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Creativity and Critical Thinking in Learning Mathematics Among Saudi Students; Comparison between Freshmen and Seniors

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Abstract

Creative thinking and creativity give important roles in learning mathematics for mathematics students. This study aims to investigate the levels of creativity and critical thinking in learning mathematics among Saudi undergraduate students. The study employed a fully quantitative research design to collect the data from 84 undergraduate students from public universities. The participants were divided into two groups freshmen and seniors. The data were collected in form of a written test. SPSS 23.0 software was used to analyse the data inferentially and descriptively. The findings showed that freshmen students have a higher level of creativity and seniors have a higher level of critical thinking. However, t-test analyses showed there is no significant difference between freshmen and seniors. Also, the results showed that freshmen students have a higher level of creativity than critical thinking while seniors have a higher level of critical thinking than creativity. This research contributes significantly to the limited studies of enhancing students' ability in learning mathematics. The findings shed new light on how creativity and critical thinking can be better promoted in mathematics education.

Keywords: Creativity; critical thinking; mathematic; learning; undergraduate students; Saudi Arabia.

Introduction

In addressing mathematical issues, creative thinking is one of the steps that is included while doing mathematical thinking. A student's capacity to think creatively about mathematics is an important part of their education (Firdaus, Kailani, Bakar, & Bakry, 2015). Among undergraduate students, creative thinking in mathematics holds a significant part in addressing the issues. The focus on critical and creative thinking is prevalent in Saudi Arabian math courses, as well as in their higher education. Due to the fact that the core of mathematics involves creative thinking, creativity is being recommended as one of the most important aspects of the education of mathematics (Hidayati, Zubaidah, Suarsini, & Praherdhiono, 2019). The act of thinkingamong students is one of the aspects that affect their math academic achievement. It is possible to consider this student's way of thinking style as a behavioural input (entering behaviour). Teachers ought to encourage their students to establish critical thinking while learning. Otherwise, society can suffer for a long period due to the lack of critical thinking in the learning process (Widana et al., 2018). Students' capacity to study mathematics is influenced by a variety of aspects, including their level of intellectual tolerance and performance. Candidates for math teachers in schools are expected to know how to deal withand foresee the obstacles that students mayexperience while studying mathematics. This is known to be part of their training course. Teachers play a critical role in ensuring that education systems are of the highest quality (Doleck, Bazelais, Lemay, Saxena, & Basnet, 2017). One of the ways to increase critical and creative thinking abilities is by focusing on the cognitive domain. Though critical thinking competence is the major feature in higher education, in reality, the lecturer seldom employs effective methods to promote studentsto apply critical thinking techniques. Research on critical and creative thinking among mathematics

undergraduates is thus needed to identify the features of this student population.The qualities of students' cognition are one of the aspects that determine student learning abilities (Sulistyo & Khristianto, 2017). These students' qualities might be considered behavioural influences (entering behaviour). Students' intellect and maturity are only two of the attributes that a variety of conditions may influence. Students need to develop critical and creative thinking skills to succeed in mathematics (Sriwongchai, Jantharajit, & Chookhampaeng, 2015). Both contributed to the solution of an issue. Employing active learning in certain lecture-based courses could be more difficult due to class size or other spacerestrictions, such as fixed seating. Hence, it maynot be feasible to break students into smaller controlled groups through these conditions, but alternative tactics like individual tasks or partnered exercises may be used and have positive outcomes (Innabi & El Sheikh, 2007).

The teaching and development of critical thinking are deliberate, logical, and goal-oriented (Aizikovitsh-Udi & Amit, 2011). Students need to work on their critical thinking abilities while still learning, and they will need to know how to assist their students in developing their critical thinking skills once they become teachers (Mulyati, Junaedi, & Sukestiyarno, 2021; Alakrash & Abdul Razak, 2021). It is the sort of thinking that goes into problem-solving, particularly drawing conclusions and reaching judgments. However, Perkins and Murphy used four critical thinking identifiers, particularly clarification, assessment, inference, and strategy; and they sought to deliver criteria of critical thinking that may be implemented quickly and effortlessly to deduce and give student features of engagement in critical thinking (Sanders, 2016).

Past studies have shown that college students' critical thinking skills increase the most while in their freshman year. In contrast, courses and initiatives aimed at improving critical thinking have shown inconsistent outcomes (Hidayati et al., 2019). Comparing courses delivered in the conventional approach with courses that emphasise problem-solving or critical thinking, student involvement, and higher-order thinking, significant advances in critical thinking levels were observed in the latter (Suastika, 2017). Higher critical thinking levels are often correlated with increased years of education, according to the study. Even so, there is relevant data to suggest that the overall performance level is inadequate. Critical thinking skills are acknowledged to be poorer than they should be at all levels of education, according to Happy, Listyani, & Si (2011). There is a lack of critical thinking skills amongmany children who go through the educational system (Sari & Hidayat, 2019). While multiple-choice assessments adversely impact critical thinking, there are multiple instructional variables that positively influence this output, mainly when it involves having an educator critically analyse a student's assessment and perform independent research, participating in group projects, and providing a class presentation. As (H. Alakrash, 2021) discovered, students who are taught to think critically are more likely to succeed in their future careers.

Literature Review

Creativity

Creativity is still considered a major research field, as evidenced by recent studies (Sitorus & Surya, 2017). It has a significant impact on the human situation since it promotes our ability to learn new things (Leikin & Pitta-Pantazi, 2013). Such evaluations and understandings of developing one's creative abilities are essential both academically and socially. Creativity evaluations are being used to investigate the well-known characteristics of creative people (Mann, 2006). Using divergent thinking tasks, the exam determines the results for each of these diverse attributes as a starting point for many conceptions of what it means to be creative (Starko, 2014; Root-Bernstein & Root-Bernstein, 2001). Divergent thinking has always been seen as one of the essential indicators of creativity. Many characteristics of this include fluency (elaboration), flexibility (creativity), and originality (uniqueness). TCT- whole-picture DP's creativity assessments are not directly linked to standard examinationssince they focus on divergent thinking rather than whole-picture creativity (Sheffield, 2013)

Critical Thinking

Wahyudi, Rukmini, & Bharati (2019) as “the individual’s own ability to deal with what is given to him ask him to perform it as he does not

reach everything that is given to him as postulates, but rather he has to look into it and be his A personal opinion based on convincing subjective evidence to accept or reject this matter" (404). Baer defines critical thinking as "that kind of thinking that can be evaluated and contained." For purposeful, accurate and continuous analyzes of any claim or belief and from any source, to judge its accuracy, validity and true value." (Wahyudi et al., 2019). Dhayanti, Johar, & Zubainur, (2018) as "a process of adopting decisions and judgments based on objective bases consistent with the observed facts, which are discussed in a scientific manner away from bias or external influences that spoil those facts, avoid accuracy, or expose them to possible interference subjective factors (54). Aiken Jr, (1973) as "the ability of an individual to express a favourable or opposing opinion in different positions, with convincing reasons foreach opinion" (156). Su, Ricci, & Mnatsakanian, (2016) as "the ability to judge, understand, and evaluate things according to certain criteria by asking questions, makingcomparisons, studying facts, classifying ideas and distinguishing between them, and arriving at the correct conclusion that leads to a solutionthe problem" (194).

Critical thinking requires the use of higher levels of knowledge in Bloom's classification (analysis, synthesis, evaluation) and is defined by the ability to solve problems, for example: compare the exponential function with the logarithmic function (Sari & Hidayat, 2019). Critical thinking skills as listed by Tong, Loc, Uyen, & Son, (2020) distinguishing between verifiable facts and value claims or claims, distinguishing between information, allegations and reasons related and unrelated to the topic, determines the level of accuracy of the novel or phrase, determine the credibility of the information source, identification of allegations, arguments or ambiguous data, identify unauthorized assumptions, investigate bias. recognize logical fallacies, recognize the lack of consistency in the course of thinking or conclusion, renew the strength of proof or claim, make a decision on the matter and build a sound ground for practical action, forecasting the consequences of the decision or solution (Kaddoura, 2010).

The Theoretical Framework of the study

Creativity

Creative thinking skills have four characteristics namely fluency, flexibility, originality, and elaboration.

1. Fluency: refers to one's ability to produce many ideas, ways, suggestions, questions,ideas, and alternative answers. refer to the competency in producing ideas to solve problems, increase understanding andremember information (Rabi & Masran, 2016).

2. Flexibility is the ability to generate ideas, answers, and questions that are varied from different perspectives. Also, t relates to the production of various ideas in thinking that involves the ability to innovate creativity from multiple aspects (Handayani, Rahayu, & Agustini, 2021).

3. Originality is the ability to generate ideas to solve problems and create unique anddistinctive thoughts. Also, it refers to unique and outstanding original ideas. The information is synthesized in a new form (Hu & Adey,2002).

4. Elaboration: It refers to the process of idea development through detailed elaboration that will increase interest and understanding in learning a topic (Rabi & Masran, 2016).

Critical thinking

The variables of critical thinking adopted in the current study are defined as:

1. Deduction: It means to reach a special result based on a general or imposed principle, or is the application of the principle, or the general rule to a special case (or cases) of the cases to which the rule or principle applies. The lowest level of thinking was deductive reasoning (Ismunandar, Gunadi, Taufan, & Mulyana, 2020).

2. Induction: It is to conclude from some observations, observations, or special examples (Dwyer, Hogan, & Stewart, 2014).

3. Interpretation: Mention the reasons rather than comparison, the similarities anddifferences, form questions and answer them, and give various examples about amathematical statement or equation (Casiraghi,2017).

4. Analyses: the ability to carefully examine something, whether it is a problem, a set of data,or a text (Peter, 2012).

5. Evaluation: refers to the student's ability to look at the given solution from several angles, and to detect the presence of error in the solution (Peter, 2012).

Al-Absi (2007) examined the prevailing aspects of mathematical thinking among third-grade students In Jordan, the study included. The results showed that the manifestations of mathematical thinking were arranged as follows: Induction, symbolic expression, guesswork, deduction, modelling, and generalization, and the percentage of students who were classified as possessing the manifestations of mathematical thinking (1.54

% of the study sample). Also, the results showed there were no statistically significant differences in the students' acquisition of the aspects of mathematical thinking attributed to gender.

Najem (2007) investigated the level of mathematical thinking and its relationship to some of the intelligence of Palestinian students, the study sample included 362 students. The results showed that the level of mathematical thinking was (93.26%), where the visual thinking was the highest level of thinking, reaching a percentage of (59.41%) while the lowest level of thinking were inferential thinking, reaching a percentage of (41.21%), and the results proved that the study sample possesses the five intelligences in different degrees, as it ranked first in the interpersonal intelligence with a relative weight of (40.57 %) followed by each of the intelligences, respectively; language, spatial, and physical-kinetic, and finally, mathematical intelligence ranked fifth with a relative weight of (69.51), and there was a statistically significant relationship between some levels of mathematical thinking and multiple intelligences among students, and statistically significant differences due to the variable of the department (scientific, literary) in favor of the scientific department, and in the level of multiple intelligences among the students of the acute class twelve and tenths are attributed to the department variable (scientific, literary) in favor of the scientific department in mathematical and interpersonal intelligence, and in favor of the literary department in spatial intelligence, and there are statistically significant differences when due to the gender variable in favor of males in visual thinking, and intelligences, spatial and physical intelligence, and for the benefit of females in linguistic intelligence.

Hamadna & Al-Qutaish (2015) explored the effectiveness of using Web Quests in improving mathematical thinking and solving the mathematical problem among Jordanian students using experimental research design,and the study found that there are statistically significant differences in the development of mathematical thinking skills among the study sample due to the difference in the teaching method and favour of the strategy of cognitive trips through the web (Web Quests), and statistically significant differences at in the averages of problem-solving; Also, there are statistically significant differences in the averages of students' attitudes towards mathematics. It is due to the difference in the teaching method and favour of the strategy of cognitive journeys through the web.

The Current Study

This study aims to achieve the objectives of measuring mathematics students' creativity and critical thinking levels by answering the following research questions:

1. What is the level of creativity among Saudi undergraduate senior and freshmen mathematics students?

2. What is the level of critical thinking among Saudi undergraduate senior and freshmen mathematics students?

Hypotheses of the Study

From reviewing the existing literature and authors' understandings and observations of learning circumstances and teaching experience, the following hypotheses were formulated as follows:

1. Senior students have a low level of creativity than freshmen students.

2. Senior students have a higher level of critical thinking than freshmen students.

Methodology

The study employed a fully quantitative research design at a science school at a midsizeuniversity

in the south region in Saudi Arabia. The college preparation program extends over eight semesters in four years. The study sample comprised 86 male students specialized in mathematics: 43 freshmen and 43 seniors. Random sampling was used to select the participants. A new written test was designed by the authors to measure students' creativity and critical thinking based on the existing instruments from the literature and authors' understanding and observations of students learning environment and circumstances. Data were gathered quantitatively based on students' scores in the developed written test. The test mainly includes two sections namely creativity and critical thinking, the test consisted of 10 questions: 5 of them tested creativity aspects, namely: fluency, flexibility, elaboration, originality, curiosity; the other 5 questions tested critical thinking aspects, namely: deduction, induction, analyses, interpretation, and evaluation. The data were collected from the student's test scores, the total score of the test is 50 divided by 5 scores for each question.After attaining agreement on the validity and relevancy of the survey from the teachers it was disseminated to all constituents. The rationale of the research was enlightened and well-versed approval was attained. The data were monitored for correctness and deficient data were barred from the investigation. The data were analyzed using the "Statistical Package for Social Science (SPSS 23.0)". The necessary official permissions were obtained from the University.Consent from the participant was obtained at the start of the online survey. Confidentiality and privacy were assured. The sample of the study is presented in Table 1.

Table 1: The study sample

Freshmen	Seniors	Total
43(50%)	43 (50%)	86

Findings and Results

Creativity

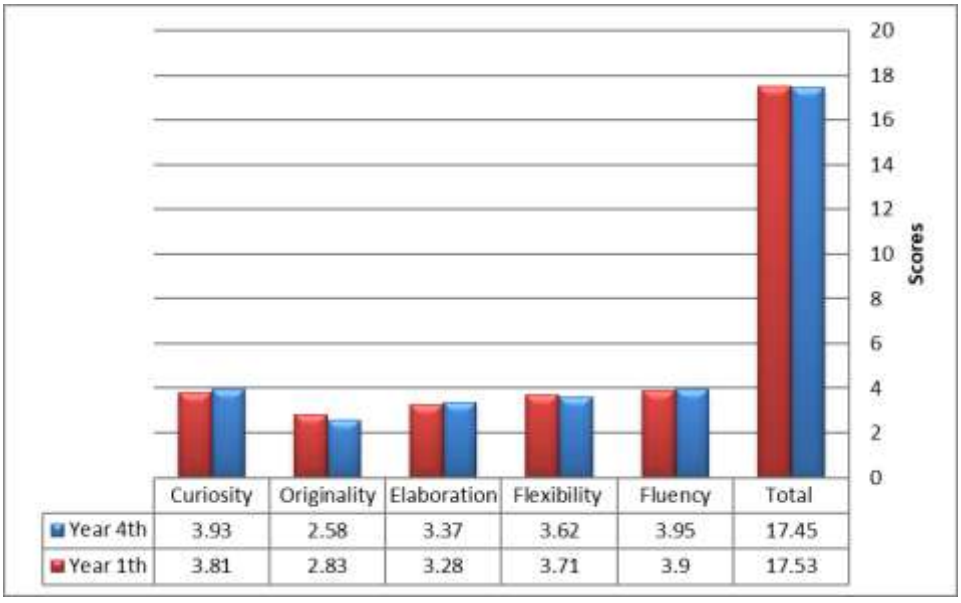
Based on the students' responses to the creativity test, the mean (M) and the standard deviation (SD) of the total scores and each of the five aspects of creativity were calculated. For Seniors: the total scores (M = 17.45, SD =2.16), Fluency (M = 3.95, SD = .48) ,

Flexibility (M = 3.62, SD = .72), Elaboration (M = 3.37, SD = .42), Originality (M = 2.58, SD

= .98), Curiosity (M = 3.93, SD = .52). On the other hand, for freshmen: the total scores (M = 17.53, SD = 2.36), Fluency (M = 3.9, SD = .47)

, Flexibility (M = 3.71, SD = .71), Elaboration (M = 3.28, SD = .48), Originality (M = 2.83, SD

= .90), Curiosity (M = 3.81, SD = .76). It can be noticed that both groups have a similar level of creativity with a slightly higher mean score for freshmen students. It can be seen from Figure 1 that senior students have a higher level of curiosity. However, freshmen students showeda higher level of originality in creativity. Similarly, freshmen students showed a higher level of elaboration and flexibility. Regarding fluency, senior students showed a higher level of fluency. Also, it can be noticed that senior students highest mean score was in fluency, while the lowest was in originality. On the other hand, similarly, freshmen students highestscore was in fluency and the lowest was in originality. These analyses indicate that both freshmen and seniors have almost similar levels of creativity. The students need to be trained to enhance the originality as it is considered the lowest aspect of students' creativity. The description of these levels was shown in Figure1



	Curiosity	Originality	Elaboration	Flexibility	Fluency	Total
Year 4th	3.93	2.58	3.37	3.62	3.95	17.45
Year 1th	3.81	2.83	3.28	3.71	3.9	17.53

Figure 1: the creativity levels of the mathematics college students

Critical Thinking

Based on the students' responses to the critical thinking test, the mean (M) and the standard deviation (SD) of the total scores and each of the five aspects of critical thinking were calculated. For Seniors: the total scores (M = 18.44, SD = 2.35), deduction (M = 3.58, SD =

.56) , induction (M = 3.21, SD = 1), analyses (M = 3.6, SD = .55), interpretation (M = 4.25, SD = .49), evaluation (M = 3.8, SD = .70). on the other hand, for freshmen: the total scores (M = 16.93, SD = 2.31), Deduction (M = 3.98,SD = .61) , Induction (M = 2.79, SD = .88),

Analyses (M = 3.48, SD = .57), interpretation (M = 3.93, SD = .53), Evaluation (M = 3.75, SD = .75). It can be seen that senior students outperformed freshmen students in all critical thinking aspects. However, the findings showeda slight difference in terms of evaluation while a big mean score difference in terms of induction and deduction. Also, it can be noticedthat senior students highest mean score was in the interpretation aspect while the lowest meanscore was in the induction aspect. Similarly, freshmen highest means score was in interpretation while the lowest was in induction. The total mean scores of seniors (M=18.44) and freshmen (M=16.93) indicates that have an approximately similar level of critical thinking. A special focus on enhancing students' induction is required to improve students critical thinking. The description of these levels was shown in Figure 2.

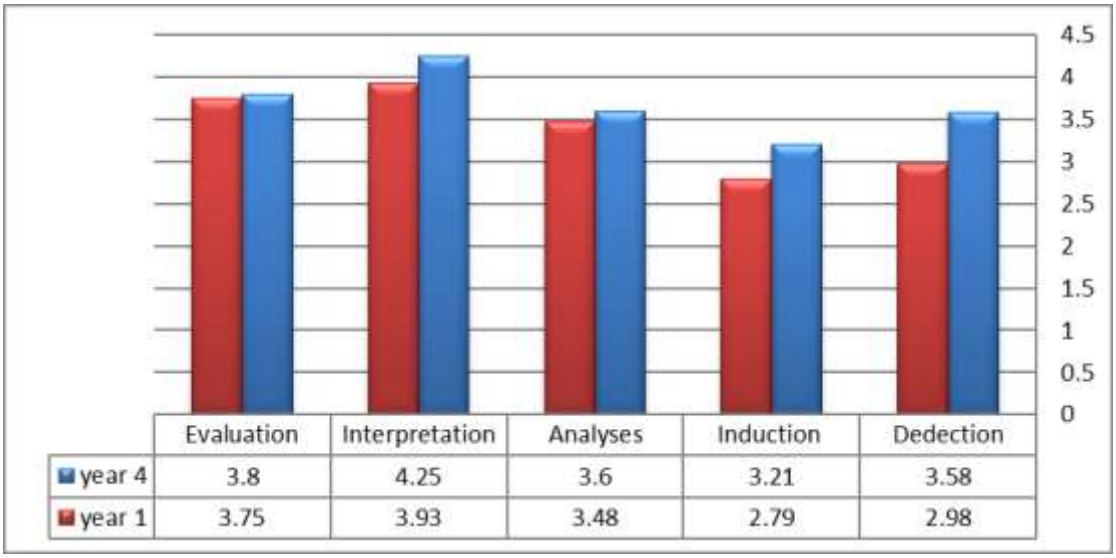


Figure 2: Critical thinking levels of the mathematics college students

T-Test Analyses

Creativity

The independent t-test was conducted to calculate and compare the difference in creativity between seniors and freshmen college students. The statistical results from the independent t-tests show that the year level did not influence the students' creativity. The year four mathematics students did not exhibit different creativity levels from those of the year one students. Table 2 presents the comparison results for the total creativity and each of the five aspects of creativity.

Table 2: Comparison of creativity by students' year level

Creativity		**Year levels**				
		Year four	Year one	*t*	*Df*	*Sig*
Total	*M*	17.45	17.53	.16	84	*Ns*
	SD	2.16	2.36			
Fluency	*M*	3.95	3.90	.49	84	*ns*
	SD	.48	.47			
Flexibility	*M*	3.62	3.71	0.57	84	*ns*
	SD	.72	.72			
Elaboration	*M*	3.37	3.28	0.93	84	*ns*
	SD	.42	.48			
Originality	*M*	2.58	2.83	1.20	84	*ns*
	SD	.98	.90			
Curiosity	*M*	3.93	3.81	.85	84	*ns*
	SD	.52	.76			

ns: not significant.

The t-test results showed there is no statistically significant difference at alpha level $p \leq .05$. Neither the year 4 nor the year 1 student scored significantly higher than the other group for the five aspects of creativity.

Critical Thinking

The independent t-test was conducted to evaluate the difference in critical thinking between seniors and freshmen college students. The statistical results from the independent t-tests show that the year level did influence someof the students' critical thinking aspects. The senior mathematics students exhibited differentcritical thinking levels on total scores and deduction, induction, and interpretation from freshmen. Table 5 presents the comparison results for the total critical thinking and each ofthe five aspects of critical thinking.

Table 3: Comparison of critical thinking by students' year level

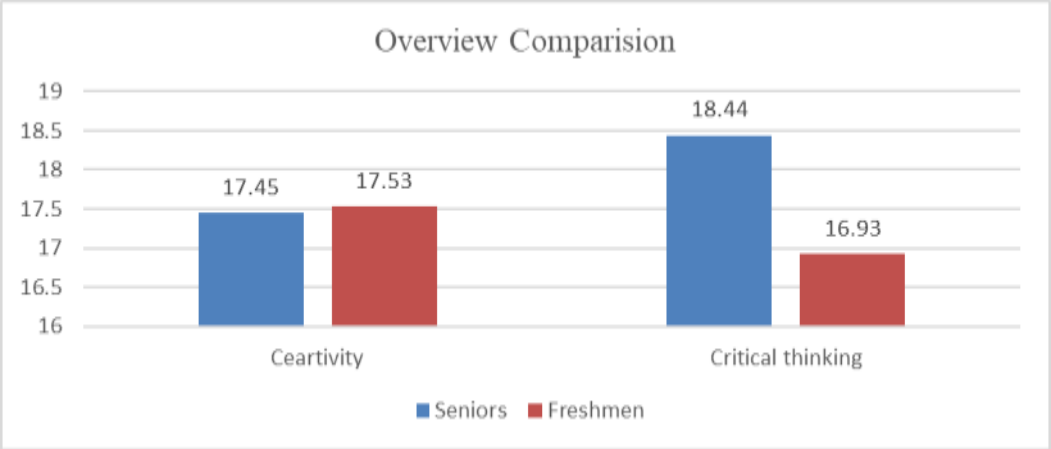
Conceptions		**Critical thinking**				
		Year four	Yearone	*t*	*df*	*sig*
Total	*M*	18.44	16.93	3.01	84	0.01
	SD	2.35	2.31			
deduction	*M SD*	3.58	2.98			
		.56	.61	4.75	84	0.001
Induction	*M SD*	3.21	2.79	2.06	84	0.05
		1.0	.88			
Analyses	*M*	3.60	3.48	0.99	84	Ns
	SD	.55	.57			
interpretation	*M*	4.25	3.93	2.90	84	0.01
	SD	.49	.53			
evaluate	*M*	3.80	3.75	0.31	84	Ns
	SD	.70	.75			

the t-test indicated that, on average, the total critical thinking scores were significantly higher for year 4 students (M = 18.44, SD =

.2.35) than scores for year 1 students (M = 16.93, SD = .2.31), t (84) = 3.01, $p < .01$. Moreover, the results from the t-test indicated that, on average, the deduction scores were significantly higher for seniors students (M = 3.58, SD = .56) than scores for year 1 students (M = 2.98, SD = .61), t(84) = 4.75, $p < .001$.

The results also showed that, on average, the induction scores were significantly higher for year 4 students (M = 3.21, SD = 1) than scores for year 1 students (M = 2.79, SD = .88), t (84)

= 2.06, $p < .05$. In addition, the results from thet-test indicated that, on average, the interpretation scores were significantly higher for year 4 students (M = 4.25, SD = 049) than scores for year 1 students (M = 3.93, SD = .53),t (84) = 2.90, $p < .01$.



Discussion

Students must develop critical thinking abilities to prosper in the seek for their future planning.If students are to become leaders, they will needto cultivate critical thinking abilities throughout their course of study and the teaching and learning process. Due to this reason, critical thinking abilities in all academic subjects, particularly mathematics, must be cultivated among students. Learning mathematics helps students improve their critical thinking abilities, which are essential for them to tackle a variety of scholastic and societal challenges.

The results of this study would complement various findings in the literature. Not only limited to the scope, but they also expand our knowledge of the development of creativity and critical thinking skills among undergraduate mathematics students. There is no doubt that mathematics students are losing their ability to think creatively. Further confirmation of (Yu, Tian, Vogel, & Kwok, 2010) critical thinking stagnation results was found in the experiment. Senior mathematics students' critical thinking abilities were much worse than those of their peers in other fields. As a result of this research, we might conclude that mathematics students' problem-solving abilities are not increasing with time or that students with a high level of critical thinking skills dropped out of their mathematics course throughout their studies. Critical thinking education, course creation, and a reformed curriculum are necessary tosolve this prevalent issue. Mathematicsstudents are at a loss if they do not possess these essential abilities, which are crucial in today's continuously changing environment. Longitudinal studies are needed to find out where mathematics students are lacking in creativity and critical thinking. Short-term fixes, such as classes emphasising creativity and critical thinking may help address these problems, though long-term solutions are required.

This research shows that freshman mathematics students are more innovative than their more experienced counterparts. There seems to be a reduction in mathematics students' ability to be more creative between their freshman and senior years of education. This might be linkedto a variety of factors, including the influence of the mathematics curriculum, freshmen students with creative abilities who opted out ofmathematics or could be the mixture of these factors. Despite the various possible explanations for these adjustments, they all have a negative impact on mathematics. The paucity of creative training in the mathematics course of study is very dominant, as is the widespread evidence of mathematics students switching to other fields (Kazerounian & Foley, 2007;Marra, Rodgers, Shen, & Bogue, 2012).

The research of critical thinking results showed that senior participants had a greater critical thinking level than freshmen. If this is the case, it shows that mathematic students are not receiving appropriate assistance for developing their critical thinking abilities. When contrasted to normative data, critical thinking seems to have halted between these two groups. If creativity is declining, this might be a result of many different circumstances. Data patterns show that more research is needed to identify how critical thinking in mathematics students is progressing.

Rietzchel et al. (2014) found that when asked to

be creative, participants generated more creative products, though they felt it was not very creative. The expectation and anticipation of being creative are postulated as the reason forthe majority of the difference between the scores of the two senior groups, which should not otherwise have been significantly different. Other studies also point to mere creative expectation and anticipation as a means of creativity improvement in study participants (Starko, 2017).

Understanding the causes of the reduction in math students' creative abilities is essential. A long-term investigation of the academic tests utilized in this research might illuminate the core reasons for the loss of creativity. Finding out what has been causing these behaviours might open up new avenues for teaching students how to think creatively. The current research findings also show that even modest measures toward improving one's creative abilities may have a significant impact. A scarcity of creative training has been found in the mathematics curriculum, along with the high rate of dropout rates among students in the math majors (Kazerounian & Foley, 2007). Theresults of this research complement various conclusions in the current literature, but they also expand our knowledge of the progression of mathematic students' creativity and critical thinking skills. A lack of originality amongmath students could be categorised as evident. Additional insights were gained when this study's data was examined in comparison to normative data given by the WGCTA. This study hence acknowledges the critical thinkingstagnation outcomes of Özyurt & Özyurt (2015)but added extra insights when comparedto normative data. When compared to theirpeers in other fields, senior math majors had much lower levels of critical thinking ability. This discovery is relevant because mathematic students' problem-solving skills are not increasing over time, or because students witha high level of critical thinking dropped out of math throughout their training. Mathematic students face a serious difficulty that necessitates the creation of critical thinking teaching, new courses, and a new curriculum altogether. In today's continuously changing world, mathematic students who lack these essential abilities are at a severe disadvantage.

Conclusion

In studying mathematics, students need the ability to think critically and creatively which require students to understand its characteristics, especially at the undergraduate level. Undergraduate students think critically through the stages on the aspects of clarification, assessment, inference, and strategy; and creative thinking through stages on the aspects of fluency, flexibility, originality, and elaboration. This study has investigated the level of creativity and critical thinking among undergraduate students in one government university. The study showed that freshmen students have a higher level of creativity and seniors have a higher level of critical thinking. However, t-test analyses showed there is no significant differencebetween freshmen and seniors. Also, the resultsshowed that freshmen students have a higher level of creativity than critical thinking while seniors have a higher level of critical thinking than creativity. This research contributes significantly to the limited studies of enhancing students' ability in learning mathematics. The findings shed new light on how creativity and critical thinking can be better promoted in mathematics education.

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