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Factors Influencing Students' Beliefs About Engineering Habits of Mind

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Abstract

The current study investigated the influence of emotional factors, gender variable, grade level and academic achievement on university students' beliefs about engineering habits of mind. The sample included 400 male and female students from the University of Wasset in Iraq. The study used the following scales: Belief scale for engineering habits of mind, engineering Self-efficacy Scale, engineering Attitude Scale and a Demographic Characteristics questionnaire. All data were analyzed using the correlational survey technique. The results of the current study showed significant positive relationships were found between the students' self-efficacy concerning engineering and their academic achievements, and their beliefs about engineering habits of mind. Furthermore, a negative, moderate and significant relationship was found between the attitudes of the students to engineering and their beliefs about engineering habits of mind. In conclusion, no significant difference was found between the grades of the students regarding engineering habits of mind and their gender.

Keywords: *Beliefs; Engineering habits of mind; Engineering; Self-efficacy.*

1. Introduction

The science of engineering requires many different skills such as developing reasoning skills, enabling concepts visualization and relationship in symmetrical figures, overwhelming problems encountered in day-to-day life, and other arithmetic knowledge (Talib et al., 2019; Harada, 2008; Frank, 2006). Furthermore, the main issue of learning engineering skills among students, is having inadequate problem-solving skills (Subramaniam et al., 2020; Özyurt, 2015). Problem-solving means that individuals are able to overcome the problems they face, and can find solutions if faced with a similar situation again (Martinez, 1998). Helping students learn how to solve problems will make their knowledge of engineering more stable and permanent (Clements, 2003; Herbst, 2006; Schoenfeld, 1992). Students have a tendency to practice previously acquired habits while trying to overcome the problems they are running into. Choosing what will work from their list of habits and using the selected habit suitably play an important role in disabling any problem encountered. These habits, known as "habits of mind", are the modes of thinking that come into play when it is not known how to solve a problem; they provide a range of possible choices to an individual (Costa & Kallick, 2009). These habits of mind can be divided into "general habits of mind" and "domain-specific habits of

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mind" (Cuoco et al.,1996; Lim & Selden, 2009). Lim and Selden (2009) classified the general habits of mind into: "experimenting", "pattern sniffing," "tinkering", "formulating", "inventing", "conjecturing", and "visualizing". While, domain-specific habits of mind were defined as "engineering habits of mind", "scientific habits of mind", "calculating habits of mind", "mathematical habits of mind", "algebraic habits of mind", "probabilistic habits of mind" and "geometric habits of mind". Since this study is concerned with engineering, the aim of the current study is to investigate beliefs about "engineering habits of mind" and the factors influencing them.

1.1 Emotional and cognitive dimensions of engineering habits of minds

Engineering habits of mind are generative ways of thinking that support learning and teaching engineering (Loveland & Dunn, 2014). Students usually tend to use engineering habits of mind when they come across an engineering-related problem. For instance, when students are asked to find the area of given a triangle or a square, their focal leaning is to instantly write in the angles or draw parallels and consequently they hunt for a solution. According to Goldenberg (1996), engineering habits of mind can be classified as: (a) the disposition to picture when rendering diagrams; (b) to define formally and informally; (c) to interpret between visually and vocally presented data; (d) to interfere; (e) to search for invariants; (f) to combine trials with assumptions; (g) to build systematic clarification and evidence; (h) to construct and reason about processes; and (i) to reason by continuity. In the same way, Cuoco et al. (1996) defined engineering habits of mind as (a) thinking about reasoning by continuousness, (b) seeking engineering invariants, (c) Investigating extreme cases and passing to the limit, (d) dynamically altering systems, (e) nonstop distortions, and (f) incessant functions. Problem-solving and the definitions of engineering habits of mind are entangled (Jimenez et al., 2021). In other words, students' problem-solving skills and their inclination to practice engineering habits of mind are influenced by each other.

Engineering habits of mind express the ways in which students, who study mathematics, approach a problem and think "like an engineer" (Lucas & Hanson, 2016; Matsuura et al., 2013). Students' achievements in problem-solving influence their engineering habits of mind and their beliefs regarding these habits (Driscoll et al., 2007; Gordon, 2011). Consequently, having positive beliefs about engineering habits of mind will increase both students' problem-solving accomplishment and their dependance on engineering habits of mind (Costa & Kallick, 2009; Erşen et al., 2018; Hanson & Lucas, 2020). If students' beliefs about engineering habits of mind can be determined and learning situations be planned with reference to those beliefs, students' achievement in problem-solving and capacity to engage in engineering habits of mind could be increased (Lucas & Hanson, 2016).

Beliefs about engineering habits of mind reflect the emotional dimension of the students' behaviors and attitudes when they face an engineering-related problem that they can't solve. The emotional dimension of engineering habits of mind comprises the beliefs and feelings that students might have while solving an engineering-related problem. The majority studies on engineering habits of mind have mostly focused on the cognitive rather than the emotional dimension of these habits (Driscoll et al., 2007; Cuoco et al., 1996; Goldenberg, 1996). Costa and Kallick (2009), explored the emotional dimension of habits of mind, classifying them into: "thinking flexibly, motivating for accuracy, handling impulsivity, collecting data through all senses, thinking interdependently, metacognition, thinking and collaborating with clarity and accuracy, persevering, finding humor, applying previous knowledge to new situations, questioning and posing problems, generating, listening with understanding and compassion, taking responsible risks, responding with amazement and awe, remaining open to constant learning".

Since this classification of habits of mind by Costa and Kallick (2009) was developed with regard to elementary school students, it only provides a small view of general habits of mind. Moreover, the emotional and the cognitive dimensions of these habits are not meaningfully distinguished from each other. This condition may cause issues in assessing the habits of advanced students and in measuring their beliefs about engineering habits of mind. Therefore, the emotional and cognitive structure of the engineering habits of mind of students was restudied by Bülbül (2016). According to Costa and Kallick (2009), evaluating the habit of "questioning and posing problems" together with the habit of "persevering" does not cause an issue in defining the habits of primary school students. Yet, when attempting to determine the beliefs of students about their habits, it is necessary to study the "questioning and posing problems" habits as belonging to the cognitive dimension.

1.2. Beliefs about engineering habits of mind and influencing factors

Since the emotional dimension of engineering habits of mind is determined by the beliefs of the university students, these are called beliefs about engineering habits of mind within the scope of the study. Beliefs about engineering habits of mind impact students' capability to resolve a problem appropriately. For instance, if students give up trying when they cannot solve an engineering-related problem instantly, they are not concentrating on how to answer it successfully. Though, if students have the habits of "persevering" and "flexibility", which are listed on the emotional dimension of engineering habits of mind, and the students are stimulated to try diverse solutions, they will know how to find the correct answer. At this stage, it is imperative to find and regulate the students' most emotional habits of mind and support them in the learning environment. If the beliefs that directly impact achievement in engineering are determined, students can be directed in line with these beliefs. This study thus focused on the engineering habits of mind of university students and the attempt was made to identify factors affecting these beliefs. In the study, the emotional factors influencing engineering habits of mind were classified as self-efficacy regarding engineering and attitude towards engineering. Self-efficacy is an individual's self-judgement about their ability to deal with the problems they meet (Elias & MacDonald, 2007; Butler, 1998). Self-efficacy concerning engineering can be defined as individuals' capacity to establish engineering-related problems, solve such problems successfully and to be self-assured in their ability to do so (Askar & Davenport, 2009). From this viewpoint, having high self-efficacy may cause individuals to have more unconventional goals for themselves and to be reliable in their choices and decisions, and it could also increase their accomplishment in problem-solving skills (Schunk, 1990). Beliefs about engineering habits of mind and problem-solving are entwined and both intend to overcome engineering-related problems students might face.

Attitudes can be defined as "individuals' pre-behavioral mental predisposition with reference to the events, situations, and objects around them and shaped on the basis of earlier life experiences". Like their beliefs in self-efficacy, individuals' negative or positive attitudes to engineering influence their achievement in engineering education. Positive relationships between students' problem-solving accomplishment and attitudes indicate why it is valuable to study the association between the above-mentioned notions and beliefs about engineering habits of mind (Nicolaidou & Philippou, 2003). Although self-efficacy regarding engineering and engineering-related attitudes represents emotional factors, university students' achievement shows their possible performance. The gender and their rating levels are also important to be considered (Alias et al., 2012).

The cognitive dimension of engineering habits of mind has four characteristics. These are the habits of "reasoning with an association", "considering precise cases and generalizing engineering-related ideas", "examining invariants", and "investigation and reflection". The emotional dimension of engineering habits of mind has ten indicators. The "persevering" factor is related to the continuous process of trying and not giving up effortlessly. The "handling impulsivity" factor is about how to think before acting. The "listening with understanding" and "responsiveness" elements are about how to listen to others thoughtfully and with sensitivity. The "flexibility" factor is about enduring open to replacements or considering other options when students make mistakes while solving problems. The "responding with amazement and awe" factor is about appreciating problem solving and representing inquisitiveness. The "remaining open to constant learning" element is associated with motivating for development and improvement; looking for new and better behaviors of doing things. "Motivating for accuracy" is about how to use standards to assess quality. "Skepticism" is associated with checking the solution occasionally, seeing that there could be more than one solution to the problem. Lastly, "self-discipline" and "bias" shape one's confidence in problem solving and the capability to practice engineering-related language efficiently in this process (Schucker et al., 2022; Altan et al., 2019).

Some studies have also confirmed the influence of the emotional factors mentioned above on university students' achievement in engineering-related and problem-solving tasks and how these are entangled with engineering habits of mind. There are also other variables like gender, academic achievement and engineering success that have an effect on students' achievement (Eshel & Kohavi, 2003). Students' success in engineering classes and with engineering problems is related to the engineering habits of mind they have and their beliefs about engineering habits of mind (Driscoll et al., 2007). The question arises with regard to which emotional factors influence beliefs about engineering habits of mind. Identifying university students' beliefs about engineering habits of mind is important as these beliefs will also impact their achievement in engineering. In this context, the aim of the current study was to identify the factors influencing university students' beliefs about engineering habits of mind. The effects of students' self-efficacy regarding engineering and their engineering-related attitude on their beliefs about engineering habits of mind were examined. The effects of students' gender, academic achievement, and their grade level on their beliefs about engineering habits of mind were also assessed.

2. Method

The current study adopted a correlational research design. This approach is focused on measuring relationships between two or more phenomena and generally includes a statistical
portion of the degree of relationship, or correlation (McMillan & Schumacher, 2010). As the current study aimed to investigate the effects of students' self-efficacy about engineering and their attitudes to engineering on their beliefs about engineering habits of mind, a correlational study design was thought to be suitable.

2.1. Participants

The study was conducted with a total of 400 university students, 200 of whom were female and 200 were male. All of the sample was selected from the university of Wasset in Iraq. All data were taken from 100 first-year, 100 second-year, 100 third-year, and 100 fourth-year students.

2.2. Measures

The study used the "engineering habits of mind belief scale", "self-efficacy scale for engineering" and "engineering attitude scale" as data collection tools over a period of one month. The grade point averages of the university students in the mathematics and engineering-based courses (general math, engineering, computer-aided engineering teaching, problem-solving, modeling, analytical engineering I, Analytical engineering II, Math education and computer, engineering and measurement teaching), which may have influenced their engineering habits of mind, were gained from their transcripts and considered to represent their level of academic achievement. The current study adopted the engineering habits of mind belief scale which was developed by Bülbül (2016). Bülbül (2016), who conducted the validity and the reliability study of the scale and the results of his study found that the variance value was 42.4% and the Cronbach Alpha reliability coefficient for the whole scale was 0.88. Based on these results, the scale was considered very reliable. This scale consisted of three dimensions: “pre-preparation belief”, “not giving up and perseverance”, “beliefs in diverse solution strategies”. The items in the scale include beliefs about engineering habits of mind such as “Before starting to solve an engineering-related problem, one should think about how to solve it”; “Even the most hard engineering-related problems can be explained if one studies hard”; “Once trying to make a choice about an engineering-related problem, the results of each choice should be compared to each other”. Cantürk-Günhan and Başer (2007) developed the self-efficacy scale for engineering. This scale consists of three dimensions: positive self-efficacy beliefs, use of engineering-related knowledge, negative self-efficacy beliefs. The scale, which was found to be valid and reliable, consists of 25 items in total, 18 of which were positive, and seven were negative. The highest score reachable from the scale was 125 and the lowest was 25. Cantürk-Günhan and Başer (2007) investigated the validity and reliability of the scale and found that the variance value was 42,42% and the Cronbach Alpha reliability coefficient was 0.87. These values prove that the scale was valid and reliable. The items in the scale included positive and negative self-efficacy towards engineering such as “I can easily understand the concepts in engineering”, “I can use my engineering knowledge in other lessons”, “I can write problems in engineering”, “I don’t think I am as good as my friends in engineering”, “I don’t have enough knowledge about engineering.”

The current study used another scale (the engineering attitude scale), developed by Bindak (2004). This measure, which consisted of 25 items in total, 16 of which were negative and nine were positive. The scale was a five-point Likert-type. The options were: “Strongly Disagree”, “Disagree”, “Partially Agree”, “Agree”, “Strongly Agree”. The highest score attainable from the scale was 125 and the lowest was 25. Bindak (2004) conducted the validity and reliability of the scale and found that the variance value was 59.2% and the Cronbach Alpha reliability coefficient was 0.94. The items on the scale, which consisted of four dimensions, included negative and positive attitudes towards engineering such as “trying to solve an engineering-related problem is fun”, “no other lesson is as boring as disagreeing with an engineering lesson”, “I would like to spend more time doing engineering”, “I like engineering”.

The aforementioned measures were applied to university students by the researcher over a period of one month. Adequate time was assigned to make sure university students’ opinions as represented by the scale were more objective.

2.3. Data Analysis

Prior to the analysis of the data gained from the participants, the normality of the distribution of the data obtained from each scale was studied. The Kolmogorov-Smirnov test was performed in addition to examining the skewness and kurtosis values of the scores. In the current study, according to the scores from the engineering habits of mind belief scale, the self-efficacy scale for engineering, and the engineering attitude scale, and the Kolmogorov-Smirnov test result of the data obtained from the academic achievements and gender scores of the students, the significance value was between -1.5 and +1.5. A significance value between -1.5 and +1.5 according to the Kolmogorov-Smirnov test indicates that the data are normally distributed. Since the data obtained from the scales applied to the students, the academic achievements of the students and the gender variables showed normal distribution, parametric tests were performed on these data. This means, the statistical method of multiple regression analysis was used when exploring the relationship between the university students’ self-efficacy regarding engineering, their attitudes towards engineering, their academic achievements and their beliefs about engineering habits of mind. While the unrelated samples between university students’ grade level and their beliefs about engineering habits of mind were analyzed using one-way ANOVA, the relationship between the gender of the students and their beliefs about engineering habits of mind were analyzed using the independent t-test.

3. Results

The result section included three parts. The first presents findings about how the affective factors and academic achievements of university students influenced their beliefs about engineering habits of mind. The second shows the relationship between university students' grade level and their beliefs about engineering habits of mind; the last section displays findings about the relationship between university students' gender and their beliefs about engineering habits of mind.

3.1. The effect of university students' emotional factors on their beliefs about engineering habits of mind

Multiple regression analysis was used to study the relationship between the university students' self-efficacy regarding engineering, their attitude to engineering, their academic achievements, and their beliefs about engineering habits of mind.

Variable	B	SE	β	T	p	Binary r	Partial r
Fixed	12.092	4.631		2.343	.000		
Academic Achievement	0.084	0.051	0.067	1.098	.001	0.623	0.442
Attitude	- 0.032	0.050	-0.201	- 0.387	0.068	- 0.412	- 0.092
Self Efficacy	0.424	0.108	0.204	4.803	.001	0.769	0.601
r= 0.792	r^2= 0.627						
$F_{(3,26)}$ = 13.80	p= .000						

Table (1). Results of the Multiple regression analysis about the estimates of beliefs of engineering habits of mind.

The results of the regression analysis of the estimates of university students about engineering habits of mind according to the variables of self-efficacy, attitude towards engineering, and academic achievements are shown in Table (1). When the binary and partial correlations between the predictor variables and the dependent variable in Table (1) were studied, there was a positive and high correlation (r= 0.769) between university students' self-efficacy regarding engineering and their beliefs about engineering habits of mind, however, when the further variables were inspected, it was seen that the correlation between these two variables was (r= 0.601). There was a high-level and positive (r=0.623) correlation between the academic achievements of university students and their beliefs about engineering habits of mind. Once the other variables between this binary correlation were inspected, the correlation was reduced to (r=0.442). In Table (1) there was a moderate-to-negative relationship (r=- 0.412) between the university students' attitudes towards engineering and their beliefs about engineering habits of mind. When other variables were measured, it was seen that this association was negative, although to a low level(r=-0.092). Accordingly, Table (2) shows that there is a significant relationship between the university students' attitudes, self-efficacy, and academic achievement and their beliefs about engineering habits of mind (r= 0.792, r 2= 0.627, p < .01). So, these three variables provided an explanation about 62% of the total variance of university students' beliefs about engineering habits of mind.

Consistent with the standardized regression coefficient (β), the order of the importance of predictor variables on beliefs about engineering habits of mind was self-efficacy, academic achievement, and attitude. Once the t-test results concerning the significance of the regression coefficients were observed, it can be understood from Table (1) that the variables of self-efficacy and academic achievement were significant predictors of beliefs about engineering habits of mind.

3.2. Relationship between university students' grade level and their beliefs about engineering habits of mind Unconnected samples between the university students' grade level and their beliefs about engineering habits of mind were analyzed by one-way ANOVA. Table (2) shows the descriptive statistics of university students' beliefs about engineering habits of mind.

Grade	N	$\bar{X}$	SD
1	100	79.31	6.43
2	100	82.74	6.67
3	100	83.22	5.46
4	100	85.46	7.70

Table (2) Descriptive statistics of beliefs about engineering habits of mind

As stated by the descriptive statistics shown in Table (2), most university students were in the fourth ($\bar{X}$= 85.46) and third years of study ($\bar{X}$= 83.22). Moreover, although the average of the university students studying in the second year was ($\bar{X}$= 82.74), and ($\bar{X}$= 79.31) for the first year. Table (3) illustrates results of the one-way ANOVA for the unconnected samples of the university students, whose descriptive statistics were shown above.

Table (3). Results of one-way ANOVA relationship between grade level and beliefs about GHoM

Source of variance	Sum of squares	SD	Mean square	F	p	Statistically significant difference
Between groups	305.998	4	76.499	12.072	.000	3rd yr>1st yr*,
Within groups	4522.929	260	17.395			4th yr>1st yr*, 2nd yr>1st yr*
Total	4828.927	264				

*p<.01

As indicated in Table (3), a significant difference emerged between the beliefs of university students regarding engineering habits of mind and their respective grade levels ($F(4,260)=12.07$, $p < .01$). To elaborate, university students' beliefs concerning engineering habits of mind exhibited substantial variations contingent upon their academic year. Subsequent to the analysis, it was established that the variations were uniformly distributed. Consequently, the Scheffe test and post-hoc analysis was implemented within this context. The Scheffe test was executed to ascertain differences across different years of study. It was revealed that university students in their third, fourth, and second years showed notably more positive beliefs compared to those in their first year of study.

3.3. Relationship between the gender of university students and their Beliefs about engineering habits of mind The relationship between the university students' gender and their beliefs about engineering habits of mind were analyzed by the independent samples t-test. The results were shown in Table (4).

Gender	N	$\bar{X}$	SD	df	t	p
Male	200	81.33	6.27	262	1.78	0.13
Female	200	81.98	7.31			

Table (4). Results of t-test analysis of the relation between gender and beliefs about engineering habits of mind.

No significant differences were found between the university students' beliefs about engineering habits of mind and their gender ($t_{(264)} = 1.78$; $p=0.13>0.05$). The female university students‟ average beliefs about engineering habits of mind score were 7.31, whereas the male university students' average problem-solving score was 6.27. Thes differences were statistically significant.

4. Discussion and Conclusion

The present study has identified factors that affect university students' beliefs about engineering habits of mind. These factors were found to exert both direct and indirect influences. The direct factors consist of affective aspects and the academic achievements of the university students, while the indirect factors involve the gender and grade level of the students. The definition of engineering habits of mind employed here suggests that they are closely intertwined with problem-solving. Previous research has demonstrated a significantly positive relationship between general beliefs about mathematical habits of mind, specific beliefs about engineering habits of mind, and students' problem-solving achievements (Hanson et al., 2022; Ladion-De Guzman, 2021; Green, 2021; Lippard et al., 2019; Lucas & Hanson, 2016; McNeill et al., 2016; Matsuura et al., 2013). This implies that there exists a connection between university students' beliefs regarding engineering habits of mind and their beliefs concerning problem-solving.

In the current study, a positive and high-level relationship was found between university students' self-efficacy of engineering and their beliefs about engineering habits of mind. Self-efficacy in the context of engineering is the individuals' confidence in themselves to be able to organize and successfully solve engineering-related problems (Brown et al., 2016; Loo & Choy, 2013; Ponton et al., 2001). "Not giving up and perseverance", which is a dimension of the engineering habits of mind beliefs scale, matches the belief in self-efficacy regarding engineering. The current study found that the stronger the university students' self-efficacy regards engineering, the stronger their beliefs about engineering habits of mind. Similarly, Wimmer et al. (2020) showed that negative self-concept was related to a sustained decrease in motivation and academic achievement. In the same way, some previous studies indicated that students' perceptions of self-efficacy in problem-solving positively affect their beliefs and problem-solving achievement (Li, Song et al., 2020; Royston & Reiter-Palmon; Güven & Cabakcor, 2013; Hoffman, 2010; Hutchison et al., 2006; Nicolaidou & Philippou, 2003; Stage & Kloosterman, 1992).

Another result obtained from the present study was that there was a moderate-to-negative relationship between the university students' attitudes toward engineering and their beliefs about engineering habits of mind. In other words, when university students' positive attitudes towards engineering increased, their beliefs about engineering habits of mind decreased. A similar result was reached by Erşen (2017) who explored the correlation between students' engineering habits of mind and their attitudes towards engineering. Erşen (2017) found a moderate relationship between students' attitudes and engineering habits of mind. Examining the reason for the presence of a moderate, negative relationship, it was observed that the routine nature of some engineering courses at universities may lead to a lack of interest among students. In other words, conducting some engineering classes with paper and pencil only may give rise to a negative attitude towards engineering in general. Using dynamic software may enable university students to develop a more positive attitude towards engineering can make engineering lessons more fun and ensure that concepts are permanently learned (Loveland & Dunn, 2014). A positive, high-level relationship was found between the academic achievement of university students and their beliefs about engineering habits of mind. Previous studies showed that engineering habits of mind and beliefs about such habits have positive effects on students' achievements (Ladion-De Guzman, 2021; Al Hinai et al., 2020; Yellamraju et al., 2019; Van Meeteren, 2018). Furthermore, as Pitterson et al., (2009) indicated, the fact that students' habits of mind are intertwined with problem-solving supports the result that their belief in their capacity to solve problems affects their academic achievement positively (Hanson & Lucas, 2020). In other words, as university students' beliefs about engineering habits of mind become more positive, so their academic performance will also improve.

Another result obtained from the present study was that there was a relationship between university students' grade level and their beliefs about engineering habits of mind. It was found that the beliefs about engineering habits of mind that the university students had in the fourth, third, and second years, were, respectively, more positive than the beliefs they had in the first year. This may be due to the fact that students have an understanding of the content of engineering courses while at university and changed their beliefs and attitudes as a result. In other words, during the teaching process, university students encountered a large number of engineering problems that they had to find ways to solve. Driscoll et al. (2007) indicated that an increase in the number of engineering problems that students were asked to solve improved their engineering habits of mind and their beliefs about these habits. This explains why the beliefs of the university students who were more advanced in their studies were more positive in the current study. First-year students may have difficulty in properly formulating beliefs about engineering habits of mind for the reason that they do not have full knowledge of the engineering courses within the university programs. Furthermore, beliefs may not be brought to an individual's conscious awareness till they are fully adopted. Nevertheless, as the grade level advanced, the average scores for the university students' beliefs about engineering habits of mind showed that they had more positive views of these habits. Costa and Kallick's (2009) research, which recommends that students' behaviors become more habitual as they get older, supports the results obtained in the current study. In the present study, no significant relationships were found between the gender of the university students and their beliefs about engineering habits of mind. In previous studies, different results have been found where habits of mind, beliefs, and successful problem-solving have been examined in the context of gender. Recently, some studies have shown that the gender variable does not influence beliefs and success in problem-solving or academic achievement, although some studies have stated the contrary (Hanson et al., 2022; Jimenez et al., 2021; Lippard et al., 2019; Lucas & Hanson, 2016).

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