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Development of spatial ability extra tasks (SAET): problem solving with spatial intelligence

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Abstract

Spatial ability contributes to performance in science, technology, engineering and mathematics (STEM). Spatial skills and creativity are required for engineering studies. Low spatial abilities can lead to the dropout of students' university studies. In this study the *Spatial Ability Extra Tasks* (SAET) was developed to evaluate engineering students' complex spatial abilities. A total of 93 first-year engineering students from University of Debrecen Faculty of Engineering and Sharif University of Technology in Tehran participated, with regard to final mathematical exam and their gender, participated in the study. SAET measures parts of spatial abilities: mental cutting and mental rotation and creativity. Analysis of the findings suggested that SAET is valid and reliable. The separate tests results have been statistically evaluated and conclusions were formulated. We used Structural Equation Modeling analysis. We separate two types of tasks by SAET which are Polyhedron part and Curved Surface part. According to obtained data, accomplished the results: students of University of Debrecen are more successful at Curved Surfaces. In addition students of Sharif University are more successful at Polyhedrons. The square cross section was found by most student in both countries in Polyhedrons. It is remarkable that first-year engineering students of Tehran are more successful at Polyhedrons by pentagon, hexagon and parallelogram solution; and students of Debrecen are more successful by square and rectangle solution. Students of Debrecen are more successful at Curved Surfaces to find circle solution of cylinder, cone and sphere; students of Tehran are more successful by finding parabola solution of cone.

Keywords Engineering students · Object manipulation · Problem solving · Spatial ability · Visual thinking

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1 Introduction

We get most of the knowledge visually, so the quality of visual thinking and spatial intelligence is very essential for us. Spatial ability has received much attention in recent years, it can be expressed that development of this ability is important for each area of science. Researchers interpreted importance of the spatial ability and studies arise in the field of mathematics education, engineering education, chemistry, physics education and psychology (Alkan and Erdem 2011; Nagy-Kondor 2016, 2017; Sorby 2009). Spatial ability is important in education, learning and problem solving. National Council of Teachers of Mathematics (2000) emphasized the importance of spatial ability, 2D and 3D geometric activities and representing geometric figures. Low spatial abilities can lead students to drop out of their university studies.

We can define spatial ability as the ability to connect constructive world and perceived world with complex system of cognitive components (Nagy-Kondor 2017), and with this ability we can recognize the relationships between visual components of objects (Bosnyak and Nagy-Kondor 2008; Nagy-Kondor 2016, 2017; Turgut 2015).

So, spatial abilities are described as a complex system, wich is essential for success in engineering and other technological fields and in learning anatomy (Alkan and Erdem 2011; McGee 1979; Nagy-Kondor and Sörös 2012; Olkun 2003; Sorby 2009; Turgut and Nagy-Kondor 2013; Vorstenbosch et al. 2013). According to Vorstenbosch et al. (2013) spatial ability may be improved by studying anatomy, this is reciprocal advantageous effect, since right spatial ability is advantageous for learning anatomy and that studying anatomy is advantageous for the students' spatial ability (based on high scores on Mental Rotation Test—high scores on anatomy examinations).

Spatial ability is related to performance in science, technology, engineering and mathematics (STEM) (Freeman et al. 2019; Nagy-Kondor and Sörös 2012; Nagy-Kondor 2017; Shea et al. 2001; Williams et al. 2010), and according to Tosto et al. (2014) spatial ability performance correlates with performance of spatial reasoning skills and mathematical reasoning skills. STEM research and education are progressively recognized as fundamental to national development, societal wellbeing and economic competitiveness (Freeman et al. 2019). According to studies (OECD 2010; Hanushek and Woessmann 2012) educational quality (tested by cognitive skills primarily in science and mathematics) is a more potent influence on economic outcomes. Results of Utku-İsmihan (2019) indicate that knowledge variables (research and development, information and communication technologies) seem to play an important role in the economic growth performances of regions (Middle East, North sAfrica and Latin American countries).

According to Shea et al. (2001) intellectually talented adolescents with better spatial (than verbal) abilities are more likely to be found in engineering, mathematics and computer science fields. Citta et al. (2019) found a positive correlation by mental rotation ability and computational thinking. Study of Rowland et al. (2019) describes qualitative interview technique that can be adopted to profit STEM education research. So, there is a wealth of empirical evidence showing a significant relationship between educational performance in STEM and spatial ability (Buckley et al. 2018).

2 Theoretical framework

According to McKim (1980) visual thinking is based on three kinds of images: seeing, imagining and drawing/painting. People with good spatial visual thinking use all this three types in interactive and flexible way (Sorby 1999). Where seeing, drawing and imagining overlap "visual thinking is experienced to the fullest when seeing, imagining, and drawing merge into active interplay" (McKim 1980, p. 7).

For engineering the mental cutting, mental rotation ability is very important. The mental cutting ability is a component of the spatial ability. The conformity in mental cutting, paper folding and surface developments where the geometry changes the stimulus undergoes a transformation (Buckley et al. 2018; Harris et al. 2012; Lin and Chen 2016; Nagy-Kondor and Esmailnia 2021; Olkun 2003; Sorby 2009).

There are several internationally used tests to measure spatial abilitiy, from these the Mental Cutting Test (MCT) (CEEB 1939) is very importante. When students solve MCT tasks, they go through three parts of information processing: recognizing the solid (from perspective picture), cutting the solid, judging the quantity of the section (Tsutsumi et al. 1999). The students who made low MCT scores, however, could not imagine the space itself, when they observed projection drawings (Tsutsumi et al. 2008). To assess spatial visualization ability, MCT is used in many cases paper-and-pencil test (Gorska 2005; Tsutsumi 2004; Nagy-Kondor 2016). There is evidence that gender roles have influence the choice of field of study and the performance of special tests (Quaiser-Pohl and Lehmann 2002). Papers reported female students achieve significantly less points than male students in MCT (Nagy-Kondor 2016; Tsutsumi et al. 1999; Yuan et al. 2019) and also a longitudinal research by Gorska (2005).

According to results of articles attempted to find possible reasons of gender difference with analysis of prospective mathematics teachers' and engineering students' MCT results (Nagy-Kondor and Sörös 2012; Nagy-Kondor 2016; Tsutsumi 2004; Tsutsumi et al. 1999). According to Yuan et al. (2019) males perform better than females in small scale and large scale spatial ability, nevertheless they show a high level of gender differences in large scale and a medium level of gender differences in small scale spatial ability. The reason why females are worse in large scale may be that females are more sensitive to emotions than males besides females parahippocampal gyrus work less effectively, furthermore females are worse in small scale than males, because females mainly adopt egocentric strategy besides females sub-gyral also work less effectively (Yuan et al. 2019). According to Quaiser-Pohl and Lehmann (2002) females are less likely to have high spatial ability, because females have less spatial experiences, than males.

On the basis of this theoretical framework we developed the SAET tasksheet to measure the spatial abilities and creativity of engineering students to answer the following questions with SAET. During the research, the authors set up four research questions (RQs), they are following:

RQ1: Is there a significant relationship between first-year engineering students' gender, age, grade of mathematics and their SAET scores?

RQ2: Is there a significant relationship between first-year engineering students' results in different types of tasks of SAET?

RQ3: Is there a significant difference between freshman engineering students at Sharif University of Technology in Tehran and the University of Debrecen Faculty of Engineering by SAET scores?

RQ4: What are the characteristics of students' SAET solution?

Hypothesis 1/a It seems to be a relationship between the Age of first-year engineering students and their SAET scores.

Hypothesis 1/b It seems that the SAET of first-year engineering students different according to their Gender.

Hypothesis 1/c It seems to be a relationship between the Math grades of first-year engineering students and their SAET scores.

Hypothesis 2 It seems that the ranking types of Tasks among first year engineering students in Hungary and Iran is different.

Hypothesis 3 It seems SAET score be different among first-year engineering students in Hungary and Iran.

Hypothesis 4 It seems SAET solutions are special charasteristics in Hungary and Iran.

3 Background and methodology

Participants in this study were 93 first-year engineering students from Hungarian and Iranian universities, University of Debrecen Faculty of Engineering and Sharif University of Technology, ranging from 19 to 24 years (mean age = 20. 50, SD age = 1.44). They have the same specialization. 53 freshman students were Hungarian engineering students (17 female 32.1%, 36 males 67.9%, mean age = 19.69, SD age = 0.63) and 40 Iranian freshman students were engineering students (10 females 25%, 30 males 75%, mean age = 21.57, SD age = 1.51). Information about participants' gender, age, nationality, grade of mathematics was recorded by the use of a self-assessment questionnaire.

The instrument used in this study is:

SAET The SAET measures parts of spatial abilities: mental cutting, mental rotation (rotation of the cutting plane into every possible places) and creativity. These skills are required for engineering studies (e.g. for Technical Drawing and Descriptive Geometry). These bodies are closer to everyday life, they can also rely on their own experience. SAET is not a multiple choice test, it is a constructive tasksheet, where students have to draw solutions. Students have to construct solutions, so they use constructive thinking and creativity and all three types (McKim, 1980) of imagery.

SAET was developed by Rita Nagy-Kondor, with 20 min and consisting of 4 tasks:

Task 1 is cross sections of cube:

Cut the printed cubes with different planes. What cross sections can you get from the cube? Draw the possible planesections.

Task 2 is cross sections of cylinder. Task 3 is cross sections of cone. Task 4 is cross sections of sphere.

There is one point for each correct solution for all tasks. Figure 1 below is a sample of solution done by one of students. As you can see, the subject mentally visualizes the cutting operation on the left 9 cubes and places the cut pieces on the right: a rectangle that is not a square, a square, an equilateral triangle, a trapezium, a hexagon, a triangle

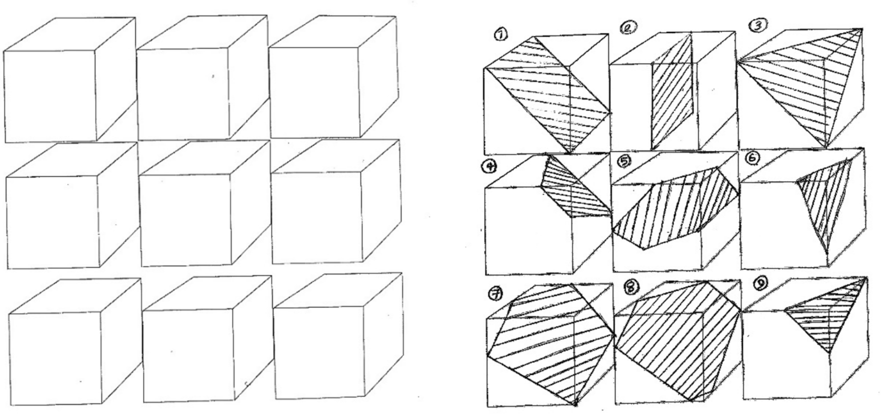

Fig. 1 Sample of solution done by one of students in task 1

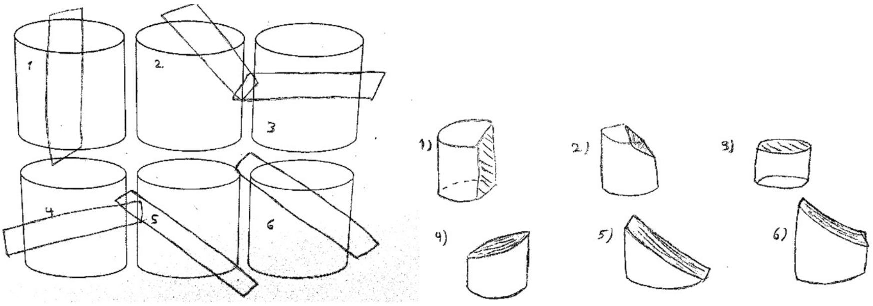

Fig. 2 Sample of solution done by one of students in task 2

that is not equilateral, a pentagon, an other hexagon and an other triangle that is not equilateral (Fig. 1).

Figure 2 below is a sample of solution done by one of students. As you can see, the subject mentally visualizes the cutting operation on the left 6 cylinders (part of the plane figure) and places the cut pieces on the right: a rectangle, a circle and ellipses (Fig. 2).

Figure 3 below is a sample of solution done by one of students. As you can see, the student mentally imagine the cutting operation on the left 6 cones (part of the plane figure) and places the cut pieces on the right: a circle (cut parallel to the circular base), a triangle (cut perpendicular to the base, intersecting the vertex), a hyperbola (cut perpendicular to the base, but not intersecting the vertex), a parabola (cut parallel to the edge of the cone, not intersecting the vertex but intersecting the base) and ellipses (cut at an angle, not parallel to the circular base and not intersecting the base of the cone) (Fig. 3).

Figure 4 below is a sample of solution done by one of students. The subject mentally imagine the cutting operation on the left 3 sphere (part of the pale figure) and places the cut pieces on the right: any cross section of a sphere will be a circle (Fig. 4).

In this research researchers separate SAET into two parts, such as Polyhedrons (Task 1) and Curved Surfaces (Task 2–4).

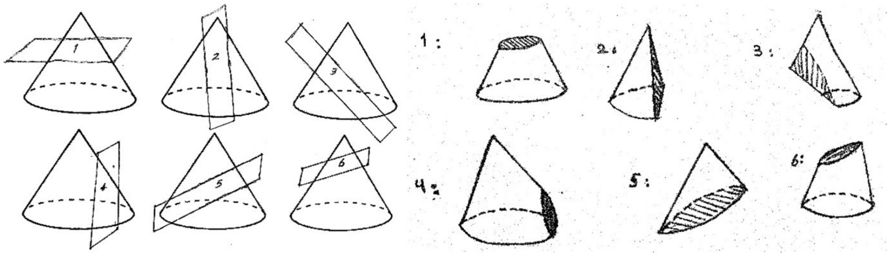

Fig. 3 Sample of solution done by one of students in task 3

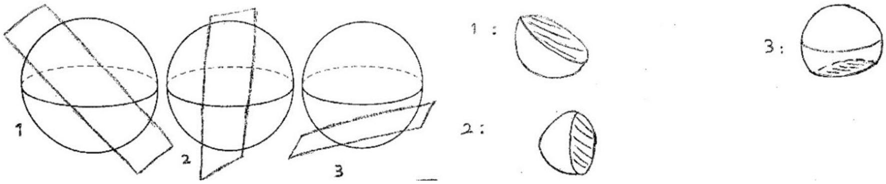

Fig. 4 Sample of solution done by one of students in task 4

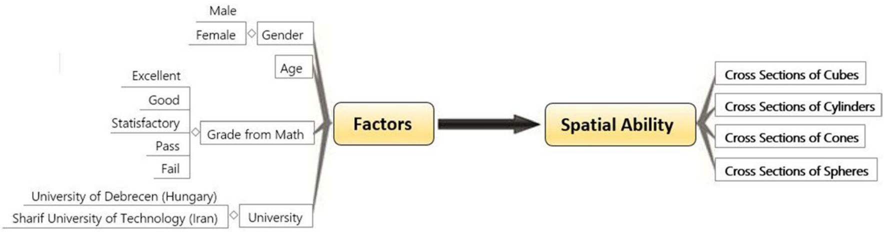

Fig. 5 Conceptual model of research

This is a descriptive-analytic study. After gathering the data through questionnaires, SPSS software and descriptive statistics and inferential statistics were used in order to analyze the data. Confidence coefficient of 95% and significance level of 0.05 were considered in test. We use structural equation modeling (SEM) software AMOS for path analysis, confirmatory factor analysis and drawing graphical models.

According to the literature of research, conceptual model will illustrate what the researcher expects to find through this research (Fig. 5). In other words, this research wants to understand the relationship between some independent variables and dependent variables. Then we compare two countries.

Table 1 Dispersion statistics of age variables by Iranian and Hungarian students

Nationality	Dispersion statistics	Data
Hungarian	Mean	19.69
	Std. deviation	0.63
	Minimum	19.00
	Maximum	21.00
Iranian	Mean	21.57
	Std. deviation	1.51
	Minimum	19.00
	Maximum	24.00

Table 2 Frequency of gender variables by Iranian and Hungarian students

Nationality	Gender	Frequency	Percent
Hungary	Female	17	32.1
	Male	36	67.9
Iran	Female	10	25
	Male	30	75

4 Results

In this section the statistical analysis both in descriptive and inferential analyses are presented to examine RQs. Tables and diagrams are arranged based on the order of the RQs came in the previous section. Therefore, the tables and diagrams start to illuminate the gender, age and Mathematics score respectively.

When our students solve SAET tasks, they go through the similar three parts of information processing like by MCT: recognizing the solid, cutting the solid and judging the quantity of the section (Tsutsumi et al. 1999).

We examined the influence of gender, age, Math score on SAET with SEM analysis: path analysis by Hungarian and Iranian students.

According to the results of Table 1, the Mean Age of Hungarian students is (19.69) years, the Std. Deviation is (0.63), the Minimum Age is (19) and the Maximum Age is (21) years. Also, the Mean Age of Iranian students is (21.57) years, the Std. Deviation is (1.51), the Minimum Age is (19) and the Maximum Age is (24) years.

According to the results of Table 2, the Hungarian students studied in this study, (32.1%) were female and (67.9%) were male, and of the Iranian students studied in this study, (25%) were female and (75%) were male.

According to the results of Table 3, which is related to the Mathematics grades of Hungarian and Iranian students studied in this study, (7.5%) of Hungarian students had satisfactory math grades, (50.9%) had good and (41.5%) had excellent scores, and (2.5%) of Iranian students had failed mathematics grades, (2.5%) passed, (25%) satisfactory, (35%) good and (35%) excellent.

Considering to the results of Table 4, which is dedicated to the SAET scores of Hungarian and Iranian students studied in this study, the total SAET score of Hungarian students was (10.50) with a Std. Deviation of (1.77), the Minimum SAET score was (6) and the Maximum was (14). Also, the total SAET score of Iranian students was equal to (10.40)

Table 3 Pearson correlation coefficient test to evaluate the relationship between Grade from Math and SAET tasks

Nationality	Grade from math	Frequency	Percent
Hungarian	Satisfactory	4	7.5
	Good	27	50.9
	Excellent	22	41.5
Iranian	Fail	1	2.5
	Pass	1	2.5
	Satisfactory	10	25
	Good	14	35
	Excellent	14	35

Table 4 Frequency of SAET tasks between Iranian and Hungarian students

Nationality	Statistics	Task 1	Task 2	Task 3	Task 4	Total Score
Hungarian	Mean	3.92	2.83	2.88	0.86	10.50
	Std. deviation	1.01	0.42	0.77	0.34	1.77
	Minimum	2	1	1	0	6
	Maximum	7	3	4	1	14
Iranian	Mean	4.95	2.07	2.80	0.57	10.40
	Std. deviation	1.37	0.65	1.01	0.50	2.08
	Minimum	2	1	0	0	5
	Maximum	7	3	4	1	14

Table 5 Independent sample T-test to compare the mean SAET of Hungarian male and female students (RQ1)

Variable	Independent samples test						Mean difference
	Gender	N	Mean	Std. deviation	T	Sig	
SAET	Female	17	10.17	1.84	0.93	0.35	0.49
	Male	36	10.66	1.74			

with a Std. Deviation of (2.08), the Minimum SAET score was (5) and the Maximum was (14).

The relationship between task types is discussed below.

According to the results (Table 5) obtained from the t-test of independent samples, because the value of the significant level of SAET is equal to (0.35) and this value with (0.93) confidence greater than the error level of (0.05), therefore, it can be inferred that the Mean SAET between the two groups of Hungarian male and female students have no significant relationship. According to the above test, male students have a higher Mean in SAET than female students and have a Mean difference of (0.49), but this difference in Mean is not a statistically significant difference and the above hypothesis is rejected.

According to the results (Table 6) obtained from the T-test of independent samples, since the value of the significant level of SAET is equal to (0.49) and this value with (0.69) confidence greater than the error level of (0.05), so it can be inferred that the Mean SAET

Table 6 Independent sample T-test to compare the mean SAET of Iranian male and female students (RQ1)

Variable	Independent samples test						Mean difference
	Gender	N	Mean	Std. deviation	T	Sig	
SAET	Female	10	10.00	1.69	0.69	0.49	0.53
	Male	30	10.53	2.20			

Table 7 Pearson correlation coefficient test to evaluate the relationship between Age and SAET tasks of Hungarian students (RQ1)

Variable	Correlations					
	Pearson correlation	Task 1	Task 2	Task 3	Task 4	Total score
Age	Correlation	−0.214	−0.262	−0.014	−0.010	−0.210
	Sig	0.062	0.029	0.460	0.472	0.066
	N	53	53	53	53	53

between the two groups of Iranian male and female students have no significant relationship. According to the above test, male students have a higher Mean in SAET than female students and have a Mean difference of (0.53), but this Mean difference is not a statistically significant difference and the above hypothesis is rejected.

Due to the correlation coefficient and the level of significance of Age and SAET of Hungarian students (Table 7), which shows a negative and inverse relationship (Fig. 6), as the Age of students increases, their SAET will decrease and vice versa. Pearson correlation coefficient is equal to (0.21), which is a weak correlation and the level of significance is reported to be (0.06), which with (0.95) confidence is greater than the standard error level of (0.05), so it can be inferred that There is no significant relationship between the two variables and the above hypothesis is rejected. All levels of significance of the 4 tasks except task 2 have been reported as non-significant and greater than (0.05), which indicates that out of 4 tasks in the SAET subset, only task 2 had a significant relationship with Age.

Considering the correlation coefficient and the level of significance of Age and SAET of Iranian students (Table 8), which is reported to be a negative and inverse relationship (Fig. 7), as the Age of students increases, their SAET will decrease and vice versa. The value of Pearson correlation coefficient is (0.01), which is a weak correlation and the level of significance is reported to be (0.47), which with (0.95) confidence is greater than the standard error level of (0.05), therefore, it can be inferred that There is no significant relationship between the two variables and the above hypothesis is rejected. All levels of significance of the 4 tasks were also reported to be non-significant and greater than (0.05), which indicates that out of all 4 tasks in the SAET subset, there was no significant relationship with Age.

Given the correlation coefficient and the level of significance of the Hungarian students Mathematics grades and SAET (Table 9), which is reported to be a direct and positive relationship (Fig. 8), the higher the students' Mathematics grades, the higher their SAET, and vice versa. The value of Pearson correlation coefficient is equal to (0.68) which is a strong correlation and the level of significance is (0.0001) which is (0.95) less than the standard error level of (0.05), so it can be inferred that the relationship

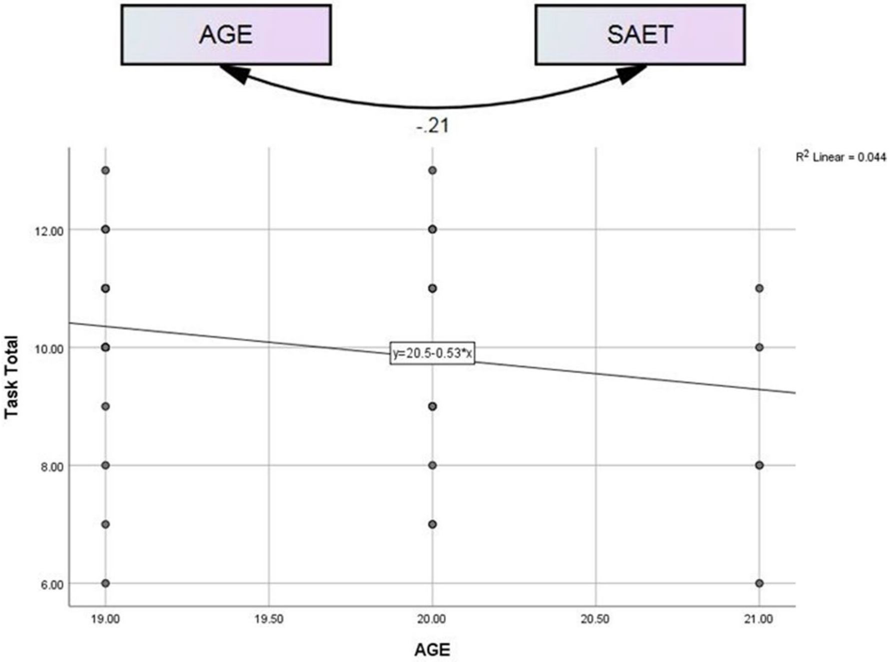

Fig. 6 Relationship between age and SAET tasks of Hungarian students

Table 8 Pearson correlation coefficient test to evaluate the relationship between Age and SAET tasks of Iranian students (RQ1)

Variable	Correlations					
	Pearson correlation	Task 1	Task 2	Task 3	Task 4	Total Score
Age	Correlation	0.039	−0.199	0.076	−0.041	−0.010
	Sig	0.406	0.109	0.320	0.400	0.476
	N	40	40	40	40	40

is not statistically significant between the two variables and the above hypothesis is confirmed. All levels of significance of the 4 tasks were also significant and less than (0.05), which indicates that all 4 tasks of the SAET subset had a significant relationship with the mathematics grades.

According the degree of correlation coefficient and the level of significance of the Mathematics and SAET score of Iranian students (Table 10), which is a direct and positive relationship, it means, as the students' Mathematics grades increases, their SAET will also increase, and vice versa (Fig. 9). The value of Pearson correlation coefficient is equal to (0.59), which is a strong correlation and the value of significance level is (0.0001), which is (0.95) less than the standard error level of (0.05), so it can be concluded that the relationship is not statistically significant between the two variables and the above hypothesis is confirmed. Significance levels of tasks 1 and 3 were also significant and less than (0.05),

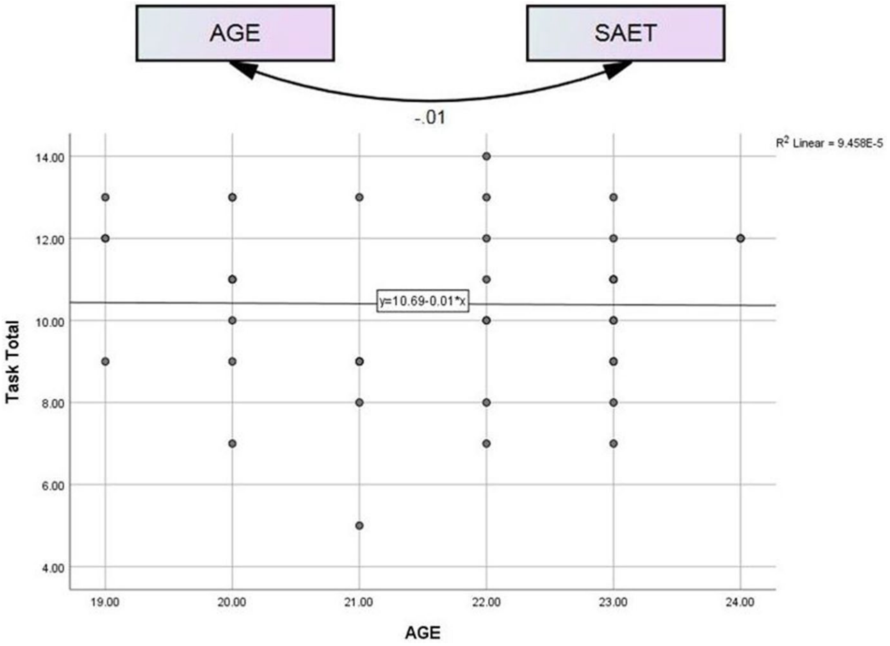

Fig. 7 Relationship between age and SAET tasks of Iranian students

Table 9 Pearson correlation coefficient test to evaluate the relationship between Mathematics grades and SAET of Hungarian students (RQ1)

Variable	Correlations					
	Pearson correlation	Task 1	Task 2	Task 3	Task 4	SAET
Grade from math	Correlation	0.592	0.368	0.365	0.398	0.677
	Sig	0.000	0.003	0.004	0.002	0.0001
	N	53	53	53	53	53

which indicates that out of 4 tasks in the SAET subset, two tasks had a significant relationship with the grades of Mathematics.

RQ2:

Data analysis in Table 11 showed that there is a significant correlation between some of tasks solutions by Hungarian students with SPSS (Task 1 and 2: $r = 0.280$, $p = 0.042$, $p < 0.05$, Task 1 and 4: $r = 0.414$, $p = 0.002$, $p < 0.01$, Task 2 and 4: $r = 0.371$, $p = 0.006$, $p < 0.01$, Task 3 and 4: $r = 0.378$, $p = 0.005$, $p < 0.01$,). So Task 4 has significant correlation with other tasks. But correlation is not statistically significant between tasks by Iranian students (Table 12).

RQ3:

Due to the consequences obtained from the T-test of independent samples (Table 13), thus the value of the significant level of SAET is equal to (0.78) and this value with (-0.27) confidence greater than the error level of (0.05), it can be deduced that the Mean SAET between Hungarian and Iranian students have no significant difference.

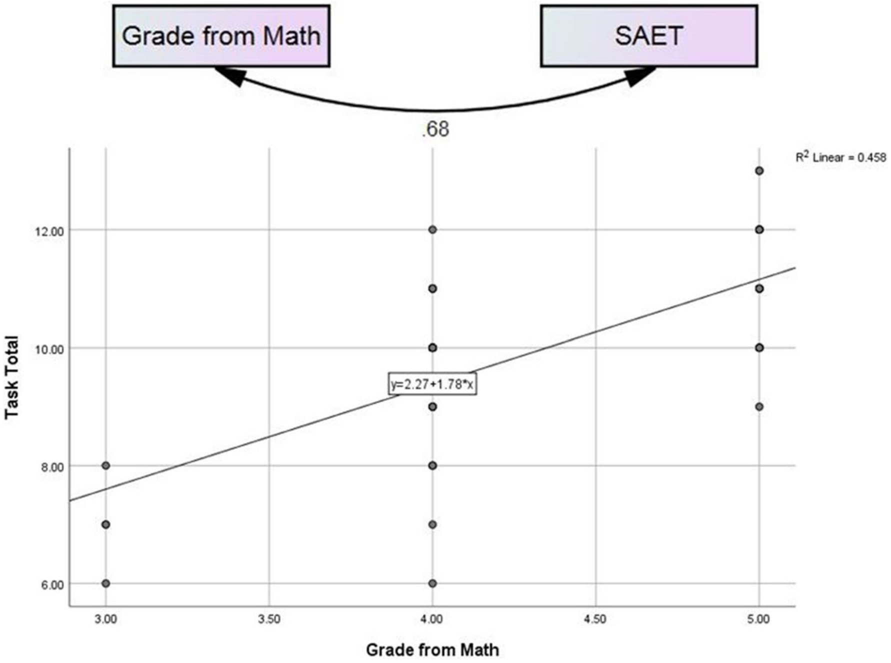

Fig. 8 Relationship between mathematics grades and SAET of Hungarian students

Table 10 Pearson correlation coefficient test to evaluate the relationship between Mathematics grades and SAET of Iranian students (RQ1)

Variable	Correlations					
	Pearson correlation	Task 1	Task 2	Task 3	Task 4	SAET
Grade from math	Correlation	0.554	0.164	0.305	0.083	0.586
	Sig	0.000	0.157	0.028	0.306	0.0001
	N	40	40	40	40	40

According to the above test, Iranian students have a lower Mean in SAET than Hungarian students and have a Mean difference of (0.1), but this Mean difference is not statistically significant and the above hypothesis is rejected.

For the two types of tasks (Polyhedron part and Curved Surfaces part), we found differences between the two countries. The results of Iranian students are better than Hungarian students in Polyhedron part of SAET (Hungary: males: 56%, females: 56.3% and in Iran: males: 73.3%, females: 62.9%). The results of Hungarian students are better than Iranian students in Curved Surfaces part of SAET (Hungary: males: 84.4%, females: 77.9% and in Iran: males: 67.5%, females: 70%). We can observe that results of Iranian female students are better than male students in Curved Surfaces part of SAET and results of Hungarian female students are better than male in Polyhedron part of SAET.

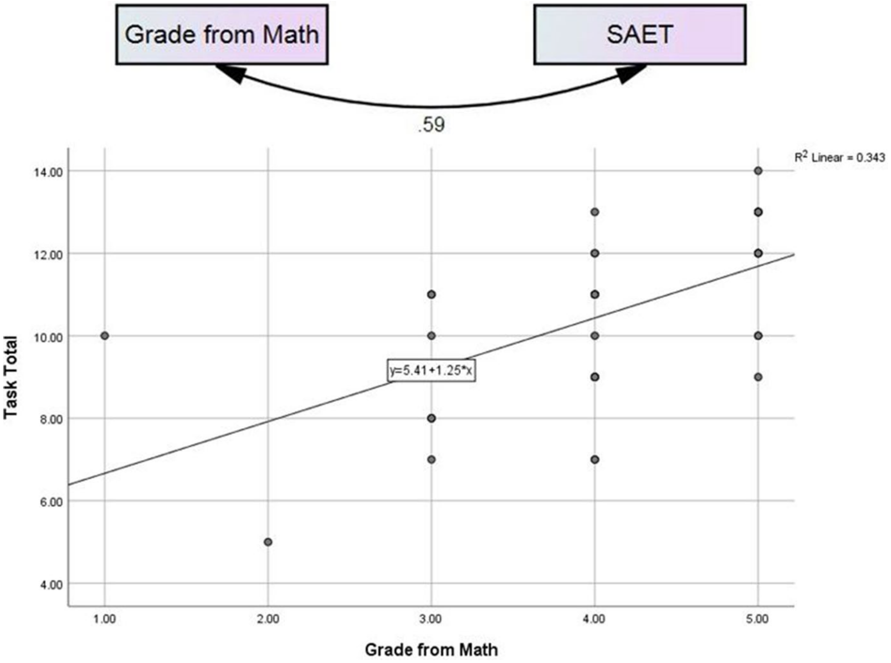

Fig. 9 Relationship between mathematics grades and SAET of Iranian students

Table 11 Relationship between task types in Hungary (RQ2)

	Task 1	Task 2	Task 3	Task 4
Task 1				
Pearson correlation	1	.280*	.135	.414**
Sig. (2-tailed)		.042	.334	.002
N	53	53	53	53
Task 2				
Pearson correlation	.280*	1	.231	.371**
Sig. (2-tailed)	.042		.096	.006
N	53	53	53	53
Task 3				
Pearson correlation	.135	.231	1	.378**
Sig. (2-tailed)	.334	.096		.005
N	53	53	53	53
Task 4				
Pearson correlation	.414**	.371**	.378**	1
Sig. (2-tailed)	.002	.006	.005	
N	53	53	53	53

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

Table 12 Relationship between task types in Iran (RQ2)

	Task 1	Task 2	Task 3	Task 4
Task 1				
Pearson correlation	1	.146	−.007	.043
Sig. (2-tailed)		.368	.964	.793
N	40	40	40	40
Task 2				
Pearson correlation	.146	1	.138	.100
Sig. (2-tailed)	.368		.395	.541
N	40	40	40	40
Task 3				
Pearson correlation	−.007	.13	1	.181
Sig. (2-tailed)	.964	.395		.263
N	40	40	40	40
Task 4				
Pearson correlation	.043	.100	.181	1
Sig. (2-tailed)	.793	.541	.263	
N	40	40	40	40

According to obtained data, the result is: first-year engineering students of Debrecen are more successful at Curved Surfaces part than students of Tehran, in addition students of Tehran are more successful at Polyhedron part than students of Debrecen.

RQ4:

We can see the results of Friedman test (Table 14). It can be said that first year engineering students in Hungary and Iran have a significant difference with other Tasks. The results of this test indicate that the Tasks are significantly different from each other in terms of mean rank. Among Hungarian students, the highest to the lowest Mean rank in Tasks is assigned to: Task 1, Task 2, Task 3 and Task 4 and among Iranian students the highest to lowest Mean rank in Tasks is determined to respectively: Task 1, Task 3, Task 2 and Task 4.

The square cross section was found by most student in both countries in Polyhedron part (Task 1). Performance is nearly the same by triangle and equilateral triangle cross section in both countries. First-year engineering students of Hungary are more successful at Polyhedron part by square and rectangle solution (square: Hungary: 98.11%, Iran: 77.5%; rectangle: Hungary: 92.45%, Iran: 72.5%). First-year engineering students of Iran are more successful at Polyhedron part by pentagon, hexagon and parallelogram (that is not a rectangle) solution (pentagon: Hungary: 13,21%, Iran: 65%; hexagon: Hungary: 11,32%, Iran: 70%; parallelogram: Hungary: 20,75%, Iran: 65%). In pentagon and hexagon solutions has the biggest difference between the two groups.

First-year engineering students of Hungary are more successful at Curved Surfaces part to find circle solution of cylinder, cone and sphere (cylinder: Hungary: 98,1%, Iran: 57,5%; cone: Hungary: 98,1%, Iran: 62,5%; sphere: Hungary: 86,8%, Iran: 57,5%). First-year engineering students of Iran are more successful at at Curved Surfaces part to find parabola solution of cone (Hungary: 43,4%, Iran: 67,5%). Performance is nearly the same by ellipse (by cylinder and cone) and hyperbola (by cone) cross section in both countries.

Table 13 Independent sample T-test to compare the mean SAET of Hungarian and Iranian students (RQ3)

Variable	Independent samples test						Mean difference
		N	Mean	Std. deviation	T	Sig	
SAET	Hungary	53	10.50	1.77	− 0.27	0.78	0.1
	Iran	40	10.40	2.08			

Table 14 Friedman test to rank the results of Hungarian and Iranian first year engineering students in different types of Tasks for evaluation (RQ4)

Nationality	Tasks	Mean rank	Statistics	Data
Hungarian	Task 1	3.79	N	53
	Task 2	2.87	Chi-Square	141.83
	Task 3	2.34	df	3
	Task 4	1.00	Asymp. Sig	0.0001
Iranian	Task 1	3.84	N	40
	Task 2	2.25	Chi-Square	102.29
	Task 3	2.84	df	3
	Task 4	1.08	Asymp. Sig	0.0001

5 Conclusion and further research

Spatial abilities of Iranian and Hungarians freshman engineering students have been studied in this paper. Their mental cutting, mental rotation abilities and creativity were measured. All data were collected during the spring semester of 2019. Results of the current study indicated that students' performance in SAET was related to their gender. According to our results first-year engineering male students were stronger than female students in both countries in SAET; according to data analysis there was a significant correlation between gender and SAET Task 3 scores (cross sections of cone) of students in Hungary. Studies showed that common mistakes in special intelligence can be one of the possible reasons, because in some cases, female students often make more mistakes than male especially in spatial abilities (Jansen-Osmann and Heil 2007).

According to our results there is a significant correlation between Math scores and SAET scores of engineering students in both countries and there is a significant correlation between some tasks solutions by Hungarian students (Task 4 has significant correlation with other tasks), but there is not significant correlation between tasks by Iranian students.

According to obtained data, accomplished the result: first-year engineering students of Debrecen are more successful at Curved Surfaces part than students of Tehran, in addition students of Tehran are more successful at Polyhedron part than students of Debrecen.

For the two types of tasks by SAET: Polyhedron part and Curved Surfaces part. We found differences between the two countries. Results of Iranian students are better than Hungarian students in Polyhedron part of SAET, and results of Hungarian students are better than Iranian students in Curved Surfaces part of SAET. We can observe that results of Iranian female students are better than male students in Curved Surfaces part of SAET and results of Hungarian female students are better than male in Polyhedron part of SAET. This seems to contradict previous researches, but probably because the tasks were not separated into two parts (Polyhedron part and Curved Surface part) in previous researches.

Another reason may be that students have already learned about the surfaces of SAET in high school. Explanation for this difference requires further research.

The square cross section was found by most students in both countries in Polyhedron part. First-year engineering students of Hungary are more successful at Polyhedron part by square and rectangle solution. First-year engineering students of Iran are more successful at Polyhedron part by pentagon, hexagon and parallelogram (that is not a rectangle) solution. First-year engineering students of Hungary are more successful at Curved Surfaces part to find circle solution of cylinder, cone and sphere. First-year engineering students of Iran are more successful at at Curved Surfaces part to find parabola solution of cone. Therefore the development of the spatial ability would deserve more attention in terms of teaching geometry in both countries in both parts (Polyhedron part and Curved Surfaces part).

According to survey results many students have problems with spatial geometry tasks. We can use models of spatial solids, virtual models and manipulation activities in classroom to develop spatial ability of students and to help students understand spatial concepts (Nagy-Kondor 2017). Studies suggest the impact of interactive animation or virtual solid tools for training spatial thinking (Kurtulus 2013; Nagy-Kondor 2010, 2016), because imagining different views of a 3D object will be easier, if they can see formal characteristics of this. According to studies augmented reality integration in learning has been identified as an important factor in developing knowledge construction in geometry learning and it can lead to the formation of spatial ability (Amir et al. 2020; Ibanez et al. 2020) and it would be particularly benefical to reveal the student's spatial problems and awareness with first-person analysis and task based interviews.

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Declarations

Conflict of interest We have no conflict of interest to discolose.

Ethical approval Participation was voluntary.

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