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# Vocational High School Students' Engineering Epistemological Beliefs*

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This study investigates the engineering epistemological beliefs (EEB) of Turkish vocational high school students. The goal of this research is to reveal changes in these beliefs across grade levels, discipline, and gender. The present study included 314 vocational high school students from five schools in two Turkish cities. A Turkish version of the epistemological belief assessment for engineering (EBAE) questionnaire was created and used to assess student EEBs. Descriptive results indicated that as grade increased, average scores of students' EEB decreased with respect to almost all dimensions of the EBAE. Males reported more sophisticated beliefs than females for all EEB dimensions except for justification for engineering knowing. Participants studying the metal technology discipline reported the most naïve EEB, while those studying information technologies displayed the most sophisticated beliefs. The results of inferential statistics showed that while the effect of gender, discipline and grade level were not significant with students' EEB, the effect of interaction of grade level and discipline on students' EEB was statistically significant. This study implies that the vocational school curricula in Turkey should be reconsidered in terms of student engineering epistemological growth.

**Keywords:** epistemological beliefs; engineering epistemological beliefs; vocational high school

## 1. Introduction

Epistemological beliefs are defined as how people view knowledge and knowing [1, 2]. Students' views of knowledge, knowing and learning affect their conceptual learning [3–5], text comprehension [6, 7], academic performance [8], and learning approaches [9–11]. Several researchers have investigated the factors affecting epistemic understandings to better understand how epistemic understandings play a role on the learning process and how epistemological beliefs can be changed. It was found that domain [12–14], grade level [14, 15], and gender [14–16] influence students' epistemological beliefs. Most studies indicate that when the grade level increases, students' epistemological development is improved as well [8, 14, 15, 18, 19]. Such a consensus has not been observed within the literature regarding gender differences; some studies observe females to have more sophisticated epistemologies [8, 14, 17], some favor males [16], and others report no observable gender differences [18]. For example, Schommer [8] and Paulsen and Wells [16] found that male students were more likely to believe in quick learning and fixed ability, but Paulsen and Wells [16] also observed that male students were more likely to show sophisticated epistemologies in simple knowledge.

Considering students' epistemological views as a research area has attracted engineering education researchers' attention as well [e.g. 20–23]. A special report in 2006 by Adams et al. [24] suggested five research areas for promoting a new discipline of engineering education. One proposed area in this report is *research on engineering epistemologies*, "what constitutes engineering thinking and knowledge within social contexts" [24, p. 259]. This call also brings to the forefront the necessity of investigating students' personal epistemologies related to engineering knowledge and knowing. Examining students' epistemological views are also emphasized in another research area in the same report: *research on engineering students' learning mechanism*, which includes their views about the nature of engineering knowledge and knowing. Students' engineering epistemologies have influence on how well they learn and what approaches they take to learn engineering, which can be used to redesign engineering curricula.

Few studies have addressed the research area of engineering epistemologies. This was clearly demonstrated in a content analysis of worldwide engineering education journals conducted by Chou and Chen [25]. Their analysis revealed the theme of engineering epistemologies has been less studied compared to the themes of engineering students' learning processes and the development of the engineering curricula based on frequently cited articles in engineering education. An example of a study that did key on personal epistemologies discussed the creation of learning environments to improve engineering students' competencies of collaborative technologies in global engineering [26]. This study urged the importance of understanding


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students' personal epistemologies to deal with their difficulties in such environments.

A major issue with most of the engineering education literature investigating students' epistemological views has been the reliance on Perry's scheme [e.g., 20, 27, 28]. This theoretical framework considers students' personal epistemologies as unidimensional. A great deal of research following Perry's work supports the multidimensional form of personal epistemologies [1, 9, 13, 29]. There is clearly a need for studies to discuss the sophistication of students' beliefs on multiple dimensions of personal epistemologies and interrelations among the dimensions.

In Turkey, many studies have been conducted to identify students' epistemic beliefs [30], but few have been carried out on students at the vocational school level. Vocational high schools deliver vocational training with the main objective of teaching specific technical skills. Nearly all studies conducted in Turkey on epistemic beliefs have been conducted via the "Epistemological Belief Questionnaire," which was developed by Schommer [31] and adapted for Turkish researchers by Deryakulu and Buyukozturk [32]. The present study is expected to make a substantial contribution to the associated literature by being the first study of Turkish vocational high school students' epistemological beliefs specific to engineering. It is estimated that this study will serve as a foundation to initiate future studies on engineering epistemologies at the high school level.

The following study investigated 10th, 11th and 12th grade vocational high school students' engineering epistemological beliefs and how these beliefs vary across grade levels, discipline, and gender. This study addresses the following research question: *What is the effect of grade level, discipline, and gender on vocational high school students' engineering epistemological beliefs?*

### *1.1 Personal epistemologies*

Personal epistemologies are defined as individuals' understanding of the nature of knowledge and knowing [1]. Based on this definition, personal epistemologies in engineering can be defined as individuals' understandings about the nature of engineering knowledge and knowing. Various researchers have developed different models to explain students' personal epistemologies [1, 29, 33–36]. These studies stem from Perry's [19] seminal work in which he introduced a theoretical scheme related to students' views about knowledge and values by indicating evolution in their interpretation of their experiences across their four years in a liberal arts college education. Perry argued that students' epistemological stances were evolved from absolutistic to relativistic views of the world. Students began by perceiving knowledge as certain and absolute, a quantitative collection of discrete items, and that the authority knows everything. Over the course of their education, students began to perceive knowledge as relative, contextual, and that the knowledge of authority is relative.

Hofer and Pintrich [1] proposed a different framework based on the review of the studies addressing students' epistemological views. They conceptualized personal epistemology into two dimensions: *the nature of knowledge and knowing*. The nature of knowledge dimension is also subdivided into the *certainty of knowledge* and *simplicity of knowledge*. The certainty of knowledge refers to the degree in which individuals view knowledge as fixed as opposed to fluid. The simplicity of knowledge refers to the degree in which individuals view knowledge as an accumulation of facts as opposed to highly interrelated concepts. The nature of knowing is also subdivided into the *source of knowledge* and *justification for knowing*. The source of knowledge refers to the degree in which individuals see knowledge as existing outside one's self, residing within an external authority, and transmitted from an authority to a learner as opposed to being constructed by the learner via interaction with others. The justification of knowledge refers to the degree in which individuals evaluate knowledge claims by using evidence or acceptance of authoritative facts [1, pp 119–120]. In this study, the students' epistemological sophistications were investigated using an instrument developed by Carberry, Ohland, and Swan [37] based on the epistemological model of Hofer and Pintrich [1].

### *1.2 Research on engineering epistemologies*

The literature review conducted for this study revealed a relatively low number of studies conducted in engineering domains to examine students' epistemological beliefs compared to other domains. Findings from these studies suggest students' epistemological beliefs are generally below expected sophistication levels and should be addressed by educators.

Marra and Palmer [20] probed the epistemological sophistication of 19 senior engineering college students' using Perry's scheme. They found that nine of the 19 students demonstrated low levels of epistemological development, while ten students indicated high levels of epistemological sophistication. The researchers also investigated similarities and differences between these two groups of students in terms of their views about teaching and learning, group work, and problem solving. Both groups favored teaching and learning experiences that lead to a certain amount of intellectual independence and group work as opposed to passively listening to faculty lecture. Although the two groups seemed to have similar beliefs about teaching and learning, the researchers argued that the underlying reasons for those beliefs might be different. They hypothesized that students holding naïve epistemological beliefs favored student-centered learning environments, but also valued the authority guiding them to find the truth. Students demonstrating sophisticated epistemological beliefs valued the facilitator role of teachers as a resource for their own construction of knowledge. The groups did differ in their perceptions related to problem solving. All students in the sophisticated group described the problem solving process using ill-structured problems, while only four students in the naïve group referred to ill-structure problems.

King and Magun-Jackson [15] investigated the effect of grade level on graduate and undergraduate engineering students' epistemological understandings when the effects of their gender, ethnicity, and high school grade point average were controlled. They found that first and second-year students indicated more naive beliefs than third and fourth year students in quick learning and certain knowledge. No significant differences were observed between graduate and undergraduate students' epistemological beliefs; however, differences were seen between gender, high school GPA, and ethnicity.

Lin and Tsai [38] examined the relationship between undergraduate engineering students' views about learning and their learning environment preferences. They found that students conceptualizing learning engineering as testing, calculating, and practicing tended to adopt the classroom learning environment. Those conceptualizing learning engineering as applying, understanding, and seeing adopted laboratory learning settings.

Carberry, Ohland, and Swan [37] investigated first-year engineering students' general engineering epistemological beliefs using Hofer's and Pintrich's [1] epistemological framework. Their participants demonstrated slightly sophisticated engineering epistemological understandings. Their sophistication toward the nature of engineering knowledge was slightly greater than that toward the nature of knowing engineering.

### *1.3 The context of vocational education in Turkey*

Vocational education all over the world is important in ensuring the future workforce learns a high level of technical skills [39]. Vocational schools educate students in line with general secondary education. In Turkey, high school lasts four years (grades 9–12) and is typically attended when students are 15–18 years old. There are various types of high schools, but three types of high schools are most prevalent: regular (generally called Anatolia school), science, and vocational schools. In Turkey, after the eighth grade level, all students take a high-stakes national exam. Students scoring highest on this exam generally enroll in science or regular high schools. Those who obtain moderate and low scores enroll in regular or vocational high schools. Vocational high schools prepare qualified students for various professions or for higher education in specialized areas. For example, vocational high schools offer courses such as information technology, ceramics, electrical science and engineering-electronics, metal technology, construction technology, and library science, which are not available to those enrolled in the regular or science high schools. The secondary education schools offering vocational and technical training enclose compulsory courses in the 9th grade. Students are allocated to job families in the 10th grade, occupational branches in the 11th grade, and attend to these branches in the 12th grade prior to graduation [40].

Their weekly course hours, depending on the discipline and the grade, range between 35 to 48 hours. All Turkish students in 9th grade are subjected to the same curriculum, but differ substantially as they progress through the remaining three years. For instance, while students in the information technologies discipline learn computer circuit designs and system control applications, students in construction technology learn cement tests and architectural project drawings in 11th and 12th grade [41]. Vocational high school graduates obtain the same degree as traditional high school graduates, but are taught required skills for specific jobs. Students who complete all four years of a vocational high school and succeed in the national exams at the end of the 12th grade generally continue their education at a college or university.

## 2. Methods

### *2.1 Research design*

A quantitative approach was utilized to investigate the effect of grade level, discipline, and gender on vocational high school students' engineering epistemological beliefs. Data were gathered from students in the second semester of the 2014–2015 academic year using a written questionnaire. Data collected from the quantitative questionnaire was analyzed, using SPSS software, to gauge students' epistemological beliefs about engineering.

### *2.2 Participants*

A convenience sampling method was used to access participant students. Three hundred and fourteen vocational high school students, ranging in age from 16 to 18 years old, from five vocational high schools in Ankara and Samsun cities of Turkey took part in the present study. These schools were chosen to study engineering epistemological beliefs at the high school level because science and mathematics curricula in Turkey do not typically include engineering concepts. Vocational school disciplines such as construction technology, electric and electronic, and information technologies include sufficiently more concepts and applications connected to the engineering domain. Only 42 of the 314 (13%) participants were female due in part to low numbers of females in Turkish vocational schools. The participants included students in 10th grade (n = 50), 11th grade (n = 97), and 12th grade (n = 167). Students belonged to five different disciplines of the vocational high school: electric-electronic (n = 99), metal technology (n = 10), information technologies (n = 147), construction technology (n = 40), and chemical technology (n = 18). The schools were identified and chosen to provide a range of socio-economic statuses.

### *2.3 Instrument*

The epistemological belief assessment for engineering (EBAE) questionnaire established and validated by Carberry et al. [37] with first-year engineering students was used in this study. The questionnaire consists of 13 items on a five-point Likert scale ranging from 1: Strongly Disagree to 5: Strongly Agree. It includes items pertaining to four dimensions or factors: certainty of engineering knowledge, simplicity of engineering knowledge, source of engineering knowledge, and justification of engineering knowledge. Each factor comprised of three items except for the last factor, which consisted of four items.

Numerous steps were undertaken to ensure the instrument was valid for vocational high school students in Turkey. First, two university English language instructors teaching English language prep school classes independently translated the EBAE into Turkish. They then cooperatively provided a final decision about the translations. The Turkish version of the questionnaire was initially administered to three students in order to avoid misunderstanding of the items. Each student was instructed to think-aloud while completing the questionnaire to ensure the translated instrument was clear and accurate. Minor corrections were made on the questionnaire prior to administration to the larger sample of 314 students. Factor analysis was conducted on the collected data revealing four factors (including 4, 4, 3 and 2 items), which varied from the original hypothesis. This was not unexpected because of variations in the new sample's age, year in school, and geographical location. Items grouping in these factors were so diverse that denominating was difficult. Reliability of the original 13 items was computed and observed to be Cronbach's alpha = 0.77.

### *2.4 Data analysis*

Descriptive and inferential statistics were used to analyze all data. Mean score statistics for grade level, gender, and discipline across dimensions of the EBAE were calculated. The aim of the study was to reveal the effect of grade level, discipline, and gender on vocational high school students' engineering epistemological beliefs. A factorial MANOVA technique was used to determine the effect of grade level (two levels), discipline (five levels) and gender (two levels) on students' EEB (four levels). Thus, this is a $2 \times 5 \times 2$ factorial design with three independent variables. MANOVA was used to compare the groups and reveal whether the mean differences between the groups differ on the combination of dependent variables [42]. Significant results obtained from MANOVA required ANOVA analyses to find whether independent variables differ on all levels of the dependent variable. If the ANOVA analysis was significant among the groups, the subsequent Bonferroni post-hoc analysis was run to determine where the specific differences existed.

## 3. Results

Initial descriptive statistics were carried out in order to disclose the item average scores on each factor of the Turkish-EBAE for each grade level, discipline, and gender. Inferential statistics were then utilized to test whether the effect of grade level, discipline, gender and the interactions among the three independent variables were statistically significant.

Students' averages on the four dimensions of EBAE are indicated in Table 1. The mean overall scores were 3.23 on certainty of engineering knowl-

**Table 1.** Mean statistics of EBAE's dimensions for each grade

| Grade | Certainty | Simplicity | Source | Justification | Mean |
|---|---|---|---|---|---|
| 10 | 3.38 | 3.35 | 3.43 | 3.65 | 3.45 |
| 11 | 3.23 | 3.22 | 3.04 | 3.92 | 3.35 |
| 12 | 3.07 | 3.02 | 3.14 | 3.34 | 3.14 |
| All | 3.23 | 3.20 | 3.20 | 3.63 | 3.32 |

edge, 3.20 on simplicity of engineering knowledge, 3.20 on source of engineering knowing and 3.63 on justification for engineering knowing. These values indicate that vocational high school students in all grades reported moderate beliefs with respect to all dimensions of EBAE.

Average scores of students' EEB decreased with respect to almost all dimensions as grade level increased. For students' beliefs about "justification for engineering knowing," 11th grade students (M = 3.92) had more sophisticated beliefs than 10th (M = 3.65) and 12th (M = 3.34) graders. 12th grade students had the most naïve beliefs on "the simplicity of engineering knowledge" (M = 3.02) when compared to all other dimensions for all grade levels.

Ratings for each of the four dimensions of EBAE across gender are listed in Table 2. The data shows that except for "justification for engineering knowing," males on average (M = 3.26) reported more sophisticated beliefs than females (M = 3.15) for all dimensions.

An analysis across disciplines in Table 3 revealed participants in the metal technology discipline to display the most naïve EEB (M = 2.97), while those in information technologies displayed the most sophisticated beliefs (M = 3.33) (see Table 3). Justification for engineering knowledge across the entire sample was shown to be scored much higher than the remaining factors—certainty (3.08), simplicity (3.03) and source of engineering knowledge (3.08)—which were all similar.

Finally, Table 4 presents vocational school students' beliefs about engineering represented by the percent of respondents who endorsed each possible response (1 to 5); items are listed in order of mean

**Table 2.** Descriptive statistics of EBAE's dimensions for female and male students

| Gender | Certainty | Simplicity | Source | Justification | Mean |
|---|---|---|---|---|---|
| Male | 3.16 | 3.15 | 3.23 | 3.49 | 3.26 |
| Female | 3.12 | 2.98 | 2.99 | 3.52 | 3.15 |

**Table 3.** Descriptive statistics of EBAE's dimensions for disciplines

| Discipline | Certainty | Simplicity | Source | Justification | Mean |
|---|---|---|---|---|---|
| Electric-electronic | 3.13 | 3.14 | 3.25 | 3.47 | 3.25 |
| Metal technology | 3.03 | 2.83 | 2.83 | 3.20 | 2.97 |
| Information technology | 3.25 | 3.19 | 3.23 | 3.63 | 3.33 |
| Construction technology | 3.11 | 3.05 | 3.17 | 3.33 | 3.17 |
| Chemical technology | 2.89 | 2.96 | 2.93 | 3.35 | 3.03 |
| All | 3.08 | 3.03 | 3.08 | 3.40 | 3.15 |

**Table 4.** Descriptive statistics of EBAE's items

| Items | Mean (SD) | 1 & 2 | 3 | 4 & 5 |
|---|---|---|---|---|
| 4. Engineering involves more than collecting information and developing solutions. | 3.87 (1.29) | 16.2 | 15 | 68.8 |
| 7. If an engineering student is having trouble in an engineering course, studying in a different way could make a difference. | 3.74 (1.31) | 18.8 | 18.5 | 62.7 |
| 1. There is often an ideal solution for engineering design problems. | 3.66 (1.27) | 19.4 | 21.7 | 58.9 |
| 11. Engineering students learn best when a teacher or expert transmits his or her knowledge to them. | 3.70 (1.23) | 16.9 | 24.5 | 58.6 |
| 10. Students usually understand engineering better when they present their solutions to their classmates and teachers. | 3.57 (1.31) | 22.3 | 19.4 | 58.3 |
| 6. A good engineering textbook should show how the material in one chapter relates to the material in other chapters. | 3.63 (1.24) | 17.5 | 26.1 | 56.4 |
| 13. Being good at engineering is a talent someone is either born with or not. | 3.55 (1.45) | 24.2 | 20.1 | 55.7 |
| 9. Most people can learn to think more like an engineer if they are given enough time. | 3.35 (1.34) | 26.4 | 25.2 | 48.4 |
| 3. In most instances, traditional engineering ideas should be considered over new ideas. | 3.22 (1.33) | 31.5 | 22.6 | 45.9 |
| 12. Engineering textbooks written by engineering experts present the best way to learn engineering. | 3.26 (1.29) | 28.7 | 25.8 | 45.5 |
| 2. Most engineering principles are set in stone and cannot be argued or changed. | 2.75 (1.27) | 40.1 | 30.3 | 29.6 |
| 8. Someone who lacks natural engineering ability most likely cannot learn engineering. | 2.59 (1.40) | 51 | 21.7 | 27.4 |
| 5. When engineers don't understand an engineering concept, they should just ignore it and move on. | 1.87 (1.32) | 74.2 | 10.2 | 15.6 |

Note: Items 1, 2, 3, 5, 8, 11, 12 and 13 are reverse coded.

score. Responses for 1 and 2 were grouped together because they both represent disagreement. Responses for 4 and 5 were grouped together because they both represent agreement. We can categorize the level of beliefs as: sophisticated—70% or more; moderate—40–70%; and naïve—below 40%. None of the items revealed students having sophisticated beliefs, but ten of the items displayed moderate beliefs compared to three items displaying naïve beliefs. On the item basis, the fourth item referring to "engineering involving more than collecting information and developing solutions" was rated highest (M = 3.84) and the fifth item referring to when "engineers don't understand an engineering concept, they should just ignore it and move on" was scored the lowest (M = 1.83).

Inferential statistics were demonstrated by carrying out a two-way MANOVA to assess the effect of grade level, discipline, and gender on students' EEB (Table 5). Assumptions of MANOVA—normality, independence of observations, homogeneity of covariance matrices of each group, and the random and independent sampling from the population – were tested. Kolmogorov-Smirnov test result was significant in all dimensions of EBAE indicating non-normal distributions. Homogeneity of covariance matrices for each group was not violated due to the insignificance of Box's M test (p = 0.082). Pillai's trace was utilized for the analysis of MANOVA because the normality assumption was not met, and it is more robust to violations [43].

MANOVA starts with the analysis of the main effects, i.e., the effect of each independent variable on the dependent variables, ignoring the effects of all other independent variables. MANOVA results for the main effects indicated that gender was found to have no influence on the students' overall engineering epistemological beliefs. Similarly, no difference was found between the students in terms of the dimensions of EBAE with regard to their discipline or gender.

Next, interaction effects, or the dependence of effect of one independent variable on the different levels of a dependent variable, were analyzed. This analysis assesses whether there are differences in students' engineering epistemological beliefs that are dependent on the binary combination of gender, grade, and discipline. Table 5 demonstrates that no significant influence of interaction of discipline and gender or grade level and gender on students' EEB were revealed; however, there was a medium significant effect of interaction of grade level and discipline on students' EEB. This suggests that students' EEB differ across discipline when taking the grade levels into account. The moderate effect is based on the Cohen's conventions for effect sizes; $\eta^2 = 0.01$ (small), $\eta^2 = 0.06$ (medium), and $\eta^2 = 0.14$ (large) effects [44].

ANOVA tests between subjects were employed to test the effects of independent variables on each dimension of EEB. The $\alpha$ level was adjusted to prevent from committing Type I error using Bonferroni's correction in which $\alpha$ level is divided by the number of dependent variables [42]. An initial $\alpha$ level of 0.05 was chosen for the analysis. The adjusted alpha value for ANOVA analysis was reduced to $\alpha = 0.0125$ because there were four dependent variables. No significant effects of the three independent variables—grade level, gender, and discipline—on each dimension were revealed for the adjusted $\alpha$ level; however, there was a significant effect of interaction of grade level and discipline on students' certainty of engineering knowledge and on justification for engineering knowledge (Table 6). This suggests that the effect of grade level on the EBAE dimensions for students

**Table 5.** MANOVA results for grade level, gender, and discipline, including their interactions

| Effect | Pillai's Trace | F | df | p | $\eta^2$ |
|---|---|---|---|---|---|
| gender | 0.003 | 0.181 | (4, 215) | 0.948 | 0.003 |
| grade | 0.065 | 1.817 | (8, 432) | 0.072 | 0.033 |
| discipline | 0.045 | 0.624 | (16, 872) | 0.866 | 0.011 |
| gender * grade | 0.009 | 0.238 | (8, 432) | 0.984 | 0.004 |
| gender * discipline | 0.075 | 1.399 | (12, 651) | 0.161 | 0.025 |
| grade * discipline | 0.052 | 2.929 | (4, 215) | 0.022 | 0.052 |

**Table 6.** Results of between subjects analysis by grade-discipline

| Independent Variables | Dependent Variable | Sum of Squares | df | Mean Square | F | p | $\eta^2$ |
|---|---|---|---|---|---|---|---|
| grade * discipline | certainty of engineering knowledge | 46.555 | 1 | 46.555 | 8.077 | 0.005 | 0.036 |
| | simplicity of engineering knowledge | 11.413 | 1 | 11.413 | 2.307 | 0.130 | 0.010 |
| | source of engineering knowledge | 3.158 | 1 | 3.158 | 0.550 | 0.459 | 0.003 |
| | justification for engineering knowledge | 73.453 | 1 | 73.453 | 6.391 | 0.012 | 0.028 |

Note: Only significant interactions are included in this table.

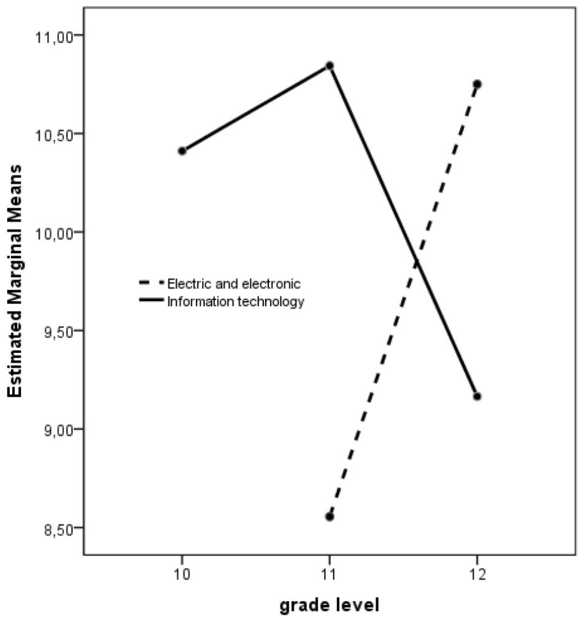


**Fig. 1.** Interaction of grade level and discipline for the certainty of engineering knowledge.

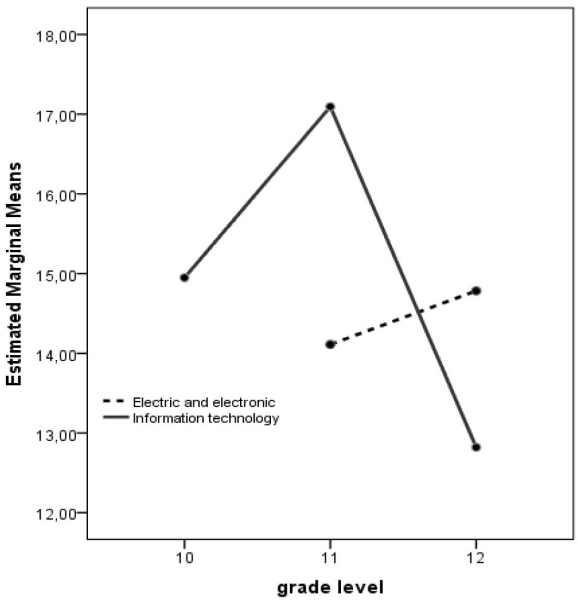


**Fig. 2.** Interaction of grade level and discipline for justification for engineering knowledge.

in different disciplines are not the same. The two effect size ($\eta^2$) values for significant interactions show small to moderate effect of grade level and discipline on students' beliefs about certainty and justification of engineering knowledge.

The plots of the mean EEB scores for each combination of groups of grade level and discipline are plotted in a line graph, as shown in Fig. 1 and Fig. 2. The interaction plot shown in Fig. 1 suggests that as the grade level changes from 11th to 12th, the certainty of engineering knowledge for students in the electric and electronic discipline increases, but information technologies decreases. Similarly, Fig. 2 indicates that as the grade level changes, the justification for engineering knowledge for students in electric and electronic remains the same, while the information technologies students again decreases. In both figures, the mean scores of electric and electronic disciple at 10th grade do not appear because no students from this discipline participated at that grade. Other disciplines do not appear in the figures because no interactions exist.

## 4. Discussion

The main goals of this study were to analyze what effects grade level, discipline, and gender might have on vocational high school students' engineering epistemological beliefs. Our first step in reaching this goal was to create a Turkish instrument to assess engineering epistemological beliefs and to provide an assessment of the engineering epistemological beliefs held by 10th, 11th and 12th grade vocational high school students in Turkey. A modified instrument developed using Carberry et al.'s [37] EBAE as a template was created, tested, and used to reveal four factors—certainty, simplicity, source, and justification for engineering knowledge—of students' beliefs regarding the nature of engineering knowledge. Previous validation of the English version of the instrument was utilized and leveraged in the validation of the Turkish-EBAE.

The results from the Turkish-EBAE were the basis for analyzing our dependent variable effects. Findings from the inferential statistics presented demonstrate the main effect of discipline and grade level on students' EEB to not have a significant impact. The interaction between grade level and discipline did have a significant impact on two dimensions of the EBAE. This suggests that the effect of grade level on the EBAE dimensions for students in different disciplines are not the same. For example, information technology students in 11th grade displayed a high mean score in the certainty of engineering knowledge, while students in the electric and electronic discipline displayed low mean scores. This trend flipped in the same disciplines at 12th grade. Likewise, at 11th grade students in the information technology discipline displayed a significantly high mean score in the justification for engineering knowledge, while students in electric and electronic discipline have low mean scores. Again, the reverse condition existed for students in these disciplines at 12th grade. We hypothesize that this finding may be directly connected to the changes in curricula after 9th grade, when students begin to take discipline specific courses. It may serve the various disciplines well to discuss across disciplines what opportunities they are providing within each major map to identify why this interaction effect emerged.

A change of students' epistemological views across grade levels varied among engineering disciplines. Students' epistemological sophistication increased across grade for the electric and electronic students. This result confirmed the findings of others that indicated a positive effect of grade level on students' epistemological sophistication [8, 14, 15, 18, 19, 33]. This same trend was not seen for the information technology discipline, where a negative impact of grade level was observed across 11th and 12th grades. In the information technology discipline, 11th grade students displayed a significantly higher mean score than 12th grade students in the justification for engineering knowledge and the certainty of engineering knowledge. Student epistemological sophistications in the remaining disciplines did not change when the grade level increased. This might imply that the curricula used in those disciplines had no effect on students' epistemological beliefs. Similar findings were observed in studies investigating the effect of educational experiences on students' epistemological understandings [47–49] and are compatible with the results of Schommer and Walker [46] who found no difference in epistemological beliefs between students in social sciences and mathematics. These results also support the studies indicating domain-dependence of epistemological beliefs [12–14]. One explanation for domain-dependence found in the present study can be that all students were studying a technological discipline, so their educational experiences might not vary enough to lead to significant changes in their beliefs regarding the simplicity and source of knowledge.

The emergent interaction effect between grade level and discipline, as well as the epistemological results across grade levels and disciplines, was accompanied by the unexpected finding that 12th graders overall had the most naïve beliefs in terms of almost all dimensions of the EBAE. This finding suggests that the educational experiences students had across grade levels may have had a negative impact on students' engineering epistemological beliefs rather than providing them with growth opportunities. We hypothesize from this finding that one possible reason for this decline in sophistication is due in part to the traditional teacher-centered instruction used in vocational schools, which does not promote changes in students' epistemological views [50]. Research-based reformed curricula are clearly needed to provide greater opportunities for students to undertake positive epistemological change. The literature suggests some interventions that can have an effect on students' engineering beliefs [28, 45, 51]. For example, Carberry, Siniawski, and Dionisio [45] used a standards-based grading system to assess specifically how well students learned course learning objectives. They found that this alternative assessment increased students' engineering epistemological sophistications. Yalvac, Ayar and Soylu [51] also demonstrated that having students collaboratively produce wiki articles could help them improve their personal epistemologies. A longitudinal study of individual students throughout their four years of high school education would provide additional insights into whether the curriculum is indeed negatively impacting epistemological growth.

Finally, gender did not have a significant impact on epistemological beliefs. Males and females reported similar engineering epistemological beliefs. This finding supports that of Kuhn, et al. [18], but is also accompanied by the caveat that only 13% of our 314 student sample were female. We recognize that a limitation of this study is that the sample sizes for each gender were not similar, but this percentage is very representative of the engineering discipline as a whole.

Overall, our findings suggest that vocational high school students hold moderate engineering epistemological beliefs. This supports our decision to investigate the EEBs of vocational school students because the resulting EEBs are relatively similar to those found by Carberry et al. for first-year engineering students. We hypothesize that Turkish vocational schools are providing valuable opportunities to their students through the vocational school curriculum, which is providing students with opportunities to question their held beliefs and develop moderately sophisticated engineering epistemologies. Students at counterpart regular and science schools are not necessarily provided with the same technical opportunities as vocational school students, which leads us to the assumption that the EEBs of vocational school students are likely more sophisticated than other Turkish high school students. Additional data of non-vocational high school Turkish students is needed to confirm this assumption.

## 5. Conclusion, implications, and future work

Our study can be interpreted to suggest that most students graduating from vocational high schools possess moderately sophisticated engineering epistemological beliefs, but that these beliefs do not progress much beyond the intellectual level at which they entered. Our findings show that students' EEBs decreasing with respect to almost all dimensions as grade level increases indicate that the vocational school curriculum in Turkey should be reconsidered in terms of providing students with opportunities to develop more sophisticated EEBs. The present study indicated that the grade level and domain are important factors on students' epistemological development. It is a widely accepted idea that the further a student progresses in a program the more they learn, which should result in increased sophisticated epistemological beliefs. In contrast, the results of this study have shown that in different domains, the effect of grade level on epistemological understanding might result in either an improvement or regression. This result excites various new research questions, including: What causes different epistemological shifts across grade levels in different disciplines? How do curricula or learning environments of those disciplines differ from each other? Why were negative, positive, and non-epistemological shifts observed within different disciplines? We advise that a series of in depth qualitative studies be undertaken to explore these future research questions, including longitudinal studies of individual students enrolled at vocational, regular, and science high schools in Turkey.

A major outcome of this study is the availability of an engineering-specific epistemological beliefs survey adopted into Turkish, i.e., the Turkish-EBAE. Other researchers and educators can now employ the Turkish-EBAE in cross-cultural studies to make comparisons across institutions, countries, and curricula. The future use of these instruments at both the secondary and higher education levels provides many opportunities for more in depth analysis of students EEBs.

We recognize that a national sample beyond the two cities included in this study would be of great value to see if the patterns hold true more broadly. A larger sample of female students and a greater balance across the disciplines is needed before a comparison between other types of schools (regular and science) can be conducted. This study is a cross-sectional survey study in which students participating in each grade level were not the same students. Therefore, the effect of grade level on epistemological beliefs discussed in this study should be viewed as providing a foundation and interpreted with caution until a longitudinal study of individual students is conducted.

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