuses on developing growth mindsets.
Theory used	Dweck's theory of growth/incremental and fixed/entity mindsets.	A use of the term 'mindset' different from Dweck's theory.	The research question focuses on Dweck's theory of mindsets.
Outcome measures	An assessment of the effectiveness of the intervention is made.	No assessment of the intervention is made.	The research question asks for measures for assessing the effectiveness of the intervention.
Date	Published before 2 April 2019 and after 31 December 1982.	Published after 2 April 2019 and before 1 January 1983.	Data collection stopped once analysis of results began. Dweck's work on growth mindsets was not available before 1983.

Duplicate studies, either within a search or between databases, were removed. When it could not be determined from the abstract if a record met the inclusion criteria, full texts were scanned. A spreadsheet with details of each study was compiled.

## RESULTS AND DISCUSSION

The number of included and excluded records (non-duplicates) based on the criteria in Table 2 are presented in Table 3. This work-in-progress paper reports only on results from journal articles and conference proceedings. The full project will include results from all sources found in the databases.

*Table 3.* Number of duplicated, included and excluded records

Database	Total records	Duplicates	Excluded	Included
Engineering Village	16	2	9	5
Scopus	63	8	53	2
PsycARTICLES	30	0	29	1
ERIC	1	0	0	1
Education Database	14	1	13	0
ScienceDirect	5	0	5	0
PsycINFO	4	0	4	0
Wiley Online Library	2	1	1	0
Academic Search Premier	1	0	1	0
Directory of Open Access Journals	1	0	1	0
ECO Papersfirst	0	0	0	0
ECO Proceedings	0	0	0	0
JSTOR	0	0	0	0
Proceedings (OCLC)	0	0	0	0
Total	137	12	116	9

A total of 137 journal and conference proceedings records were returned from searching 14 databases. Twelve duplicate records were excluded, leaving 125 records. In total, 116 records were excluded, many for multiple reasons. The first-noted exclusion reasons were: no intervention (62), not involving engineering students (24), not involving growth mindsets (24), no assessment of mindset (2), and no full text for a paper that couldn't be included based on the abstract alone (1). Table 4 summarises the details of the nine included records [9 – 17]. The two oldest included records [14, 15] involved universities and authors from the United Kingdom. The other seven records all had American authors and were based in universities in the United States. The only abstract in language other than English was translated using Google Translate and then excluded. Restricting the search terms to English may have limited the findings.

The dominant intervention pattern was sharing mindset ideas with students (through readings [9, 10, 12, 13], videos [10, 11] or lectures [14, 15]) followed by discussion or reflective writing, including students writing advice for other students. This pattern was evident in seven of the included studies [9 – 15]. One of those studies [15] also used two other interventions: a 'crib sheet' of alternative strategies when a computer programme fails (to counter the fixed mindset approach of re-trying the same strategy or giving up when stuck), and feedback of assignments stating that students who put in time and effort usually succeed. The remaining two studies [16, 17] used open-ended projects or assignments as a means of encouraging growth mindsets by valuing alternative strategies rather than a single correct answer.

Table 4. Summary of Included Records

Paper	Research design	Details of intervention	Findings
[9]	Qualitative. Five-part intervention. Reading and discussion.	Reading group with two authors and eight students met five times in a semester to discuss their reading of Dweck's book <i>Mindset</i> .	Students reconsidered past interpretations of experiences and projected forward on possible changes towards a growth mindset. Students understood that growth mindset "was not an all or nothing switch to be flipped."
[10]	Mixed. Four-part intervention. Videos with discussion, reading with written answers to questions.	In week 1, students watched Carol Dweck explaining growth mindsets on TedTalk and Khan Academy videos, followed by class discussion. In weeks 4, 9 and 13 students read an article on growth mindsets and wrote answers to questions.	Students already had growth mindsets to begin with. Greater shifts to growth mindsets were noticed in (non-traditional) students 10+ years out of high school.
[11]	Mixed. Three-part intervention for belonging, part 2 on mindsets. Work in progress. Video and discussion.	A first-day collaborative activity to establish classroom norms; a midquarter activity on growth mindset and metacognition; and a one-to-one instructor/student meeting. For mindset intervention, students watched the Ted Talk video by Eduardo Briceño, then discussed in groups "What kind of situations trigger your fixed mindset." Students shared strategies they believed would develop growth mindsets and the class worked together to identify what classroom situations might trigger fixed mindsets and how classmates, teaching assistants, and/or instructors can work together to encourage growth mindsets.	Work-in-progress. Students rated how the growth mindset intervention (amongst other course components) influenced their sense of belonging. Sense of belonging was measured by survey responses. "Researchers anticipate that the three interventions will improve student sense of belonging and will look to use the survey response data to evaluate the relative effectiveness of the interventions as perceived by the students."
[12]	Quantitative. Reading and reflective writing.	Online, students read a short scientific article explaining that the brain, "similar to other muscles", gets stronger with regular practice, then answered reflective questions, including giving examples of the use of growth mindsets in their lives, and giving advice to future first year students. In the social belonging intervention, students read stories about adjusting to university from the perspectives of senior students at the university, and answered reflective questions. The stories were based on focus group interviews with senior students. The first story was selected to be from a student that matched the reader's race and gender.	Latino/a students who received the growth mindset intervention had significantly higher first-semester grade point averages (GPAs) than did their peers in the control group (3.13 vs 2.73) but African American students in the growth mindset intervention did not achieve higher GPAs than their peers in the control group. The growth mindset intervention may be less effective for (1) students with higher high school GPAs (2) students with higher ACT scores and (3) students with higher baseline growth mindset beliefs.

[13]	Quantitative. Single intervention. Work in progress. Reading and reflective writing.	Students were assigned to a control, growth mindset or belonging group. The growth mindset group read an article comparing the brain to a muscle that gets stronger with regular practice and wrote a reflective essay; the belonging group read excerpts from fictional seniors of various ethnicities and genders describing their integration into the university and wrote a reflective essay in one of thirteen course assignments.	Before the interventions, under-represented minorities (URMs) had higher growth mindset scores than non-URMs and women had higher feelings of belonging than men. After 1 year in this 6 year project, among women, the growth mindset intervention resulted in lower course performance compared to the control and belongingness groups. Among men, the belongingness intervention resulted in higher course performance than in the growth and control. The interventions did not differentially affect course performance among URMs. Among non-URMs, the belongingness intervention led to improved course performance compared to the growth mindset and control conditions.
[14]	Mixed, two-part intervention in weeks 1 and 2. Lecture, students write advice to other students.	Lecture on growth mindset mid-way through computer science course. One week later, students were given one page reminder of lecture and asked to write advice for new students, describing a time when they learnt something new other than programming, being specific about the kinds of mistakes they made and how they overcame them, and giving advice to a beginning programmer, emphasizing how they can grow their programming intelligence through dealing with programming challenges.	Few statistically significant differences both from pre-survey to post-survey and between control and intervention groups. Statistically significant changes were evident across institutions, some increasing growth mindset, some decreasing. In a follow up course, students did recall the intervention but didn't think it changed their mindsets.
[15]	Quantitative, three-part intervention over one semester. Lecture and reflection; crib-sheet; feedback sheet.	(1) Four 10-15 minute tutor talks about an aspect of growth mindsets and then taking students through a reflective exercise focusing on their own learning experience and relating it to mindsets. (2) Crib-sheet of 35 things to try if your programme fails, to encourage using different strategies rather than the fixed mindset trait of repeatedly trying the same inappropriate strategy. Half a lecture spent explaining the purpose of the sheet. (3) Adding this text to feedback sheet on fortnightly assignments, "Remember, learning to program can take a surprising amount of time & effort – students may get there at different rates, but almost all students who put in the time & effort get there eventually. Making good use of the feedback on this sheet is an essential part of this process."	In the first week, 19 (21%) of the students displayed a fixed mindset and 38 (43%) a growth mindset. The crib-sheet intervention did not affect mindset and test scores. Teaching about mindsets shifted students towards growth mindsets but did not impact class test scores. The students' mindset showed a two-way interaction between the time interval from weeks 1 and 7 and the mindset training intervention. There were two-way interactions with mindset training and rubric interventions on both the first class test and final exam.

[16]	Quantitative, single intervention over one semester. Open-ended design project.	Open-ended design project in an Introduction to Engineering course.	Students had a very slight drift toward fixed mindset and away from growth mindset over the course of their first year. Results were not statistically significant but did show a small effect size (fixed: $p=0.265$ , $ d =0.135$ ; growth: $p=0.282$ , $ d =0.113$ ). In the semester after the intervention students had a shift toward growth mindsets.
[17]	Mixed, four-part intervention over one semester. Open-ended creative assignments.	Four open-ended creative assignments given to students in an engineering statistics course, e.g. make your own exam questions.	Fixed mindset was negatively related to performance on the real-world probability assignment, and positively related to performance in the statistical independence assignment. Creative self-efficacy was negatively related to performance on Assignment 3, which was designed to test students' motivation and ability to search for different solutions to a well-posed problem. Results should be interpreted with caution, as they were examined in only half of the sample, and there was sizable uncertainty in the posterior regression coefficient distribution. There were modest relationships between perceived creativity and actual creativity.

The dominant methodology was quantitative or mixed methods, using existing mindset and belongingness scales, analysis of reflective answers, and focus group discussions to assess students' mindsets. The only qualitative study [9] used thematic analysis of students' written responses to reading group discussions of Dweck's book *Mindset: The new psychology of success*. It could be argued that this study should be excluded since it didn't use a scale to assess students' mindsets. However, it was included because the themes that resulted from analysis of the reading group sessions suggested that students had developed growth mindsets due to the intervention. This was the only included record with a qualitative assessment of mindset.

The results from these nine studies do not provide strong evidence of shifts towards growth mindsets as a result of the interventions aimed at engineering students. Where mindsets were compared to course marks, there was no correlation between growth mindsets and higher academic performance, which agrees with [4]. The thematic analysis in [9] concluded that the growth mindset framework was useful for students' reflections on past experiences and allowed them to project possible changes they would make to strengthen their growth mindsets.

We offer some reasons for why the growth mindset interventions with engineering students did not produce big changes towards growth mindsets. Firstly, engineering

students may already start with growth mindsets, as was the case in [10]. A second reason is that shifting beliefs is often a slow process and most of the included studies reported on results gathered over a semester or a year. Follow-up studies, as planned in [13], may show that growth mindset interventions are effective over longer time spans than a year. A third reason is that there may be a trend for engineering students to develop a fixed mindset in their first year, as observed in [7], particularly in students taking computer science. Interventions may be off-setting the trend towards stronger fixed mindsets.

Finally, interventions that increase growth mindsets have been shown to be most beneficial for students from lower socio-economic backgrounds and minority students [8]. If the trend of increasing diversity in engineering courses continues, growth mindsets interventions may show stronger results from a more diverse population.

### **SUMMARY AND ACKNOWLEDGMENTS**

Developing growth mindsets appears to help in the development of creativity in students even if this does not result in a short-term increase in academic performance. This systematic literature review of growth mindset interventions for engineering students points to a research field that is still developing. Further research, including studies on the same students over more than one year, can help us to understand the complexities of how to develop and assess growth mindsets in engineering students, particularly for engineering classes with a high level of diversity among students. The range of interventions used in the reported studies provide inspiration for new interventions suited to engineering students.

This research is supported by the National Research Foundation (NRF) in South Africa and the Research Office at the University of Cape Town. Opinions expressed, and conclusions arrived at, are those of the authors and are not necessarily to be attributed to the NRF.

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