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Self-directed learning approach in mathematics

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Abstract

This study was undertaken to investigate the effect of Self-Directed Learning Approach on student's performance in mathematics, attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy. The study utilized parallel groups pretest-posttest experimental design. Survey questionnaires and 50-item mathematics test were used to gather data among ninety-six (96) Bachelor of Secondary Education (BSEd) first-year students, and each student was randomly assigned to the experimental group and control group. Data were analyzed using Shapiro-Wilk normality test, mean, standard deviation, paired samples *t*-test, *t*-test for independent samples, analysis of covariance, Cohen's d, and Pearson-r. Findings revealed that the traditional approach (TA) students' attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy are not significantly related to students' mathematics performance in both sum of written works and posttest scores. Contrarily, the self-directed learning approach (SDL) students' attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy are factors that positively influence their mathematics performance in terms of achievement test but not of written works. It was concluded that TA and SDL are equally effective in learning mathematics concepts and in developing positive attitude towards mathematics. Conversely, SDL is more effective than TA in developing students' metacognitive skills, critical and creative thinking skills, and self-efficacy, and in retaining and making mathematics concepts more meaningful and worthwhile. It is therefore highly recommended that students and teachers may undergo SDL training to equip and capacitate them with the necessary knowledge, values, and skills needed in self-directed learning.

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Introduction

The study of mathematics comprises a comparatively abstract subject of study that demands patience, determination, perseverance, and discipline in learning. This is because mathematics is more than just counting; it is also about selecting and applying the precise, detailed, accurate, and efficient information needed in problem solving. Johnsons and Rising (1972) stated that solving a mathematical problem is a complex mental process which requires visualization, imagination, analysis, abstraction, and cohesion of ideas.

COVID 19 pandemic rendered the students helpless for most of them lack access to technology. Even while technologies are made available and accessible to all, it does not ensure effectiveness in the learning process unless students are provided the much needed guidance and assistance to be able to self-direct. With the greater and tauter demands and challenges brought by the pandemic in education, many state universities and colleges started to initiate innovative and creative ways to meet the educational needs of the learners. The Isabela State University at Cabagan specifically the Regional Center for Innovation and Teaching Excellence, a research center of the College of Education, recently conducted a Design Express Project involving faculty and administrators to design an intervention to develop self-directed learners – to develop their own abilities to learn by themselves and take advantage of the opportunities of formal educational systems to achieve their learning goals.

In any situation, students are expected to take the initiative and begin their self-learning. In order to study mathematics, it is necessary to initiate self-learning, schedule learning time, identify learning needs, formulate learning objectives, select learning resources and materials, determine and implement appropriate learning strategies, and evaluate learning goals and outcomes. All these pertain to self-directed learning (SDL). Kleden (2015) mentioned that students will put in their utmost effort since they are the ones who designed their own learning, thus, optimum resources would be employed in achieving their learning goals, and students are rendered to be responsible for what they have set and will employ all that is necessary in order to succeed.

According to Knowles (1975), a pioneer of self-directed learning, self-directed learning is a process by which individuals take initiative, with or without the assistance of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes. Garrison (1997), a pioneer of self-directed learning, defined self-directed learning as an approach where learners are motivated to assume personal responsibility and collaborative control of the cognitive (self-monitoring) and contextual (self-management) process in constructing and confirming meaningful and worthwhile learning outcomes. Hashad (2019) mentioned that adopting a self-directed approach to learning would assist learners compensate for knowledge gaps and would allow them to capacitate and develop the necessary skills and values needed for lifelong learning.

SDL is an educational concept that has gained increasing attention in recent years, particularly in the context of higher education. Many literatures and recent studies focused on the evaluation and analysis of students' Self-directed Learning Readiness (SDLR) and its relationship to students' mathematics performance.

Self-directed learning is a learning process that is personal, purposeful, progressive, and developmental. The individual component of self-directed learning encourages autonomy, choice, and self-actualization, all of which are essential in mathematics learning. SDL requires various knowledge, skills, and values to ensure successful independent study. Thus, students together with the teachers and administration must undergo training on becoming self-directed learners and analyze and interpret its nature, effect, and implication.

This study is geared towards the development of self-directed learners to develop positive attitude of students in mathematics, to improve their self-directed learning skills which are metacognitive skills, critical and creative thinking skills, and self-efficacy, and to increase their performance in mathematics. This will benefit the students in terms of providing pieces of evidence and opportunities to teach themselves the most essential skills and characteristics to become a self-directed learner and life-long learner.

Moreover, the study geared towards the development of an instructional guide on how to become self-directed learners. This instructional guide will capacitate and equip the students with the knowledge, values, and skills needed in self-directed learning.

This study was conducted to determine the effect of Self-Directed Learning Approach on student's performance in mathematics, attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy. Specifically, it aimed to answer the following questions:

1. Is there a significant difference between the pretest and posttest scores of students exposed in Self-directed Learning Approach in mathematics in terms of
    - 1.1 Attitude towards Mathematics
    - 1.2 Metacognitive Skills
    - 1.3 Critical and Creative Thinking Skills
    - 1.4 Self-efficacy?

2. Is there a significant difference between the mathematics performance of students exposed in Traditional Approach and Self-directed Learning Approach?

3. Is there a significant difference between the posttest scores of students exposed in Traditional Approach and Self-directed Learning Approach in mathematics in terms of
   - 3.1 Attitude towards Mathematics
   - 3.2 Metacognitive Skills
   - 3.3 Critical and Creative Thinking Skills
   - 3.4 Self-efficacy?

4. Is there a significant relationship between students' performance in mathematics and the following variables
   - 4.1 Attitude towards Mathematics
   - 4.2 Metacognitive Skills
   - 4.3 Critical and Creative Thinking Skills
   - 4.4 Self-efficacy?

Literature Reviews

Self-directed learning (SDL) is defined as a lifelong learning experience, during which the learner takes control over and assumes responsibility for his/her own learning and learning experiences (Knowles, 1975). He states that self-directed learning is the ability of humans to learn on their own. This construct (SDL) of Knowles (1975) has become the foundation of research with respect to self-directed learning.

He also provided one of the earliest, and most widely adopted, definitions. In his view, self-directed learning comprises a five-step process:

> *"Individuals take the initiative, with or without the help of others, in (1) diagnosing their learning needs, (2) formulating learning goals, (3) identifying human and material resources for learning, (4) choosing and implementing appropriate learning strategies, and (5) evaluating learning outcomes."*
>
> (Knowles, 1975, p. 18).

Guglielmo (1977) describes a self-directed learner as someone who exhibits initiative, independence, and persistence in learning. A self-directed learner is goal-orientated, assumes responsibility for his/her own learning and views problems as challenges. In addition, a self-directed learner is self-disciplined, self-confident, displays a high degree of curiosity, and has a desire to learn. Furthermore, a self-directed learner manages time successfully, uses basic study skills, and sets an appropriate pace for learning.

The 'self' in the term 'self-directed learning' is the object of introspection or the reflexive action, 'directed' means to put straight, and 'learn' involves acquiring knowledge or skill through real-life experiences (Shin, 2011; Soanes & Stevenson 2004). Self-directed learning therefore refers to students' deliberate actions in making informed decisions to direct and manage their own learning. This involves setting learning goals, managing their learning activities and applying appropriate skills and strategies to achieve the learning aims (Knowles 1975).

Self-directed learners include reflective assessment in their daily lives— helping propel them toward fulfilling their commitment to improve—by building feedback loops into their personal systems (Thomas, 2018).

Hashad (2019) mentioned that adopting a self-directed approach to learning would assist learners with compensating for the knowledge gap and would allow them to develop the skills necessary for lifelong learning. Students in higher education learning environments will be better prepared for the future when they become self-directed learners, motivated more by learning than performance (Fein, 2014).

Seifert et.al (2016) describe self-directed learners as learners who tackle learning by exploring beyond what traditional education offers—find some of their greatest challenges in developing the ability to work against this complicated and powerful system of education that has been culturally engrained for centuries. Learners are often positioned in an environment that encourages them to (often blindly) acquiesce to strategic moves within the power system rather than to explore and develop on their own terms.

According to Bullock (2013), students need to be prepared for an everchanging world and should therefore be equipped with skills necessary for self-directed learning. These skills include metacognitive skills (Cheriyan, 2015; Kleden, 2015; Shannon, 2008), critical and creative thinking skills (Garrison, 1992; Guglielmo, 1977; Hendricson, 2007; Mizirow, 1985; Paul, 1990), and self-efficacy (Artis & Harris, 2007; Bandura, 1997; Meng et al., 2019; Saeid & Eslaminejad, 2016; Turan & Koc, 2018). These are the abilities required for students to be self-directed learners.

Learners are viewed as autonomous and capable of smart decision-making, have a sense of responsibility to themselves and others, are inherently good-natured, have a desire to reach self-actualization, and have a unique and unlimited potential for growth (Elias & Merriam 1995; Morris, 2019).

Self-directed learning represents a process of learning that is individual, purposeful, and developmental. The individual nature of self-directed learning emphasizes autonomy, choice, and self-actualization. Self-directed learning heightens the ability of learners to learn and develop new skills, acquire new knowledge, and maximize their performance in mathematics.

Thus, the self-directed learning approach is expected to enhance students' mathematics performance, develop positive attitude towards mathematics, and improve students' metacognitive skills, critical and creative thinking skills, and self-efficacy. Also, it is expected that mathematics performance is related to students' attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy. These relations among variables are illustrated in Figure 1.

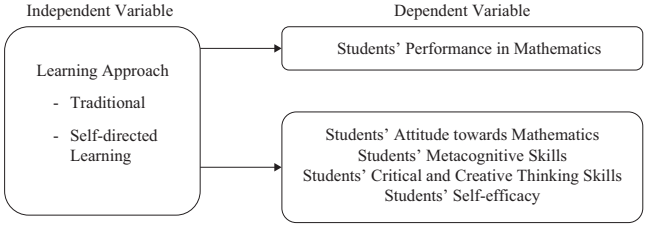

Figure 1 Conceptual framework of the study

Methodology

This study used the Parallel Groups Pretest-Posttest Experimental Design (Figure 2). Subjects of the study were randomly assigned to the experimental group and control group. After the randomization, pretest scores were obtained prior to administering the treatment, followed by the posttests on the same measures after the treatment. The researcher used the self-directed learning approach with the experimental group and traditional approach with the control group. This study also used correlational research design to determine the relationship between student academic performance and attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy.

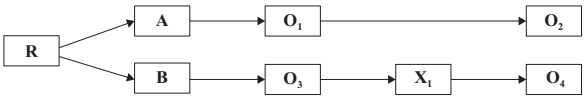

Figure 2 Parallel groups pretest-posttest experimental design

Participants

The subjects of the study were composed of 96 Bachelor Secondary Education (BSEd) first-year students enrolled in GEC 3 – Mathematics in the Modern World during the first semester, school year 2020–2021. The subjects of the study were chosen from the two out of three BSEd first year sections of the College of Education, Isabela State University at Cabagan. Each student was randomly assigned to the experimental group and control group. One group was exposed to the traditional approach while the other group was exposed to the self-directed learning approach. Each group consisted of forty–eight (48) students.

Data Collection

There were two instruments used in data gathering in this study. These were the mathematics test and the survey questionnaires for attitude towards mathematics and self-directed learning skills.

The instrument used in evaluating the performance of the students is a 50-item mathematics test. The researcher developed a 100-item mathematics test covering the topics planned to be covered during the experiment. Prior to the preparation of this test, a table of specifications was constructed to ensure content validity and fair distribution of items to topics covered in the experiment. The test was pilot tested with 37 students from the same year level, who were also enrolled in GEC 03 but were not part of the experiment. The results were analyzed, and only 50 items were retained after the procedure. The retained items fall under the acceptable difficulty index (0.41–0.60) and discrimination index (+0.20 – + 1.00). An appropriate number of items in each topic was considered to satisfy the table of specification. The test was subjected for reliability test using test – retest method. Pearson – r was used to determine the reliability of the test. A reliability coefficient of 0.82 was obtained, which is classified as high.

The survey questionnaire used in determining students' attitude towards mathematics was adapted from Yasar (2014) Mathematics Attitude Scale with a reliability coefficient of α = 0.956 (excellent); metacognitive skills survey questionnaire was adapted from Meijer et al. (2013) Metacognition Questionnaire with a reliability coefficient of α = 0.81 (high); critical and creative thinking skills survey questionnaire was adapted from from Cottrell (2005) Critical Thinking Skill and Kumar et.al. (1997) Creativity Styles Questionnaire with a reliability coefficient of α = 0.8 (high) and α = 0.81 (high) respectively; and self-efficacy survey questionnaire was adapted from Gaumer and Noonan (2018) Self-efficacy Formative Questionnaire with a reliability coefficient of α = 0.894 (high).

Pilot testing was conducted with the third section, participants who were not part of the experiment, to test the reliability of the survey questionnaires. Chronbach alpha was used to determine the reliability of the survey questionnaires. Results showed that Metacognitive Skills Survey Questionnaire (α = *0.925*) and Critical and Creative Thinking Survey Questionnaire (α = 0.958) have excellent reliability while Students' Attitude towards

Mathematics Survey Questionnaire (α = 0.818) and Self-efficacy Skills Survey Questionnaire (α = 0.875) have good reliability.

Pretests on mathematics test, attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy were conducted before the start of the intervention for both groups. Results showed that significant difference existed only on the metacognitive skills between the pretest scores of students in the control group and experimental group. This suggests that students in the control group have higher metacognitive skills than students in the experimental group, but both groups are of equal ability in mathematics, of equal attitude towards mathematics and of equal level of critical and creative thinking and self-efficacy before the intervention was conducted prior to the experiment.

The study was implemented for six (6) weeks in the period from December 2020 to January 2021. There were two interventions in the study. These were self-directed learning approach and traditional approach. The students on the experimental group were trained on how to become self-directed learners while the students on the control group were not trained. Traditional teaching intervention was used to both experimental and control groups. The training on becoming self-directed learners was conducted in partnership with Regional Center for Innovation and Teaching Excellence (ReCITE), a research center of the College of Education, through the leadership of Prof. Ruby L. Mamauag, ReCITE Director. This training included key components of a four-stage process on how to become a self-directed learner: self-evaluation, setting learning contract, practicing creative pathways, and self-reflection. Also, this training aims to boost the necessary skills in self-directed learning: metacognitive skill, critical and creative thinking skill, and self-efficacy. Training-workshops were carried out through synchronous and asynchronous modality within 5 sessions. This training equipped students with the knowledge, values and skills needed in self-directed learning. The insights, understanding and experiences gained through this training equipped the students on how to effectively empower and mold themselves to become effective self-directed learners.

On the other hand, traditional teaching intervention consisted of videoconferencing and provision of audio-visual and printed materials. There were 12 sessions of an hour and a half (1.5 hours). Six topics were discussed throughout the study - Chapter IV: Logic - (1) Logic Statement and Quantifiers; (2) Truth Tables, Equivalent Statements; and Tautologies; and (3) Conditional, Biconditional, and Related Statements and Chapter V: Geometric Designs - (1) Recognizing and Analyzing Geometric shapes, (2) Designs, Arts, Culture, and (3) Geometric Transformations.

Data Analysis Procedure

Prior to running the different parametric tests, Shapiro-Wilk normality test was used to investigate the normality of the data. Moreover, *t*-test for Independent Samples was used to test the hypothesis on the differences of scores in mathematics performance, attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy. The test was first performed on the pretest scores between groups to determine if existing initial differences exist and if such differences are significant. *t*-test for Independent Samples was also used to compare the posttest scores on mathematics performance, attitude towards mathematics, critical and creative thinking skills, and self-efficacy between students exposed to traditional and self-directed learning approach while One-way Analysis of Covariance was utilized to test whether the difference between the metacognitive skills posttest scores was significant, while controlling for their pretest scores. Cohen's d and partial eta squared were used to investigate the effect size between compared means. On the other hand, Paired Samples *t*-test was used to determine the effect of self-directed learning approach on the students' mathematics performance, attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy, the pretest and posttest scores. Also, Pearson-r was used to investigate the relationship among variables.

Results and Discussion

Comparison of Pretest Scores and Posttest Scores on Attitude towards Mathematics, Metacognitive Skills, Critical and Creative Thinking Skills, and Self-efficacy between Students Exposed in Self-directed Learning Approach

Paired samples *t*-test was utilized to compare the pretest and posttest scores on attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy between students exposed in self-directed learning approach. Table 1 presents that there was no significant difference between the pretest and posttest scores on attitude towards mathematics of students after being exposed to self-directed learning. This implies that students have the same attitude towards mathematics before and after the treatment of self-directed learning approach.

Moreover, results revealed that there was a significant difference between the pretest and posttest scores on students' metacognitive skills, critical and creative thinking skills, and self-efficacy after being exposed to the self-directed

learning approach. The magnitude of difference in metacognitive skills is 24.40 and in self-efficacy is 5.38, which are both very large with *Cohen's d* of 1.216 and 1.585, respectively. Results imply that 38.88 percent of students' metacognitive skills posttest scores and 44.41 percent of self-efficacy posttest scores were higher than their pretest mean scores in metacognitive skills and self-efficacy. Also, there was a mean difference of 17.55 on self-efficacy, which is moderately large (d = 0.722). This shows that 26.42 percent of students' posttest scores on critical and creative thinking skills is higher than their pretest scores. Results further imply that self-directed learning greatly improved the students' metacognitive skills, critical and creative thinking skills, and self-efficacy.

Thus, self-directed learning boosts students' ability to plan, employ, and modify learning strategies (metacognitive skills), students' ability to relate new ideas and experience to previous knowledge as well as creatively and actively sharing new understanding in order to verify and validate it (critical and creative thinking skills), and students' confidence to use core learning skills (self-efficacy).

Comparison on Mathematics Performance between Students Exposed in Traditional Approach and Self-directed Learning Approach

An independent samples t-test was conducted to compare the mathematics performance between students exposed to the traditional approach and the self-directed learning approach. Table 2 shows that there was no significant difference at α = .05 level of significance on the mathematics performance between students exposed to the traditional approach and students exposed to the self-directed learning approach in terms of sum of written works. Therefore, students exposed to traditional and SDL approach equally performed in written works such as quizzes, activities, exercises, and assignments.

It is mentioned by Thomas (2018) that self-directed learners include reflective assessment in their daily lives—helping propel them toward fulfilling their commitment to improve—by building feedback loops into their personal systems. They monitor their learning by verifying their ideas, thinking, and understanding to their classmates, teachers, friends, and other support groups.

Also, Table 2 presents that there was a significant difference at α = .05 level of significance on the mathematics performance between students exposed to the traditional approach and students exposed to the self-directed learning approach in terms of posttest scores. The magnitude of difference was 3.44, which is moderately large (d = 0.553). This means that 70.88 percent of SDL students' posttest scores was higher than the posttest mean score of the students exposed to the traditional approach. Thus, the findings further imply that the students exposed to the SDL approach performed better in posttest scores than students exposed to the traditional approach. The findings

Table 1 Difference on the pretest scores and posttest scores in attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy between students exposed in self-directed learning approach

Variables	*N*	*M*	*SD*	*t(47)*	*p*	*d*	(95%) CI
Attitude towards Mathematics							
Pretest	48	71.15	7.35	-1.647	.106		[-4.35, .433]
Posttest	48	74.00	7.86				
Metacognitive Skill							
Pretest	48	130.52	11.67	-8.425**	.000	1.216	[-30.22, -18.57]
Posttest	48	154.92	18.32				
Critical and Creative Thinking Skill							
Pretest	48	147.35	22.24	-4.50**	.000	.722	[-24.60, -10.48]
Posttest	48	164.90	17.09				
Self-efficacy							
Pretest	48	52.47	5.17	-11.395**	.000	1.585	[-6.57, -4.60]
Posttest	48	57.85	6.37				

Note: * means significant at .05 level
** means significant at .01 level

Table 2 Difference on mathematics performance between students exposed to traditional approach and self-directed learning approach

Mathematics Performance	*N*	*M*	*SD*	*t(94)*	*p*	*d*	95% CI
Sum of Written Works							
Traditional	48	161.46	8.43	1.971	.052		[.0249, 6.983]
SDL	48	164.94	8.86				
Posttest Scores							
Traditional	48	35.08	5.99	2.704**	.008	.553	[.913, 5.961]
SDL	48	38.52	6.45				

Note: * means significant at .05 level
** means significant at .01 level

support the findings of Khoo (2018) that the use of strategies on self-directed learning helps students to learn and retain mathematics concepts. This develops self-regulatory qualities of these motivated learners to thrive in the 21st Century.

Self-directed learning invokes both cognitive and social issues, which leads to "self-direction" and "learning" effectively. The findings suggest that self-directed learning is also a collaborative approach to construct and confirm meaningful (cognitive) and worthwhile (social) learning, where the students assume their responsibility for constructing their meaning to knowledge and to make the constructed knowledge meaningful and worthwhile.

Comparison of Attitude towards Mathematics, Critical and Creative Thinking Skills, and Self-efficacy between Posttest Scores of Students Exposed to Traditional Approach and Self-directed Learning Approach

t-test for independent samples was utilized to investigate the difference on attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy between students exposed to traditional approach and self-directed learning approach. Table 3 shows that there was no significant difference at α = .05 level of significance on the attitude towards mathematics between students exposed to the traditional approach and students exposed to the self-directed learning approach. This suggests that students are of equal of attitudes towards mathematics regardless of whether they are exposed to the traditional approach or SDL approach.

Likewise, Table 3 presents that there was a significant difference at α = .05 level of significance on the critical and creative thinking skills between students exposed to traditional approach and students exposed to self-directed learning approach, $t(94) = 5.992$, $p = 0.000$. The magnitude of difference was 21.11, which is very large ($d = 1.22$). This implies that 88.88 percent of SDL students' critical and creative thinking skill ratings is higher than the critical and creative skill mean rating of students exposed to the traditional approach. Results further imply that students exposed to the SDL approach are more critical and creative thinker than students exposed to the traditional approach.

Lastly, it was also revealed in Table 3 that there was a significant difference at α = .05 level of significance on the level of self-efficacy between students exposed to traditional approach and students exposed to self-directed learning approach. There was a mean difference of 3.89, which is moderately large ($d = 0.70$). This implies that 75.80 percent of the SDL students' self-efficacy ratings is higher than the self-efficacy mean rating of students exposed to traditional approach. The findings further suggest that students exposed to the SDL approach have higher level of self-efficacy than students exposed to the traditional approach.

Comparison on Metacognitive Skills between Posttest Scores of Students Exposed to Traditional Approach and Self-directed Learning Approach

One-way Analysis of Covariance was conducted to compare the metacognitive skills between posttest scores of students exposed to traditional approach and self-directed learning approach using their pretest scores as covariate. Table 4 reveals that there was a significant difference at α = .05 level of significance on the metacognitive skills between the posttest scores of students exposed to the

Table 3 Difference on attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy between posttest scores of students exposed to traditional approach and self-directed learning approach

Variables	*N*	*M*	*SD*	*t*(94)	*p*	*d*	(95%) CI
Attitude towards Mathematics							
Traditional	48	70.73	8.68	1.934	.056		[-.086, 6.63]
SDL	48	74.00	7.86				
Critical and Creative Thinking Skills							
Traditional	48	143.79	17.42	5.992**	.000	1.22	[14.11, 28.10]
SDL	48	164.90	17.09				
Self-efficacy							
Traditional	48	53.96	4.64	3.424**	.001	0.70	[1.64, 6.15]
SDL	48	57.85	6.37				

Note: * means significant at .05 level
** means significant at .01 level

Table 4 Difference on metacognitive skills between posttest scores of students exposed to traditional approach and self-directed learning approach

Metacognitive Skills	*N*	*M*	*SD*	*Adjusted M*	*SE*	*F*(1, 93)	*p*	pn^2
Traditional	48	134.75	18.32	130.95	2.425	60.432**	.000	0.394
SDL	48	154.92	18.32	158.71	2.425			

Note: ** means significant at .01 level

traditional approach and the self-directed learning after controlling their pretest scores. The mean difference was 20.17, which is large (n^2 = .394). This suggests that 39.40 percent of the students' metacognitive posttest scores is explained by the treatment they are exposed to. Hence, this further implies that students exposed to the self-directed learning approach have higher metacognitive skills than students exposed to the traditional approach.

According to Bullock (2013), students need to be prepared for an everchanging world and should therefore be equipped with skills necessary for self-directed learning. These skills include metacognitive skills (Cheriyan, 2015; Kleden, 2015; Shannon, 2008), critical and creative thinking skills (Garrison, 1992; Guglielmo, 1977; Hendricson, 2007; Mizirow, 1985; Paul, 1990), and self-efficacy (Artis & Harris, 2007; Bandura, 1997; Meng et.al., 2019; Turan & Koc, 2018; Saeid & Eslaminejad, 2016).

A self-directed learner manages aspects involved in their learning, how they will learn or demonstrate their learning, monitor their progress and evaluate whether they have learnt (metacognition); they are critically reflective and creatively interact and share their thinking with others (critical and creative thinking); and benefits from being taught, practicing, becoming proficient, and feeling confident in the use of core learning sills (self-efficacy).

Relationship between Students' Attitude towards Mathematics, Metacognitive Skills, Critical and Creative Thinking Skills, and Self-efficacy and Mathematics Performance

Pearson – r was conducted to investigate the relationship between students' attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy and students' mathematics performance. Table 5 reveals that there was no significant relationship at α = .05 level of significance between students' attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy and students' mathematics performance in both sum of written works and posttest scores of students exposed to the traditional approach. This further implies that there is not sufficient evidence to believe that the more positive/negative the students' attitude towards mathematics, and the higher/lower the level of metacognitive skills, critical and creative thinking skills, and self-efficacy, that students exposed to the traditional approach will perform better/worse in quizzes, activities, exercises, and assignments and posttest.

On the other hand, Table 5 presents there was no significant relationship at α = .05 level of significance between students' attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy and students' mathematics performance in terms of sum of written works of students exposed to self-directed learning approach. This suggests that there is not sufficient evidence to believe that the more positive/negative the students' attitude towards mathematics, and the higher/lower the level of metacognitive skills, critical and creative thinking skills, and self-efficacy, that students exposed to self-directed learning approach will achieve higher/lower performance in quizzes, activities, exercises, and assignments.

Table 5 also reveals that there was a significant relationship at α = .05 level of significance between students' attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy, and students' mathematics performance in terms of posttest scores of students exposed to self-directed learning approach. This suggests that the more positive the students' attitude towards mathematics, and the higher the level of metacognitive skills, critical and creative thinking skills, and self-efficacy, the higher their performance in mathematics achievement or vice versa after being exposed to the self-directed learning approach.

Table 5 Relationship between students' attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy and mathematics performance

Variables	Sum of Written Works			Posttest Scores		
	r	*p*	Description	*r*	*p*	Description
Attitude towards Mathematics						
Traditional	.069	.640	Negligible	.144	.327	Negligible
SDL	.203	.167	Low	.206*	.016	Low
Metacognitive Skills						
Traditional	-.048	.744	Negligible	-.002	.989	Negligible
SDL	.039	.792	Negligible	.367*	.010	Low
Critical and Creative Thinking Skills						
Traditional	-.129	.382	Negligible	.012	.936	Negligible
SDL	.085	.564	Negligible	.248*	.049	Low
Self-efficacy						
Traditional	-.085	.566	Negligible	.043	.772	Negligible
SDL	.024	.870	Negligible	.322*	.026	Low

Note: * means significant at .05 level

** means significant at .01 level

The results of the study support the findings of other related studies that students' attitude towards mathematics (Andamon & Tan, 2019; Capuno et al., 2019; Cerbito, 2020), metacognitive skills (Amin & Sukestiyarno, 2015; Embodo & Baraquia, 2019; Ozsoy, 2011), critical and creative thinking skills (Susanti & Hartono, 2019), and self-efficacy (Kaya & Bozdag, 2016; Kesan & Kaya, 2018; Komalavalli, 2019; Mumcu & Aktas, 2015; Mundia & Metussin, 2018; Ozkal, 2019; Schober et al., 2018; Tian et al., 2018) is significantly related to the mathematics achievement. By virtue of its findings, this study joins the school of thought that relates students' attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy significantly to students' performance.

This suggests that students' attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy are predictors of students' mathematics achievement after being exposed to self-directed learning approach.

Conclusions and Recommendations

Basing on the findings of the study, it is therefore concluded that traditional approach and self-directed learning approach are equally effective in learning mathematics concepts and in developing positive attitude towards mathematics. On the other hand, the self-directed learning approach is more effective than the traditional approach in improving students' metacognitive skills, critical and creative thinking skills, and self-efficacy and in retaining mathematics concepts and making it more meaningful and worthwhile. Furthermore, students' attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy are not related to mathematics performance of students exposed to the traditional approach in both written works and achievement test. Also, students' attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy are positive factors of mathematics performance of students exposed to the self-directed learning approach in terms of achievement test but not of written works.

Based on the conclusions of the study, it is therefore highly recommended that students of ISU-Cabagan may undergo SDL training to equip them with the knowledge, values, and skills needed in self-directed learning. Moreover, instructors who are primarily facilitators of learning, may also undergo training that will equip and capacitate them with necessary skills and competencies needed for self-directed learning approach. Lastly, further study may be conducted exploring the path analysis effect of attitude towards mathematics, metacognitive skills, critical and creative thinking skills, and self-efficacy to mathematics performance of self-directed learners.

Conflict of Interest

The authors declare that there is no conflict of interest.

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