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Mindset for Software Architecture Students

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Abstract
Software architecture students need to believe that they can change their abilities in order to become proficient with software architecture design. Addressing students' beliefs about their capabilities introduces the realm of mindset. This paper reports about a survey that we conducted in a large university to study a set of factors associated with the students' mindset. The study found that the students' mindsets weakly correlates with their cognitive levels and are associated with their expectations from the course. In addition, it found that the students who prefer practicing software architecture have more open mindset than the ones who prefer quizzes. The findings provide new knowledge about the connections between the mindsets of the students, their perception of software architecture, and their approach to learning software architecture practices. The results could be used to design intervention strategies to improve the ability of the students to learn software architecture.

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Comments
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Mindset for Software Architecture Students

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Abstract—**Software architecture students need to believe that they can change their abilities in order to become proficient with software architecture design. Addressing students' beliefs about their capabilities introduces the realm of mindset. This paper reports about a survey that we conducted in a large university to study a set of factors associated with the students' mindset. The study found that the students' mindsets weakly correlates with their cognitive levels and are associated with their expectations from the course. In addition, it found that the students who prefer practicing software architecture have more open mindset than the ones who prefer quizzes. The findings provide new knowledge about the connections between the mindsets of the students, their perception of software architecture, and their approach to learning software architecture practices. The results could be used to design intervention strategies to improve the ability of the students to learn software architecture.**

I. Introduction

Software architects critically assess the impact of high-level design options and technology choices for their projects [1] and gain cumulative knowledge (architectural design decisions and the resulting design) through experience. Teaching students software architecture is challenging. The students frequently express their lack of confidence (measure of one's believe in their abilities [2]) when designing software architecture. They argue that they do not have experience to do so.

Becoming a software architect is an evolutionary process where the person gradually gains experience and confidence. Students need to believe that they can change their abilities, through practice and reflection, in order to become proficient with software architecture design. Addressing students' beliefs about their capabilities introduces the realm of mindset. Mindset theory posits that people's pre-existing beliefs about intelligence and abilities lie along a continuum that is anchored by the extremes of fixed mindset (incapable of change) and growth mindset (capable of change with effort) [3].

Previous studies in educational psychology have established that mindset is a measurable trait [4]. In educational settings, once a baseline for mindset is established for a given population, interventions can be introduced to manipulate the mindset in that population toward a growth mindset. Educators in science, technology, engineering, and mathematics (STEM) fields have been increasingly interested in understanding students' motivation for learning so that they can help students persist in challenging curricula. Examples of subjects where the mindset of course participants has been examined include pre-calculus [5], computer programming [6], and statistics [7].

We developed a survey to assess the students' mindsets and a set of related factors. We gave the survey to senior undergraduate students who were enrolled in a course on software architecture at a large university in November 2018. The answers of forty-eight students out of sixty responses are found to be of good quality and selected for the study. Then, we used statistical inference techniques to find the association of students' mindsets to their cognitive levels, expectations from the course, preferred learning methods, and confidence.

The contributions of this paper are:

1) We identified a mild correlation between mindset and cognitive level.
2) We found that the students' expectations differentiate their mindset.
3) We found that the students who prefer quizzes and the ones who prefer practice have different mindsets.

The presented findings provide new knowledge about the connections between the mindset of students, their perception of software architecture, and their approach to learning software architecture practices.

The paper is organized as follows. Section II discusses related work, Section III discusses the process used to collect the data, Section IV discusses the data analysis, Section V summarizes the results and discusses their impacts and limitations, and Section VI concludes the paper.

II. Related Work

Clerk et al. [8] studied the mindset of architects in using their architectural knowledge to design software architectures. They found that architects have mindset of positiveness (the architects always take the right decisions) and tend not to use their architectural knowledge to identify potential weaknesses in their designs. They concluded that practitioners have a mindset that does not favor a period of reflection to evaluate their design.

In a study closely related to present work, the relationship between mindset and exam performance was investigated for students enrolled in an accounting course [9]. It was found that the majority of the students (72%) held growth mindsets and there was a mild association between the students' mindset scores and exam scores.

Other studies have assessed the mindsets of course participants and then developed interventions to improve mindset and motivation. In a pre-calculus course, participants in one section of the course received mindset and motivation interventions during the course [5]. The mindset about mathematics improved for the treatment group, but there was no difference in course performance between the control and treatment sections.

There are some indications that student beliefs about intelligence may differ from beliefs about aptitudes for subjects like mathematics [7] and computer programming [6]. Scott and Ghinea [6] found that students can begin to form a more fixed mindset toward programming as the course instruction proceeds. Therefore, it is important for educators to monitor the beliefs and perceptions of their students in order to promote student persistence in introductory STEM courses.

Education-publishing giant Pearson embedded recently messages into their MyLab programming software (a software commonly used in java and C++ courses) to study the impacts of mindset intervention [10]. The study found that the students who received the targeted messages solved less problems than the ones who did not receive such messages. However, the study found that the students who received the growth-mindset messages successfully solved more problems than their counterparts, supporting the idea that encouraging a growth-mindset can help the students to have better results.

III. Data collection

We conducted a quantitative study to assess the relationship between students' mindsets and their cognitive levels, their preferred learning methods, their expectations from the course and their confidence in designing software architecture at the end of the course. The study uses the students' responses to a questionnaire as data source. We discuss in the following the preparation of the study and its conduct.

A. Preparation of the study

We designed a questionnaire to assess the students' mindsets, their cognitive levels, their expectations from the course, their preferred learning methods, and their confidence in designing software architecture.

To assess the students' cognitive levels, we designed a scenario and a set of related multiple choice questions, which are listed in Table I. The table shows the assessment questions and the associated Bloom's cognitive levels [11]. To simplify the survey, we did not include questions at the understand and evaluate Bloom's levels.

TABLE I
Evaluation of the students' cognitive levels.

Scenario	Suppose you have been assigned to extend the architecture of an intelligent transportation system to visualize on a mobile phone the information of a given vehicle. With this scenario in mind, answer the following questions to the best of your ability
	Question
Creation	Given that the project is small, would you use the design process as-is?
Analysis	The customer requested to use an existing access control service. What is the impact of the decision on the requirement: the system shall be available 100% of the time?
Application	The customer requested that the solution ensures secure communication between the vehicle and the central service with limited impact of the performance of the service. How would you solve that?
Remembering	The customer expects frequent modifications after first deployment. Which pattern/tactics would you use to address the need?

TABLE II
Students' mindsets assessment questions [4].

Growth-mindset questions	
1.	Your intelligence is something very basic about you that you can't change very much.
2.	You can learn new things, but you can't really change how intelligent you are.
3.	No matter how much intelligence you have, you can always change it quite a bit.
4.	You can always substantially change how intelligent you are.
Growth-mindset questions	
1.	You are a certain kind of person, and there is not much that can be done to really change that.
2.	No matter what kind of person you are, you can always change substantially.
3.	You can do things differently, but the important parts of who you are can't really be changed.
4.	You can always change basic things about the kind of person you are.

We used the mindset assessment questions developed by Dweck [4], listed in Table II, to assess the students' mindsets. We used a five-point Likert scale [12] for response options for each of the questions. We used the following factors to identify the students' expectations: (1) no expectation, (2) learn about design of architecture, (3) curious about the topic, (4) the course is related to another course, (5) heavy coding, (6) learn about different types of architectures, (7) learn about different architectures styles, (8) related to what they learned in the internship, (9) learn about different design pattern, (10) a theoretical course, (11) a project-based class, (12) learn about software development, (13) learn architecture evaluation, (14) learn about the architecture design process, and (15) learn about the architecture design practices. In addition, we used the following factors to identify the preferred learning methods for each student: (1) group assignments, (2) individual assignments, (3) case studies, (4) reading, (5) in-class group activities, (6) no definitive answer, (7) quizzes, (8) drawing diagrams, (9) evaluate work of peers, (10) learning on own/Internet, (11) assignments, (12) other courses, (13) practice, (14) in-class posters, (15) lectures, and (16) live demo. These factors were identified in an exploratory study [13].

B. Context of the study

Our subjects pool included 80 junior and senior undergraduate students who were enrolled in a course on

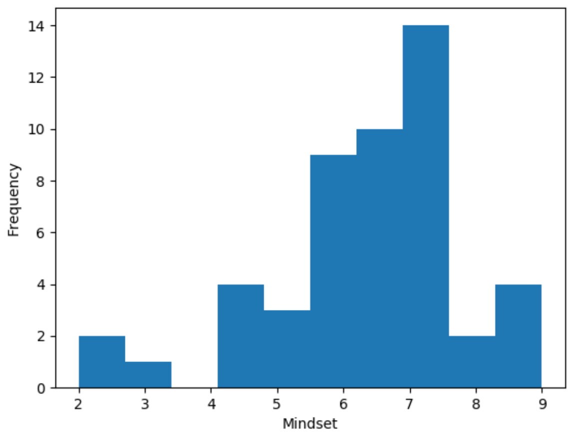

Fig. 1. Frequency of the students' mindset scores.

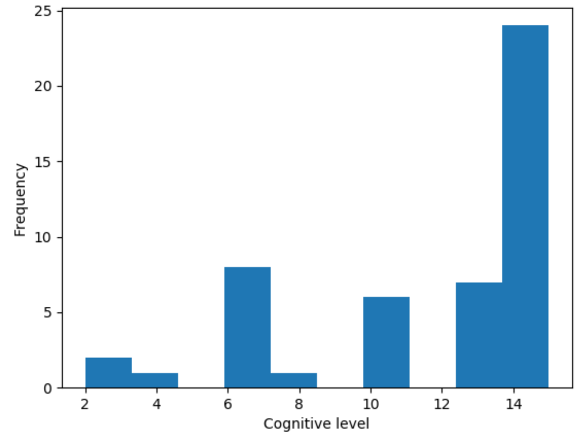

Fig. 2. Frequency of the students' cognitive Levels.

software architecture at a large university in November 2018 (Fall 2018 semester). The course is required for software engineering students and is optional for computer engineering students. An electronic survey that included the questions used in the study was made available to the students. The students submitted their answers anonymously and had to inform the instructor by email to get the bonus points. Sixty students (60) answered the questionnaire. Only the answers of forty-eight students are found to be of good quality and were therefore selected.

We used the method of Ravenscroft et al. [9] to compute the mindset score. We reversed the scores for the fixed-mindset questions, summed up the scores of the eight questions and divided the total by the number of questions, eight.

Equation 1 provides the formula that we used to compute the cognitive level of each student.

$$\begin{aligned}\text{Cognitive\_level} = &\ (\text{Remembering\_score} \times 8) + \\ &(\text{Application\_score} \times 4) + \\ &(\text{Analysis\_score} \times 2) + \text{Creation\_score} \quad (1)\end{aligned}$$

The next section discusses the results obtained from the collected data.

IV. Data analysis

Figure 1 shows the frequency of the student's mindset – a mindset score of 5 or more indicates a growth mindset and a score less than 5 indicates a fixed mindset. The mean of the mindset is 6.26 and standard deviation is 1.48. The students' mindset distribution succeeds the D'Agostino normality test [14] with f-statistic of 19.04 and p-value of 7.31e-05.

We analyze in the following the relationship of the students' mindsets and their cognitive levels, preferred learning methods, expectations from the course, and confidence in designing software architecture.

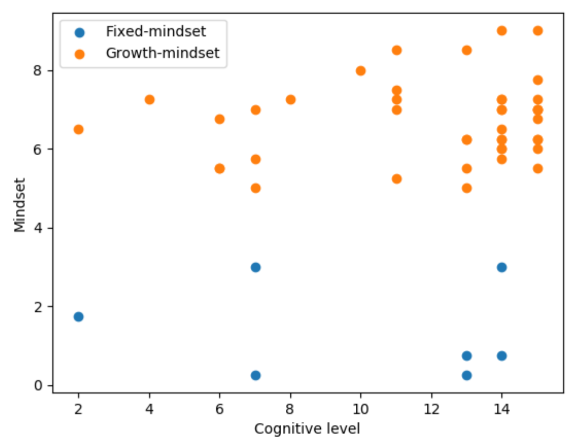

Fig. 3. The relationship between the students' cognitive levels and mindset scores.

A. Relationship of the mindset and cognitive level

The students' mindsets are, in general, weakly correlated with the cognitive levels; the Pearson' correlation coefficient [15] is 0.237 with p-value 0.10. In fact, we can confirm that the students' mindset scores correlate with the remembering cognitive level (coefficient 0.31 and p-value of 0.02) but cannot confirm the correlation of the students' mindset with the other individual levels.

Figure 2 shows the frequency of the cognitive levels of the students and Figure 3 shows the plot of the students' mindset scores as a function of the cognitive levels. We observe that there is a positive tendency of the growth mindset (mindset score higher than 5) and cognitive levels (correlation coefficient 0.149 and p-value 0.34) and negative tendency for the fixed mindset (mindset score

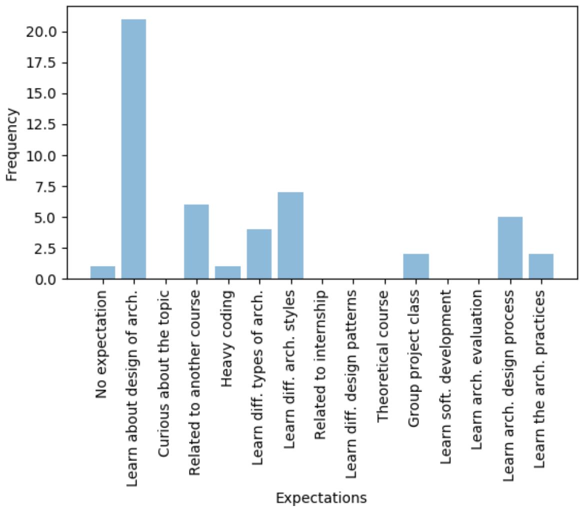

Fig. 4. Frequency of the student's expectations from the course.

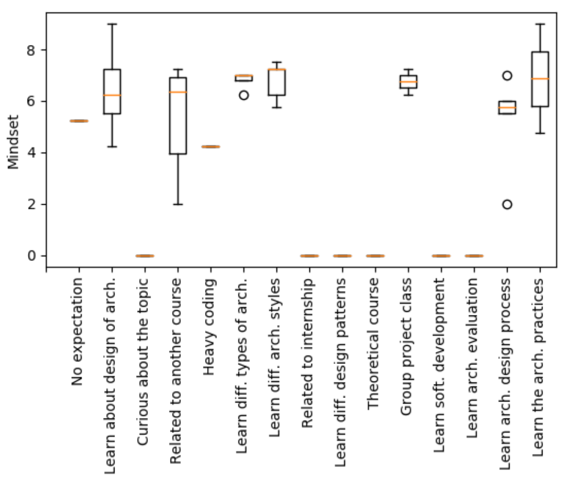

Fig. 5. The relationship of the student's expectation and their mindset scores.

higher than 5) and cognitive levels (correlation coefficient -0.169 and p-value 0.71). The confidence in the tendencies is weak, however, we observe that the students who have high fixed mindset have also high cognitive levels.

B. Relationship of the Mindset and Expectation

Figure 4 shows the frequency of the students' expectations and Figure 5 shows the box-plot of the relationship between the student's mindset scores and their expectations from the course. We observe that the students who expect the course to require heavy coding have the least mindset scores and the students who expect the course to be about architecture design practices have the highest mindset scores. The one-way ANOVA test [11] confirms

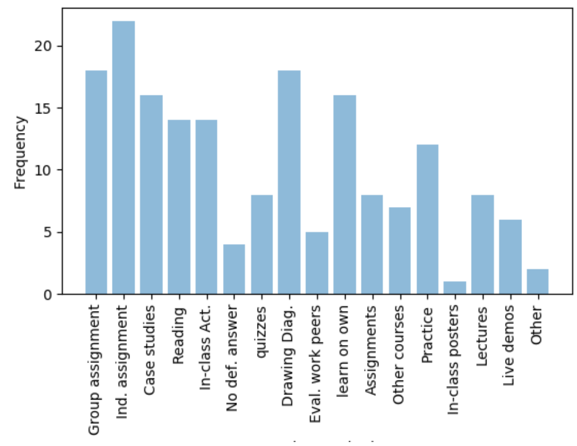

Fig. 6. Frequency of the students' preferred learning methods.

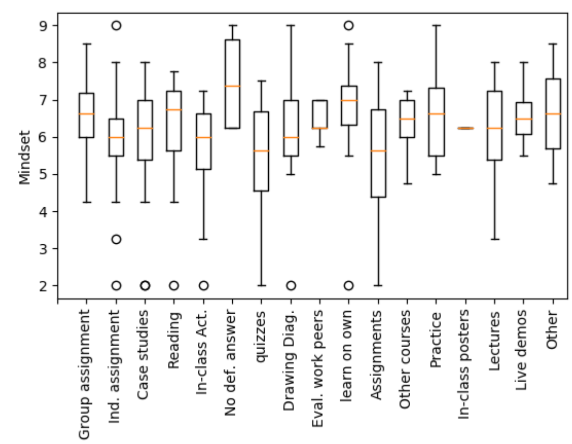

Fig. 7. The relationship of the students' preferred learning methods and their mindset scores.

that student' expectations are related to their mindset scores; the f-statistic is 7.57 and p-value is 2.12e-07.

C. Mindset and learning methods

Figure 6 shows the frequency of the students' preferred learning methods and Figure 7 shows the box-plot of the relationship between the students' mindset scores and their preferred learning methods. We observe that the students who do not have definite answer have the highest mindset score mean and the students who prefer quizzes and assignments have the lowest mindset score mean. We cannot, however, confirm using one-way ANOVA that the preferred learning methods discriminate the students' mindset scores as we may expect; the obtained f-statistic is 1.033 and p-value is 0.42. Using t-test, we found, however, that the students who prefer practicing software architecture have higher mindset scores (mean 6.62) than the ones who prefer quizzes

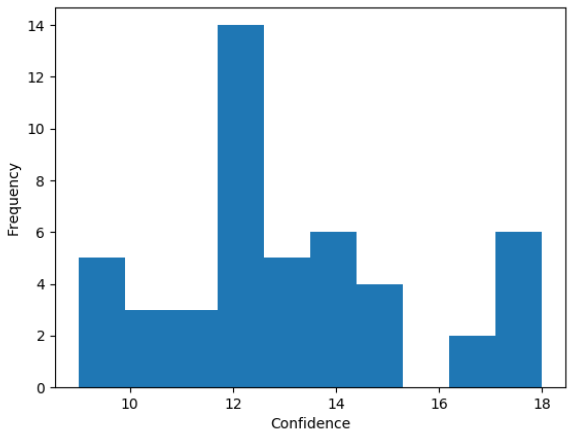

Fig. 8. Frequency of the students' confidence in designing software architecture.

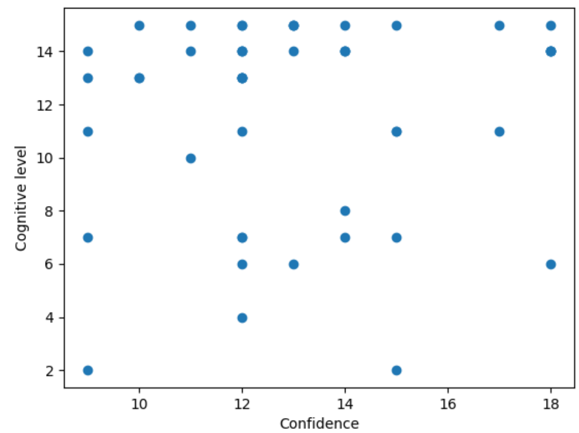

Fig. 10. The relationship of the student's confidence and their cognitive levels.

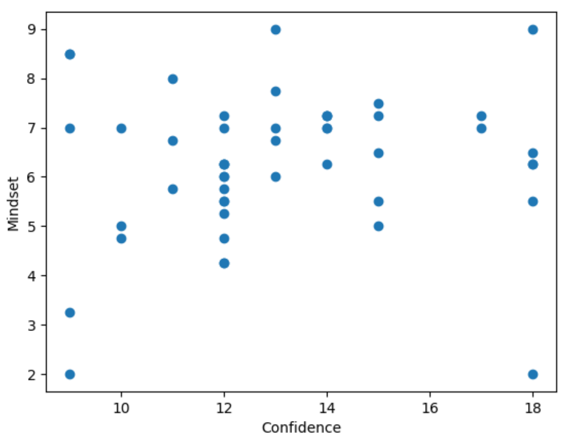

Fig. 9. The relationship of the student's confidence to design software architecture and their mindset scores.

(mean 5.34); the obtained p-value is 0.08, and Cohen size effect is 0.80.

D. Relationship of the mindset and confidence

Figure 8 shows the frequency of the students' confidence to design software architecture and Figure 9 shows the plot of the mindset as a function of the confidence. We observe that the data are dispersed. The coefficient of the Pearson's correlation of the confidence and student's mindset scores is 0.10 with p-value of 0.47. Therefore, we cannot confirm that there is a weak correlation between the confidence and students' mindset scores.

Figure 10 shows the plot of the confidence and cognitive levels of the students. The plot shows again that the data are dispersed. The coefficient of the Pearson's correlation of the confidence and student's cognitive levels is 0.10 with p-value of 0.47. Therefore, we cannot confirm that there is a weak correlation between the confidence and students' cognitive levels as we may expect.

V. Discussion

This section summarizes the results and discusses their impacts and limitations.

A. Summary

We analyze in this paper the relationship of the students' mindsets and their cognitive levels, preferred learning methods, expectations from the course, and confidence in designing software architecture. It turns out that the mindset scores are normally distributed (succeeded the normality test) but, in average, the students have a mild growth mindset. We found that the students' mindsets weakly correlates with their cognitive levels and are related to the students' expectations. We couldn't confirm, however, the relationship between the preferred learning methods of the students and their mindsets, except that the students who prefer practicing software architecture have more open mindset (their mindset scores are higher) than the ones who prefer quizzes. We also couldn't confirm the existence of a relationship between the students' confidence to design software architecture and their mindsets. Figure 11 depicts these relationships.

B. Impacts of the results

The findings in this work contribute new knowledge about the connections between mindset and the choices that students make when studying software architecture. The relationship between study preferences and mindset can be used by software engineering educators as they seek to develop meaningful learning activities and formative assessments for their students in upper-level courses. This kind of baseline assessment of mindset may provide a foundation for curricular change at the

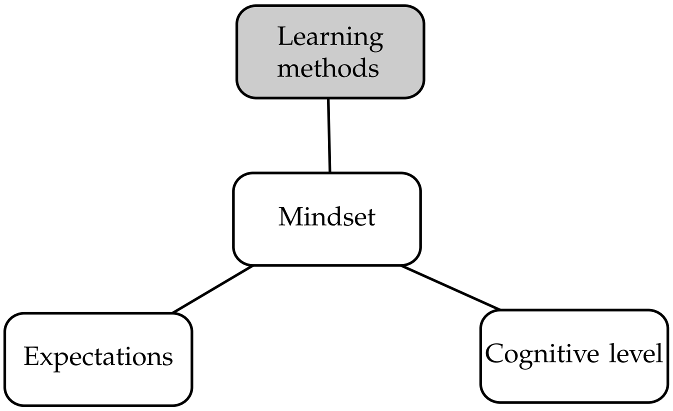

Fig. 11. Mindset and related factors.

department level. More broadly, it would be interesting to build on this work by replicating the survey in software architecture courses across institutions to identify possible relationships between curricular approaches (for example, a department that uses project-based learning or team-based learning) and mindset in third and fourth year engineering students.

C. Limitations of the study

The survey is offered to all the students at the same time, which limits the impacts of selection bias and instrumentation threats. In addition, the history, mortality, and maturation threats do not apply to this study [16].

The number of students who participated in the survey is forty-eight, which is good number to generalize the results for the same context: same university and same course. However, the study was performed in only one semester in one university. This may limit the generalization of the results to other institutions.

VI. Conclusion

We conclude that the students' mindsets are weakly correlated with their cognitive levels and are also associated with their expectations from the course, and the students who prefer practicing software architecture have higher growth-mindset than the ones who prefer quizzes. The findings could be used in the future to design intervention strategies to improve the ability of the students to learn software architecture.

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