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High school students' engagement in science learning: scale adaptation and relationship with epistemological beliefs

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ABSTRACT

Research worldwide is looking for ways to reform science education and increase student engagement in science education. Determining students' engagement in science education can provide insight into the effectiveness of teaching and learning activities. For this reason, the Student Engagement in Science Learning scale, which was previously developed in a different sample, was adapted into Turkish. In this context, a two-way study was conducted. First, the validity and reliability study of the scale was conducted. 625 high school students participated in the study ($M = 16.01$, $SD = 1.21$). The results showed that the scale had good fit values for its four-dimensional and 20-item structure. Then, with the help of the adapted scale, the relationship between engagement in science learning and demographic variables and epistemological beliefs was tested. In this context, it was found that participation in science learning differed in some dimensions of the scale in favour of male students. In addition, the level of participation in science learning varied according to grade level. A weak relationship was found between students' engagement in science learning and epistemological beliefs. The study provides pioneering results in students' engagement in science learning and includes predictions about the variables that must be considered.

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Adaptation; epistemological beliefs; student engagement; science learning

Introduction

Science learning is an important situation that requires students to be able to solve a problem, develop a sense of curiosity about the subject and make decisions accordingly (Bae & Lai, 2020). Therefore, the vision of science learning includes the processes of students understanding the problem and participating in problem-solving processes (Miller et al., 2022). Therefore, students' participation in learning activities is important. Learning engagement refers to students' active participation in learning processes (Reeve, 2013). Encouraging students to participate in learning is one of the main goals of science education (Li et al., 2023). Previous studies have shown that when students actively participate in learning activities, they may continue to participate in science-related learning areas in the future (Fredricks et al., 2016).

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Educational researchers have recognised that students' engagement in science learning is increasingly important (Bae & Lai, 2020). Engagement in science learning is analyzed to determine the degree of students' engagement in science and examined in detail with specific dimensions. Students' cognitive, affective, behavioural, and active engagements in science are the dimensions that constitute science engagement (Chiu, 2021; Li et al., 2023). Researchers in science education have addressed students' engagement in science learning with certain variables other than the specified dimensions. In this regard, it has been stated that socio-psychological student engagement should be addressed by considering classroom, family and community ecologies (Lawson & Lawson, 2013). Student engagement in science learning has been addressed in terms of personal and context factors (gender, class, ethnicity and socioeconomic status) (Bae & DeBusk-Lane, 2019; Fredricks et al., 2019; Gray et al., 2020; Sökmen, 2021). Research in science education continues to identify practical factors to encourage students' engagement in learning (Sinatra et al., 2015). Therefore, students' engagement in science learning environments can inform teaching and learning (Inkinen et al., 2020). This shows that studies investigating students' engagement in science learning should be continued and examined through different variables.

Previous studies have reported that engaging in science learning impacts students' motivation and academic achievement (Sinatra et al., 2015). This has shown that engagement in science learning is critical for learning (Rimm-Kaufman et al., 2015). Accordingly, a proven validity and reliability tool is necessary to measure students' engagement in different science learning environments. However, data collection tools that can measure students' engagement in science learning are specific, and no Turkish tool is available. Therefore, this study aimed to adapt the engagement in science learning scale to Turkish culture. Then, the relationship between students' engagement in science learning and demographic variables and epistemological beliefs was examined using the adapted instrument. Accordingly, the study was structured as Study-1 and Study-2. In Study-1, the Student Engagement in Science Learning (SESL) instrument developed by Li et al. (2023) was adapted into Turkish. In Study-2, Turkish students' engagement in science learning was evaluated in terms of gender, grade level, parental education level and epistemological beliefs.

Rationale for the study

Science education in Turkey is conducted within the framework of a centralised curriculum directed by the Ministry of National Education (MoNE, 2024). It has been influenced by exam-oriented teaching for many years (Yılmaz & Bülbül, 2017). National-level centralised exams, such as the high school transition system and exams for higher education institutions, significantly influence both teachers' teaching practices and students' learning processes (Acar & Buldur, 2021). In this context, it has been reported that classroom instruction is primarily focused on knowledge transfer, and students are pressured to prioritise exam success over engaging in the science learning process in a cognitive, affective, or active manner (Kesik & Bayram, 2015).

However, Turkey's new science education programme (MoNE, 2024) aims to enable students to achieve higher-level outcomes such as scientific inquiry skills, scientific literacy, and research-based learning. Theoretically, this vision requires student-centered, multidimensional learning approaches; however, in practice, it is unclear to what extent these goals are being realised (Korkmaz, 2023). Therefore, there is a need for comprehensive measurement tools that can examine students' science classroom experiences not only in terms of cognitive effort but also in terms of emotional engagement, behavioural engagement, and agentic engagement (Reeve, 2013; Reeve & Shin, 2020).

In the current literature, there is no original scale that addresses student participation in science education in Turkey in a multidimensional manner and provides sufficient psychometric evidence. Previously developed local measurement tools have either been limited to cognitive or affective participation or have provided limited validity in contextual adaptations (Candaş & Özmen, 2020; Korkmaz, 2023). At this point, the introduction of a tool based on contemporary learning models, such as SESL, which can measure students' active participation in classroom learning through its multidimensional structure, will contribute not only to science pedagogy but also to evaluations of policy and practice.

Moreover, the reflection of various socioeconomic, cultural, and regional differences in education in Turkey can lead to significant differences in students' attitudes, interests, and participation levels in science (Alkış Küçükaydın et al., 2024). In this context, the adaptation of SESL provides a meaningful foundation not only in terms of measurement and evaluation but also for promoting more inclusive and student-centered practices, aligning with the goals of equitable science education.

In addition, the literature highlights the practical benefits of self-report-based participation scales in evaluating teaching processes, emphasising that teachers can review their classroom practices and respond more effectively to students' learning needs (Fredricks et al., 2004; Reeve et al., 2022; Sinatra et al., 2015). In this context, the adaptation of SESL into Turkish not only fills an academic gap but also has the potential to generate functional data for practitioners and policymakers.

Conceptual background

Engagement in science learning

Engagement refers to students' academic progress in the educational process, their satisfaction in terms of motivation, and their interaction with these environments by organising their learning environments themselves (Reeve et al., 2022). Engagement in science education refers to the level or degree of students' participation in science lessons (Li et al., 2023). Therefore, one of the main goals of science education is to ensure participation (Berland et al., 2015).

Student engagement in science learning continues to receive increasing attention from educational researchers, practitioners and policymakers (Bae & Lai, 2020). Although research emphasises the importance of students' engagement in science learning, research results show that students lack interest and motivation (Sinatra et al., 2015). Scientific data collection tools that measure students' engagement in science learning are very important. The SESL instrument developed by Li et al. (2023) serves this purpose. The main components of the SESL are as follows: a) cognitive, emotional, behavioural and agentic engagement.

Cognitive engagement

Cognitive engagement is the mental effort students expend in completing learning tasks (Greene, 2015). In this context, students understand process and integrate more complex information to create a more coherent mindset for learning. For this, students adopt and use cognitive strategies in the learning process (Walker et al., 2006). Students who are so cognitively intensive manage and control their efforts to not break away from their learning process and not to break their concentration. In this process, they use more complex learning styles to ensure meaningful learning in the school environment (Sinatra et al., 2015). It is important to include some instruments to measure students' cognitive engagement in a course and to use these instruments to evaluate teaching effectiveness (Barlow et al., 2020). At this point, Li et al. (2023) addressed students' engagement in science learning in the cognitive dimension.

Emotional engagement

Emotional engagement refers to students' emotions towards learning activities (Sinatra et al., 2015). In other words, emotional engagement is the expression of emotions that mobilise students' positive and energising emotions during learning activities. In this respect, students who are emotionally engaged in course activities feel good and work with pleasure (Reeve et al., 2022). Accordingly, measuring emotions is also important in students' engagement in science learning (Li et al., 2023).

Behavioural engagement

Student's behavioural actions, such as paying attention to learning activities, concentrating, and continuing without giving up at the point of difficulty, are defined as behavioural engagement (Sinatra et al., 2015). It has been observed that students with behavioural engagement show better academic performance and exhibit positive behaviours in the classroom environment (Wang & Holcombe, 2011). Accordingly, behavioural engagement in science education refers to the effort made by students and the persistence of this effort (Li et al., 2023).

Agentic engagement

Students inevitably have interests, goals, and dreams that they set for themselves. These can be achieved by intrinsically motivating students and embracing their efforts (Sheldon & Corcoran, 2019). Teachers are the most important triggers that actively influence students. When teachers support students in expressing their interests, goals, and dreams and moving in this direction, students are more actively engaged in classroom practices (Reeve & Shin, 2020).

Agentic engagement is the proactive participation of students in a learning environment that contributes to and supports them in the learning and teaching process. At this point, the fact that students follow a path in the learning process by informing the teacher of their ideas before the activity instead of accepting the learning environment and the current situation and decisions of the teachers as they are shows that they take an active role in the classroom (Reeve & Shin, 2020). Agentic engagement participation supports student learning, development, and performance; secondly, it supports learning activities related to their interests and desires. The items in the representative participation dimension of the student engagement scale in science learning developed by Li et al. (2023) measure the degree to which students actively participate in scientific activities.

Present study

This study aimed to adapt the SESL, which was previously developed and tested for validity and reliability in the Chinese sample, to the Turkish sample. In this context, firstly, the validity and reliability studies of the SESL were conducted. Then, the variables that may be related to science participation were discussed.

Previous literature has mentioned that science engagement is related to gender. In their study, Fredricks et al. (2016) found that students' level of science engagement favoured girls regarding gender. Accordingly, cognitive and behavioural engagement in science lessons has a moderate effect in favour of girls. In the emotional engagement dimension, there was no significant difference in terms of gender. Wang and Holcombe (2011) found that boys showed lower levels of behavioural and cognitive engagement than girls. In the study by Fırat and Açıkgül Fırat (2021), it was revealed that there was a significant difference in favour of girls in terms of gender in the affective, cognitive, behavioural and social engagement dimensions of science. Based on the results of these studies, Turkish high school students' engagement in science learning is expected to differ according to gender. The hypothesis tested in this context is as follows:

H1 = Engagement in science shows a significant change according to gender.

The study also investigated whether high school student's participation in science learning differs according to their grade level. In the literature, Sökmen (2021) examined the relationship of grade level on the components of middle school students' participation in science. The results showed that students' participation in science was unrelated to grade level. A similar study found that student engagement did not differ significantly with grade level (Reeve, 2013). However, the literature on the relationship between grade level and science engagement is limited. Therefore, we aim to contribute to the future literature by addressing the grade level in this study. The hypothesis tested in this context is as follows:

H2 = Engagement in science shows a significant change according to grade level.

Research has shown that students' participation in science is related to their parent's level of education and that as the level of parental education increases, students' participation in science also increases. Wang et al. (2020) examined the effect of parental education on students' academic performance. Accordingly, there was a linear relationship between parental education and children's academic performance. It was also observed that the father's education had a more significant impact on the child's academic performance than the mother's. Açar-Özçelik and Bahçivan (2020) also found that parental education level positively and significantly affected students' learning outcomes. Based on the results of these studies, it is expected that Turkish high school students' engagement in science learning will differ according to their parents' level of education. The hypothesis tested in this context is as follows:

H3 = Engagement in science shows a significant change according to parents' educational level.

Science education supports students' epistemological beliefs about constructing and evaluating scientific knowledge (Berland et al., 2015). Researchers have argued that students' epistemological beliefs are directly related to science learning (Lederman et al., 2002). In the literature, Açar-Özçelik and Bahçivan (2020) found that high school students' epistemological beliefs are related to their conceptions of science learning. Guo et al. (2022) investigated how high school students' epistemological beliefs affect their science identity. The study's results revealed that epistemological beliefs directly support high school students' efficacy and performance beliefs about science. Mete (2023) also found a significant relationship between students' epistemological beliefs and science learning approaches. It was also concluded that epistemological beliefs predicted the effort-based learning approach to science. Therefore, epistemological beliefs have been important in educational research, especially in science learning (Kampa et al., 2016). Based on all these, we expect that there is a relationship between Turkish high school students' engagement in science learning and their epistemological beliefs. The hypothesis tested in this context is as follows:

H4 = There is a significant relationship between engagement in science and epistemological beliefs.

Study 1: adaptation of the student engagement in science learning

Participants and procedure

High school students from the Mediterranean Region of Turkey participated in the study at the beginning of the 2024–2025 academic year. The students were selected from two public schools in this region. Before data collection, permissions from the ethics committee were obtained from the university where the researchers worked. Then, research permission was obtained from the Provincial Directorate of National Education. School principals were contacted, and the purpose of the study was explained. School principals who wanted to participate in the study directed the researchers to the teachers. Participants under 18 years of age informed their teachers whether they would participate in the study with their parent's permission, and other participants informed their teachers whether they would participate with their consent. The relevant questionnaire forms were then delivered to the teachers, and the questionnaires were administered to the participants as a paper-and-pencil test during study hours.

625 students, 364 (58.2%) females and 261 (41.8%) males, participated in the study. The mean age of the students was 16.01 years ($SD = 1.21$). 136 (21.8%) of the students were in 9th grade, 40 (6.4%) in 10th grade, 216 (34.6%) in 11th grade and 233 (37.3%) in 12th grade. 74 (11.8%) of the students reported that their mothers and 62 (9.9%) fathers had primary school education or below. Again, 67 (10.7%) of the students reported that their mothers and 70 (11.2%) fathers had secondary school education; 213 (34.1%) of the students reported that their mothers and 203 (32.5%) fathers had high school education. The mothers of 271 (43.4%) and fathers of 290 (46.4%) of the students had undergraduate or higher education.

Procedure and translation of the instrument

Both cultural transfer and linguistic translation procedures were used in scale adaptation. In this context, a comparison was made between the dominant culture of SESL and Turkish culture. Although there are significant differences between Chinese and Turkish cultures in historical and socio-educational contexts, there are some similar tendencies toward student engagement, especially in science education. First of all, both cultures traditionally prioritise respect for the teacher and adherence to authority, and in recent years, a transition to student-centered science teaching approaches has been observed in both countries (Alkış Küçükaydın & Ayaz, 2025; He et al., 2023). This transformation supports students' active participation in science lessons, inquisitive thinking, and involvement in experimental processes.

In the PISA assessments conducted by the Organization for Economic Cooperation and Development, the difference between the science literacy scores of China (especially Shanghai) and Turkey is striking. Still, there are parallels in the learning environments and teaching methods reported regarding student engagement (OECD, 2019). Students' engagement in science lessons in both cultures often depends on the teacher's methodology and classroom climate. Motivational and affective factors affecting students' engagement were similarly identified in each sample (Mete, 2023; Tuan et al., 2005).

In this context, in the process of adapting the SESL into Turkish, meaningfulness was sought not only in terms of linguistic but also cultural relevance. The conceptual structure of the scale and its sub-dimensions of student engagement are interpreted similarly in both the Chinese and Turkish samples, and educational policies encourage these structures (Sökmen, 2021; Zhao & Kuh, 2004). Therefore, the applicability of the SESL scale to the Turkish sample is supported in terms of theoretical framework and cultural context. Apart from linguistic appropriateness, three experts obtained feedback on the conceptual equivalence of the items in the SESL. The experts made suggestions about the appropriateness of the items for Turkish culture. These suggestions were mainly related to the wording of the items. For example, the phrase 'in science class' was changed to 'in science courses.' This is because there is no separate science classroom in Turkey. Therefore, in line with the suggestions, there was no need to change the content of the items.

The English version of the SESL instrument was translated into Turkish through forward and backward translations using the parallel blind technique by two independent bilingual associate professors other than the researchers of this study (Behling & Law, 2000). The translators specialise in science education. Therefore, the translators made the necessary revisions for semantic, conceptual and idiomatic equivalence in the translation and back-translation processes of the instrument. The relevant statements in the instrument were then subjected to an ambiguity and inconsistency review by the authors of the study. An expert opinion from the Turkish language field decided upon the instrument's Turkish form. Before the implementation, the scale items were reviewed by four high school students from outside the sample to test the comprehensibility of the items. Thus, the Turkish version of the SESL was finalised to evaluate its psychometric properties. Throughout the process, the cross-cultural adaptation of the SESL instrument was checked following the procedures of Borsa et al. (2012).

Measures

Student engagement in science learning scale

The SESL is a four-dimensional scale developed by Li et al. (2023) that assesses high school students' science engagement. The scale includes four dimensions, each consisting of five items: cognitive engagement, emotional engagement, behavioural engagement, and agentic engagement. The scale is scored on a four-point Likert scale ranging from 1 (Strongly disagree) to 4 (Strongly agree). Scores on the SESL range from 20 to 80, with higher scores indicating higher levels of student engagement in science learning. The scale was subjected to validity and reliability analyses in this study.

Data analysis

Within the scope of the SESL instrument adaptation study, the data's normality distributions were first tested. In this context, the skewness and kurtosis values of the instrument items were examined. In this context, it was seen that skewness values ranged between −.115 and .064, and kurtosis values ranged between −.205 and .663, thus meeting the normality assumptions (Tabachnick & Fidell, 2013). The instrument's construct validity was tested with confirmatory factor analysis (CFA) using the maximum likelihood method. The following values were taken into consideration to evaluate model-data fit in CFA: $\chi^2/df < 3$; RMSEA and S-RMR < .10; AGFI, GFI, NFI, IFI, CFI, and TLI > .90 (Schermelleh-Engel et al., 2003). Cronbach's alpha, McDonald's omega, and composite reliability (CR) were examined to assess the reliability of the SESL. In addition, factor loadings and average variance extraction (AVE) values were calculated for validity. All analyses were performed using IBM SPSS Statistics 26, AMOS 21, and Jamovi 2.3.28.

Results

CFA was first applied to test the model-data fit of the SESL. For the four-factor model as in the original structure of the instrument, the initial analysis values obtained without any changes were as follows: χ^2 (164) = 624.514 ($p < .01$), $\chi^2/df = 3.80$, RMSEA = .06 (CI = .06/.07), S-RMR = .05, AGFI = .88, NFI = .87, IFI = .90, GFI = .90, CFI = .90, TLI = .88. Since the goodness-of-fit values obtained in the first analysis were low, we first merged the error terms between items #2 (In science class, I will tell the teacher whether I enjoy participating in science activities or not.) and #3 (In science class, I let my teacher know what I'm interested in.) of the agentic engagement dimension. The same procedure was repeated for items #2 (In science class, I take the initiative to participate in science learning activities.) and #3 (In science class, I focus on doing science learning activities.) in the behavioural engagement dimension. In the final analysis, the following goodness of model values was obtained: $\chi^2/df = 2.30$, RMSEA = .06 (CI = .05/.06), S-RMR = .05, AGFI = .90, NFI = .90, IFI = .92, GFI = .92, CFI = .91, TLI = .90. Thus, this form accepted the model (Figure 1).

Table 1 summarises the CFA analysis of the modified model. Accordingly, the factor loadings of the items in the instrument ranged between .820 and .531 and were found to

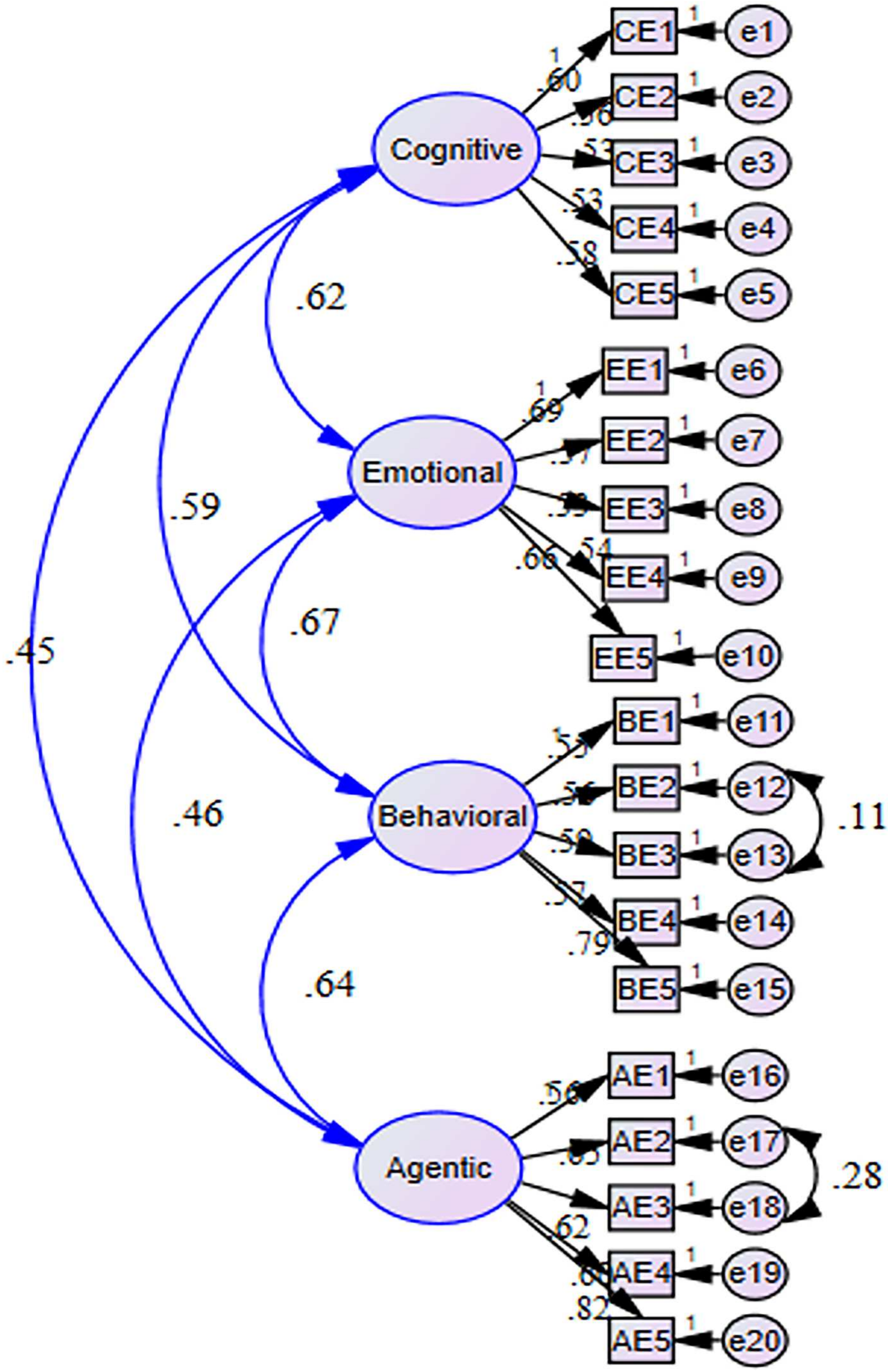

Figure 1. CFA results for the engagement modified model.

be significant at the $p < .01$ level according to the t-values. This shows that the tested model has good convergent validity (Hair et al., 2010). Also, AVE values greater than .50 mean good convergent validity. Values between .30 and .50 mean acceptable

Table 1. Summary of confirmatory factor analysis of SESL.

Variables	Gender	N	Mean	*SD*	*df*	*F*	*p*	Partial η^2
Cognitive engagement	Female	364	2.81	0.54	1–623	1.799	0.18	0.03
	Male	261	2.87	0.60				
Emotional engagement	Female	364	2.94	0.67	1–623	0.567	0.45	0.01
	Male	261	2.99	0.70				
Behavioral engagement	Female	364	2.68	0.57	1–623	5.681	0.01	0.09
	Male	261	2.80	0.64				
Agentic engagement	Female	364	2.57	0.62	1–623	7.114	0.01	0.11
	Male	261	2.72	0.72				

convergent validity (Fornell & Larcker, 1981). In this context, the items constituting the instrument are valid. Table 1. Descriptive Statistics Results Related to Gender.

The related table also presents Cronbach's alpha, McDonald's omega, and CR values. Cronbach's alpha values for the sub-dimensions of the SESL instrument range between .74 and .81, McDonald's omega values between .75 and .81, and CR values between .70 and .79. In this case, we can also report that the instrument meets the reliability criterion (Gefen et al., 2000). In addition, the square root of the AVE values (shown in bold) and the correlation values between the dimensions that make up the instrument were examined. Accordingly, the correlations between the dimensions ranged between .67 and .45. This indicates that each sub-dimension significantly contributes to students' engagement in science learning. The most substantial relationship between the dimensions was between emotional engagement and behavioural engagement ($r = .67$, $p < .01$). The correlation between cognitive engagement and agentic engagement was moderate and positive ($r = .45$, $p < .01$).

Study 2: investigating the relationship between engagement in science, demographic variables and epistemological beliefs

Participants

The participants of this study were the students in Study-1.

Instruments

The demographic characteristics form

Within the study's scope, students were asked to indicate their age, gender, grade level, and parental education level.

Epistemological beliefs scale

The epistemological beliefs scale, a self-report scale developed by Conley et al. (2004), was used. The Turkish validity and reliability study of the scale was conducted by Alkış Küçükaydın et al. (2024). The epistemological beliefs scale consists of four subscales (source, certainty, development, and justification). There are 26 items in the 5-point Likert-type scale (1 = strongly disagree to 5 = strongly agree), and the items belonging to the first two dimensions are analyzed by reverse coding. Accordingly, the higher the score on the overall scale, the more sophisticated the beliefs are. In this study, the Cronbach's alpha coefficient of the scale was .81.

Data analysis

The study examined whether high school students' engagement in science learning varies according to gender, grade level, parents' education level and epistemological beliefs. The SESL scale's sub-dimensions were considered when determining students' engagement in science learning and the sub-dimensions were determined as dependent variables. Multivariate analysis of variance (MANOVA) was used to compare the means of the dependent variables according to the groups. Accordingly, firstly, MANOVA assumptions were tested.

In the sub-dimensions of the SESL scale, first univariate and then multivariate normality distributions were tested. Skewness and kurtosis values were examined for univariate normality distributions (−.445 and 1.08 for cognitive engagement; −.645 and .396 for emotional engagement; −.347 and .597 for behavioural engagement; −.248 and .147 for agentic engagement). The same was tested for independent variables (.335 and −1.89 for gender; −.642 and −1.00 for grade level; −.886 and −.321 for mother education level; −.957 and −.138 for father education level). Thus, it was accepted that the data met the normality assumptions (Tabachnick & Fidell, 2013). For the control of multivariate normality, Mahalanobis distance values were calculated using the multiple linear regression process steps. The condition of equality of variance-covariance matrices, which is one of the assumptions of MANOVA, was checked with Box test of equality of covariance matrices ($F_{gender} = 1.851$, $p > .05$, $F_{grade\ level} = 1.683$, $p > .05$, $F_{mother\ education\ level} = 1.50$, $p > .05$, $F_{father\ education\ level} = .950$, $p > .05$). Then, the condition of equality of error variances was checked with Levene's test ($p > .05$). Analyses were conducted according to Wilk's Lambda statistic (λ). The effect size of the selected statistic was shown by partial eta squared (η^2). The Pearson correlation coefficient tested the relationship between students' science participation and epistemological beliefs.

Results

The study tested hypotheses H1, H2, H3, and H4. The results are presented respectively.

Hypothesis 1

First, the relationship between students' engagement in science learning and gender was examined. According to the one-way MANOVA results, students' engagement in science learning according to their gender varied according to the dimensions of SESL (F [4-620] = 2.369, $p = .04$, partial $\eta^2 = .015$, $\lambda = .985$). While there was no significant difference in the cognitive engagement (F [1-623] = 1.799, $p = .18$) and emotional engagement (F [1-623] = .567, $p = .45$) sub-dimensions of SESL according to gender, behovioral engagement (F [1-623] = 5. 681, $p = .01$, partial $\eta^2 = .009$) and agentic engagement (F [1-623] = 7.114, $p = .01$, partial $\eta^2 = .011$) dimensions in favour of male students.

Hypothesis 2

The analysis showed a significant difference between students' grade level and their engagement in science learning (F [4,618] = 3.451, $p = .01$, partial $\eta^2 = .022$, $\lambda = .936$).

Accordingly, according to grade level, there was no significant change in cognitive engagement (F [3-621] = 1.138, $p = .33$). However, in the other sub-dimensions of emotional engagement (F [3-621] = 2.807, $p = .03$, partial $\eta^2 = .013$), behavioural engagement (F [3-621] = 9.841, $p = .01$, partial $\eta^2 = .045$) and agentic engagement (F [3-621] = 3.462, $p = .01$, partial $\eta^2 = .016$), significant differentiation was found in favour of the 9th graders.

Hypothesis 3

Students' engagement in science learning was then tested according to their parents' education level. Results showed no significant difference between students' engagement in science learning and their mother's education level (F [4-618] = 1.635, $p = .76$, $\lambda = .969$). Similarly, students' engagement in science learning was unrelated to their father's education level (F [4-618] = 1.967, $p = .36$, $\lambda = .963$).

Hypothesis 4

Finally, the relationship between students' engagement in science learning and epistemological beliefs was tested. Pearson correlation test results showed that all sub-dimensions of SESL were weakly correlated with epistemological beliefs ($r_{\text{cognitive engagement}} = .09$; $r_{\text{emotional engagement}} = .15$; $r_{\text{behavioural engagement}} = .16$; $r_{\text{agentic engagement}} = .17$). Descriptive analysis results regarding the data obtained within the scope of Study-2 are presented in the Appendix.

Discussions

In Study-1, the Turkish adaptation of the SESL instrument developed by Li et al. (2023) was conducted. In this context, the validity and reliability values of the instrument were examined, and the model-data fit was tested using CFA. In this context, the Turkish structure of SESL was tested and found to have excellent fit values. In the instrument's agentic engagement and behavioural engagement dimensions, it was observed that the original structure of the scale was confirmed even though error terms were combined between some items. Accordingly, no items were added or removed from the original SESL.

Moderate and positive relationships were found between the dimensions of SESL. The values obtained (r = .62, r = .59; r = .67) are compatible with the values stated in the original scale (r = .73, r = .59; r = .69). The reliability coefficients of the scale ($\alpha = .74$; $\alpha = .81$; $\alpha = .77$; $\alpha = .79$) were also close to the values in the original scale ($\alpha = .70$; $\alpha = .75$; $\alpha = .74$; $\alpha = .85$). These correspondences indicate that the SESL is a valid and reliable instrument for measuring students' science engagement in science classrooms in Turkish culture. Both the domain-specific (science) and contextual (cognitive, affective, behavioural, and agentic) nature of the SESL helps to capture new trends in science learning (Li et al., 2023). Although the original scale was developed in mainland China, the cultural similarities will help to eliminate potential concerns about its application. Variables such as twenty-first-century principles emphasised in the science curricula of both cultures, students being active learners, and their participation in science classrooms (Ministry of Education, P. R. China, 2014; Ministry of National Education, Turkey, 2024) suggest that the SESL is a suitable tool for Turkish culture.

Following the adaptation of the SESL to Turkish culture, in Study-2, students' engagement in science learning according to demographic variables and the relationships with epistemological beliefs were tested. Accordingly, while there was no significant difference in the cognitive engagement and emotional engagement dimensions of students' engagement in science learning according to gender, there was a significant difference in favour of male students in the behavioural engagement and agentic engagement dimensions. These results confirmed that science engagement varies according to gender in previous studies. Fırat and Açıkgül Fırat (2021) found that there was a significant difference in favour of girls in terms of gender in the emotional, cognitive, behavioural and social engagement dimensions of science. Similarly, the study conducted by Fredricks et al. (2016) determined that students' science engagement levels differed in favour of girls in terms of gender. This difference was found to favour girls in the cognitive and behavioural dimensions.

In other studies, it was found that female students perceived themselves as weaker in science compared to male students (Hazari et al., 2013; Williams & George-Jackson, 2014). This situation shows that there is variability in students' participation in science learning according to dimensions in the context of gender. Brotman and Moore (2008) explained that the underrepresentation of many groups in science and technology caused this situation. In addition, the variability in gendered engagement in science learning across dimensions may be due to cultural differences. Vincent-Ruz and Schunn (2018) argued that gender has a different function in science engagement and emphasised that men and women construct scientific knowledge within a culture.

The study's other result determined that students' engagement in science learning differed according to grade level. Previous studies reported that grade level did not make a difference in students' engagement in science (Reeve, 2013; Sökmen, 2021). In the study by Kaya and Kaya (2019), it was observed that there was a positive and significant relationship between fourth and eighth-grade students' liking for science and interest in learning science. It was determined that there was a quantitative decrease in eighth-grade students' interest in the course. This situation may be related to the education system. The fact that the Turkish education system has an exam-based education and the intensity of courses and exams increases as the grade level increases may have led to decreased student participation in science learning.

The study observed that students' engagement in science learning did not differ according to their parents' education level. Wang et al. (2020) found a linear relationship between parents' education level and students' academic performance. In the study conducted by Korkmaz (2023), a positive relationship was found between students' participation in science and the value given to science by parents in the behavioural participation dimension. In our study, the reason why the level of parental education did not make a difference in students' participation in science learning may be related to the Turkish education system. Students are promoted to the next grade based on their in-class performance and the score they get in the written exam. Therefore, the sense of passing the class may have been practical in students' participation in science learning. Moreover, the support provided by parents in this age group may not be a very important factor.

Finally, it was found that there was a weak relationship between students' engagement in science learning and their epistemological beliefs in all sub-dimensions. This result is only partially consistent with theoretical expectations that students who think in a more epistemologically sophisticated manner will participate more actively in the learning process (Greene, 2015; Sinatra et al., 2015). However, the fact that science education in Turkey is still exam-centered, teacher-focused, and based on knowledge transfer may limit students' ability to translate these beliefs into classroom behaviour (Şen et al., 2023; Üztemur et al., 2021). Even if students have developed complex approaches to knowledge, teaching environments may not support the transformation of these beliefs into agentic or behavioural participation. Indeed, a recent study has shown that epistemological beliefs are related to scientific identity and learning experiences but that this relationship can vary in a context-sensitive manner (Alkış Küçükaydın & Ayaz, 2025). Therefore, to observe the impact of epistemological beliefs on students' science learning processes more clearly, it is necessary to create pedagogical environments that facilitate the transformation of these beliefs into behaviour.

Similar to this result, Lederman et al. (2002) concluded that students' epistemological beliefs are directly related to science learning. Recently, Mete (2023) also found a significant relationship between students' epistemological beliefs and science learning approaches. Açar-Özçelik and Bahçivan (2020) also found that high school students' epistemological beliefs are related to their conceptions of science learning. Epistemological beliefs that affect understanding and learning are important in shaping the learning process and conducting teaching practices in the classroom (Mete, 2023). This situation supports that epistemological beliefs are related to students' participation in science. Perry (1968), who conducted the first studies on epistemological beliefs, states that epistemological beliefs are a perspective on what knowledge is, how it is obtained, its limits and criteria. Therefore, students' use of the knowledge they have about science learning by participating in science can show that it is related to students' epistemological beliefs.

Student engagement is one of the most critical aspects of educational environments (Betts, 2012). Therefore, this adaptation study seems important to measure Turkish students' engagement in science learning. With the use of the instrument in research and applications, the extent to which students participate in science learning can be revealed. This way, evidence can be obtained on why students are not engaged in science learning. It is necessary to keep students' learning active and make it easier. In this direction, teachers can encourage students to stay energised by keeping them motivated and engaged (Havik & Westergård, 2019). This shows that student engagement is an important prerequisite for the highest and deepest level of learning (Cents-Boonstra et al., 2020).

Previous studies have proven that student engagement is related to academic and social aspects of school life. It has been found that students have a successful academic process until they graduate from high school (Appleton et al., 2006), improve their knowledge and skills positively (Ladd & Dinella, 2009), provide positive improvements in their emotional state, and reduce school absenteeism, school dropout, and delinquent behaviours (Skinner et al., 2008). At this point, it is important to ensure student participation and research how to increase student participation.

As a result, the SESL scale measures student engagement in cognitive, affective, behavioural, and agentic dimensions in the classroom context (Li et al., 2023). However, current theoretical approaches define engagement as a dynamic, task-oriented, and multi-layered construct, emphasising that it is shaped by the school, task, and social interactions beyond the classroom (Betts, 2012; Reeve et al., 2022). Therefore, while SESL helps assess classroom engagement, it may provide more meaningful results when used with broader engagement models. In particular, supporting it with data sources such as qualitative observation and experience sampling will contribute to a more holistic understanding of student engagement (Fredricks et al., 2004; Sinatra et al., 2015).

Limitations and recommendations for future studies of study 1 and study 2

Although important results regarding the SESL instrument's psychometric properties have been made, the current study has several limitations. Firstly, the self-report method used may contain potential response biases due to influences such as social favorability. However, self-report instruments offer significant advantages in economically and practically assessing subjective constructs such as student engagement with large samples. In future research, it would be useful to use methods such as observation and qualitative data collection to directly examine the behavioural aspects of engagement and to conduct comparative analyses with self-report data. Secondly, the current study's data was collected from only one region of Turkey. Therefore, data collected from different regions may help provide different perspectives for the instrument's validation. In addition, engagement in science learning was associated with gender, grade level, parental education level, and epistemological beliefs in this study. In future studies, engagement in science learning could be tested with models that address variables such as students' science motivation or classroom environment.

Finally, the procedures applied for the SESL in the study were limited to CFA. Cronbach's alpha, McDonald's omega, CR, AVE, and correlation values were examined for convergent validity and reliability. Despite these limitations, the results of the current study supported the usefulness of the Turkish version of the SESL. They highlighted its potential in determining students' engagement in science learning in the context of Turkish-speaking populations.

Conclusions

Students' engagement in science learning in science classrooms is expressed in cognitive, affective and behavioural engagement (Fredricks et al., 2004). In addition to these concepts, recent studies have also introduced the concept of agentic engagement, which emphasises that students express their preferences in the classroom environment and proactively engage in the learning environment (Reeve et al., 2022). In this context, students can initiate, become motivationally ready for, and sustain their learning for science engagement in science classrooms (Schneider et al., 2016). However, there is a need for tools that will enable us to have information about students' readiness. For this purpose, the study adapted the SESL (Li et al., 2023) scale assessing engagement in science learning in Turkish. The analysis showed that the Turkish version of the SESL is valid and reliable for Turkish-speaking communities.

Furthermore, the SESL was used to examine whether Turkish students' engagement in science learning varied according to gender, grade level, and parental education level. In addition, a weak relationship was observed between engagement in science learning and epistemological beliefs. The results can be considered a pioneering study in this area, showing that a specific theory addressing engagement in science learning has not yet been found. Thus, future research could provide more information about students' understanding of engagement in science learning and related variables. Testing broader engagement models in science learning and epistemological beliefs will make this possible.

In conclusion, this study provides a valid and reliable instrument that measures students' engagement in science learning across four classroom-based dimensions. However, current theoretical approaches consider engagement to be a more dynamic, task-oriented, and contextually shaped construct (Betts, 2012). Therefore, it is suggested that self-report-based instruments such as the SESL are particularly useful for classroom practice and the evaluation of instructional processes, but they should be supplemented with multi-source data collection approaches to reflect broader understandings of engagement.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Ethics approval

This study was approved by the ethics committee of the Akdeniz University (09.10.2024-1034495).

Data availability

The data that support the findings of this study are available from the corresponding author upon request.

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