2024

SciEd
SEAQIS Journal of Science Education

SEAQIS Journal of Science Education (SciEd)
ISSN: 2987-8101 | E-ISSN: 2964-7533
Vol: 4, No: 2, PP: 01-13
www.journal.qitepinscience.org

Research Paper Open Accsess

Students' Direct and Deferred Concept Understanding and Self-Efficacy Using the Inverted Learning Approach in Biology

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Article history:
Received: January 23, 2024
Revised: July 30, 2024
Accepted: July 31, 2024

Abstract

The increasing availability of data and technological advancements, along with the influx of various educational platforms, reflects the evolving knowledge acquisition and transfer paradigm in the digital age. This highlights the need for educators and institutions to adapt their approaches and recognise the significance of harnessing educational technology as a powerful tool to promote the widespread adoption of flexible online learning. An Inverted Learning Approach (ILA) is an innovative pedagogical design that maximises off-class learning by providing students with access to instructional resources. This allows students to self-pace their learning and become more independent and ready for in-class activities. The study followed a quasi-experimental study, employing a two-group pre-test and post-test controlled group design. It zeroed in on determining how ILA affects the direct and deferred concept understanding and self-efficacy of Science, Technology, Engineering, and Mathematics (STEM) students enrolled in a biology course. The use of ILA was the treatment given to the experimental or intervention group, while the Expository Online Teaching (EOT) was given to the comparison group. A total of 287 STEM students were involved in the study and taught by the same teacher to maintain parity of conditions except for the treatment. Informed consent and assent forms were likewise collected as required by the Research Ethics Board to safeguard the research participants, monitor likely risks and benefits, and establish high ethical standards where the study was conducted. Gagne's nine instructional events were designed in the learning plan to develop a clear instruction flow between the two groups. The students' levels of direct and deferred concept understanding were measured using the Researcher-validated Biology Achievement Test (RBAT) on the pre-test, post-test, and postponed test, and the results were analysed using ANOVA and post-hoc tests. Results revealed that students taught using ILA had significantly higher mean gains in post-test and retention test scores than those taught using the EOT. The level of self-efficacy among ILA students has also shown a significant increment compared to their counterparts. In other words, ILA significantly improved students' direct and deferred concept understanding and self-efficacy.

Keywords: Biology Education; Concept Understanding; Inverted Learning; Online Learning; Self-Efficacy

Introduction

Technological advancements have rapidly transformed various sectors, including education. However, the sudden shift to virtual classrooms has placed a significant strain on teachers. Lal (2020) argues that traditional face-to-face instruction is more convenient due to the substantial time, effort, and preparation required for online teaching, which has altered the roles of both educators and students. Conversely, Sharma (2020) posits that online learning offers a safer and more accessible educational platform during the

pandemic, allowing students to continue their studies without health risks. In twenty-first-century education, the concept of teachers as experts who impart wisdom to their students is no longer appropriate (Nair, 2020). Thus, everyone is now on social media and attempting to share information on social media platforms because access to knowledge and technological skills is possible with a few clicks on their phones, tablets, and computers.

Learners acquire information that may or may not be integrated with learning and experience. This is referred to as the direct concept understanding. They can use these directly acquired concepts to solve issues more systematically (procedural knowledge) and, eventually, become independent and create skill-based behaviour (skill tuning of procedural knowledge). Because learning gains may be forgotten, it is crucial to focus on efficient teaching strategies that encourage students to learn and form meaningful associations, resulting in more extended learning (Al-Balushi & Al-Balushi, 2018). Tests or assessments not only measure stored information or concepts acquired by students (Cheng, 2023), but they can also improve learning and long-term retention (Karpicke & Roediger, 2007). This retentive learning is described in the study as deferred concept understanding. In most learning processes, assessing the retention of information is considered (Adiansyah et al., 2021; Nurisya et al., 2016; Talar & Gozaly, 2020). The ability to still remember concepts, and details in memory (Tapilow & Wawan, 2008) for a particular timeframe is referred to as retention, and this is crucial in the teaching and learning process (Adiansyah et al., 2021; Anderson & Krathwohl, 2001).

Related to learning performance is the students' ability to accomplish schoolworks. This is self-efficacy, which includes internal behaviours such as judgments about one's capacity to finish a task or goal (Harsch, 2008; Schunk & Miller, 2002; Riskiningtyas & Wangid, 2019) and confidence in one's performance and abilities (Grabau, 2015). When faced with a problem, students who strongly belief in their ability to learn would participate more readily, work more, and stay longer than students with low self-efficacy (Riskiningtyas, & Wangid, 2019). In this context, a student's online learning self-efficacy is influenced by their confidence in their ability to interact in an online environment (Code et al., 2021).

To enhance Biology education, innovative instructional materials, pedagogy, and curriculum updates are essential (Cheng & Bagarinao, 2023). Flipped learning is a promising approach that is gaining traction and prioritising active student engagement (Bond, 2020). While its potential is recognised in both higher education and K-12 settings, its application at the secondary level is relatively new (Offerman-Celentano, 2017). Researchers and educators, particularly in the context of the "new normal," have shown increasing interest in this method (Evseeva & Solozhenko, 2015). The Inverted Learning Approach (ILA) restructures classroom time for interactive activities while delivering content through pre-class instructional videos and independent tasks (Chang & Hwang, 2018; Barral et al., 2018). Despite successful implementations in various educational contexts (Rossi, 2015; Christiansen et al., 2017; Lee & Park, 2018; Burkhart et al., 2020), many aspects of inverted learning remain unexplored (Strohmyer, 2016). Specificallyn, evidence supporting the efficacy of ILA in online Biology education for high school students is limited.

1. There is still a paucity of information regarding the role of the ILA in improving one's efficacy, motivation, self-regulation, and retention (Chickering & Gamson, 1987; Grabau, 2015). As it is now, it seems that there is already information that ILA is not at all effective in improving these variables, as there is only less scientific proof that tells this. Thus, this study has investigated how students could successfully examine whether the new learning norm, such as using ILA, works for them (Pintrich, 2004; Sletten,

2015; Grabau, 2015). The Self-Determination Theory (Ryan & Deci, 2000; Deci & Ryan, 2002) supports the idea that ILA can improve learning retention. This is because students become more autonomous, engaged, and competent when learning the materials provided prior to the class. As a result, their motivation to learn becomes intrinsic, leading to longer-lasting learning. Therefore, this study focused on how the Inverted Learning Approach, a relatively new pedagogical approach at the secondary level (Offerman-Celentano, 2017), was relevant for applying how students gain direct and deferred concept understanding in this time of changing educational landscape. It further delved into how the approach could affect learners' self-efficacy, which indicates how they feel about themselves, their firsthand experience, as well as their drive and level of confidence in learning quarter-long topics in Biology.

Methodology

Research design

This study employed a two-group quasi-experimental, controlled group design. It used a quantitative approach to obtain the levels of direct and deferred concept understanding through the Researcher-validated Biology Achievement Test (RBAT) and the level of self-efficacy through a self-efficacy questionnaire.

The ILA served as the treatment given to the experimental or intervention group, also known as the ILA group. Meanwhile, Expository Online Teaching (EOT) was given to the conventional group or the EOT group.

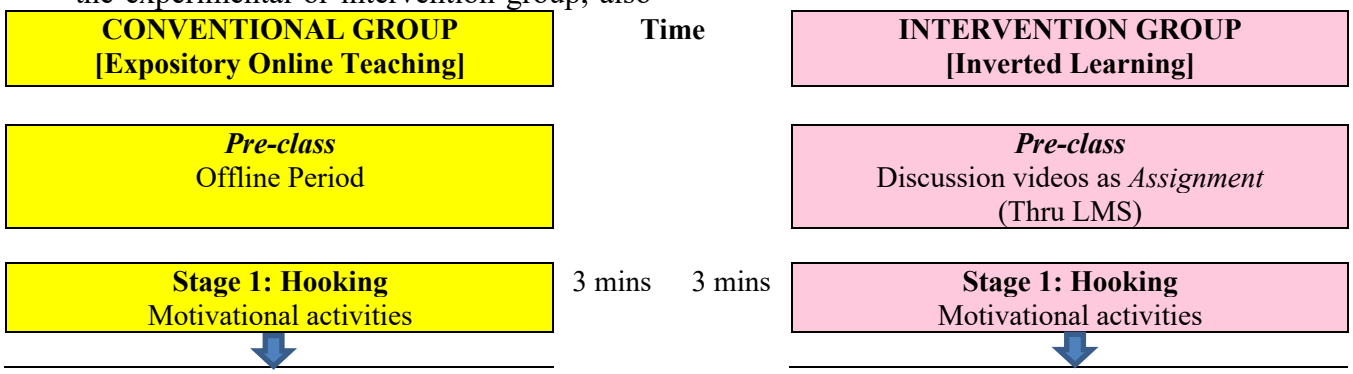
Locale and sample

Six (6) Grade 12 STEM classes during the school year 2022-2023 from Notre Dame of Cotabato in Cotabato City were the respondents. Each class comprises 45-48 students who are all taught by the same science teacher to maintain parity of conditions except for the treatment.

Data gathering instruments

Several learning resources and tools were used to collect relevant data for the study, including:

Curriculum Maps and Learning Plans designed by the researcher contain the learning goals, namely: 1) Acquisition; 2) Meaning Making; and 3) Transfer. Meanwhile, learning plans have these stages: 1) Explore; 2) Firm-up; 3) Deepen; and 4) Transfer. This instructional design or format was recommended by the Private Educational Assistance Committee (PEAC). To establish a clear flow of instruction between the intervention and conventional groups, Gagne's Nine Events of Instruction were paralleled or incorporated into the three main parts of the learning plan template. The Comparative Flowchart of the Events for the Conventional and Intervention Groups is reflected in Figure 1.



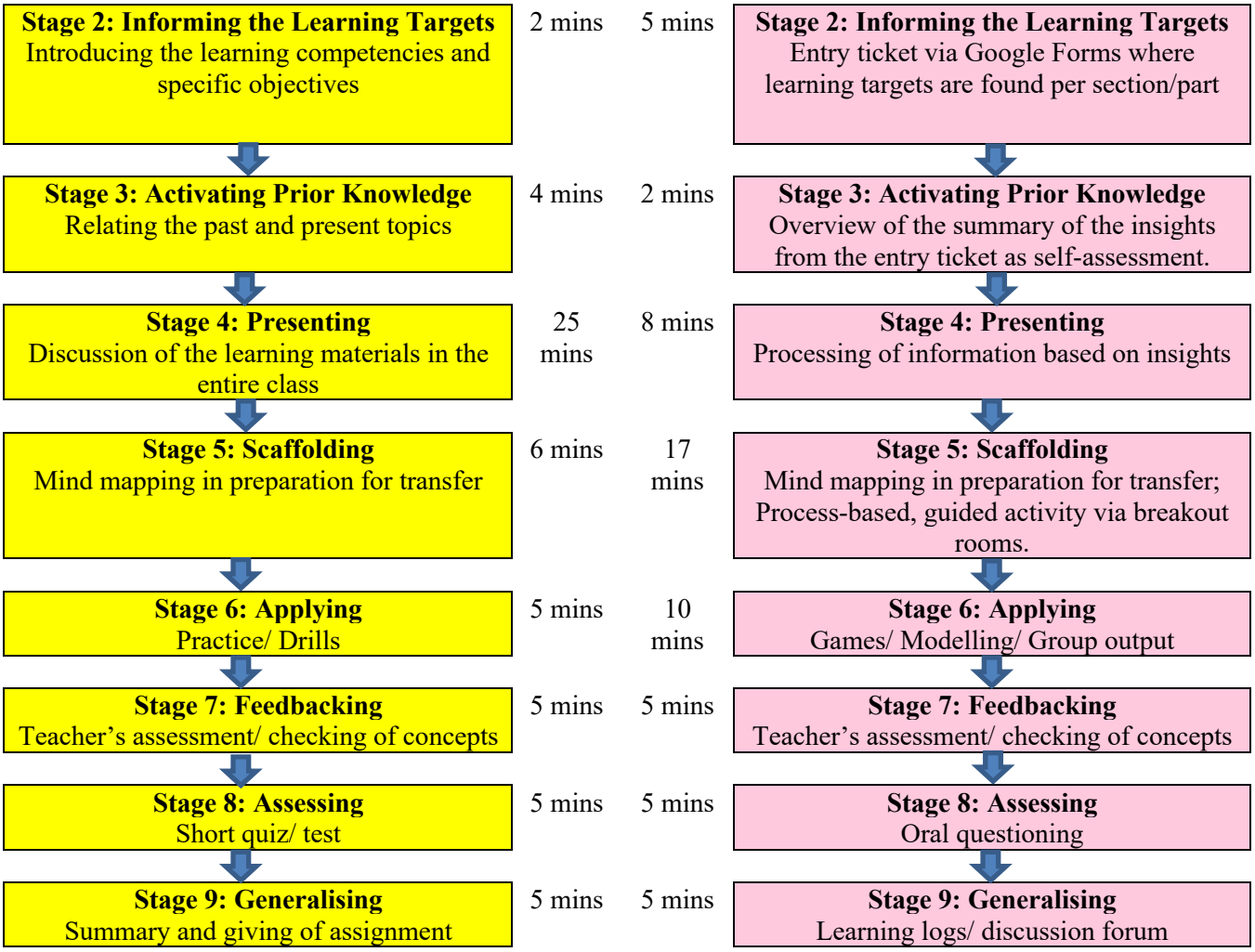


Figure 1. Comparative Flowchart of the Events for the EOT and ILA Groups

A. Microsoft Teams (MS Teams), which was used to host synchronous online classes. It is the official Learning Management System (LMS) for distributing all learning/instructional materials to the respondents of the study. Each class had its own team comprised of channels for instruction and communication.

B. Teacher-made pre-recorded discussion videos related to Bioenergetics, which were developed and validated using the tool of Acedo & Robles (2019). It showed that the learning videos were acceptable (4.42 ± 0.51), relevant (4.45 ± 0.40), usable (4.63 ± 0.38), and appropriate (4.70 ± 0.36).

C. Researcher-validated Biology Achievement Test, which is also known as the RBAT. This was used as a Pre-test, Post-test, and Retention test to assess students' concept understanding. It has 50 multiple-choice questions, 60% of which are knowledge-based, and 40% are process-based. Each objective question has four options, with only one correct answer. For internal consistency, its Kuder-Richardson Formula 20 (KR-20) value of 0.844 can be interpreted as adequate, highly reliable, and acceptable.

D. Self-Efficacy Questionnaire for Online Learning (SeQoL) from Tsai et al. (2020) & Shen et al. (2013), which was re-validated to make it and its terms more appropriate to assess self-efficacy in the context of high school students.

Data gathering procedure

Prior to fielding the research, the paper was subjected to a full board research ethics

review last June 2022. This review aims to safeguard potential research participants, monitor likely risks and benefits, and establish high ethical standards for the research conducted. For approval to conduct the pilot and actual run of the study, communication letters of permission were given to the school principal. The importance of data privacy and child protection policies was highlighted. Curriculum materials such as curriculum maps and learning plans were submitted to the science department chairperson for use in an online (virtual) class observation. This process has ensured uniformity and parity in teacher behaviour except for the application of treatment. To reduce the novelty effect of the method, some selected topics in the first quarter (August to October 2023) were occasionally flipped for practice and the intervention was gradually introduced to the experimental groups only.

Data analysis procedure

The random assignment of the classes into intervention and conventional groups was determined by their pretest scores, which were tested for equal variances, normality, and homogeneity of groups. The data from the RBAT's pre-test, post-test, and retention tests were processed both descriptively and inferentially. Standardised effect sizes also determined the magnitude or strength of a relationship between the groups in the study thus, describing the extent or practical significance of using the ILA. In addition, a t-test for dependent samples (before and after) was carried out to compare and analyse their test scores and self-efficacy levels between groups. The level of significance for evaluating the hypotheses was set at 0.05. Analysis of Variance (ANOVA) was run to compare the means of the students' performance between the ILA and EOT groups and post hoc tests were also conducted to determine the differences between the pre-test and post-test means; pre-test and retention test means, and post-test and retention test means.

Ethical considerations

Participants were fully informed about the nature and purpose of the study, the processes involved, the potential risks and benefits, and the freedom to withdraw at any time without consequence. Parents and guardians of minor participants signed the informed consent agreement, declaring that all parties understood the research and its implications. Furthermore, the minors (student participants) were provided with assent forms to confirm that their participation was voluntary and that they understood the study. This approach to consent emphasises the commitment to preserving the highest ethical standards while safeguarding the rights and welfare of the respondents throughout the research process. Data were temporarily stored in the researcher's Google Drive associated with their UP email. Moreover, the results of the study would be shared or disclosed in aggregate, and the findings would be disseminated widely through a school-level research colloquium, publications, and paper conferences.

Results and Discussion

On Direct Concept Understanding

Students who were taught using the ILA had a significantly higher mean score (28.5 ± 8.28) than those taught using the expository online teaching (EOT) approach (25.8 ± 6.91). These results confirm the study of Purwanti & Suryawati (2022), which indicated that applying inverted learning resulted in a significant difference in the performance of students who received it compared to those exposed to a non-flipped online method, who got comparably lower scores. Table 1 showed the t-test results of the direct concept understanding of the EOT and ILA students. As indicated by the results, the post-test scores of the ILA students are significantly higher ($t = -2.8539$; $p<0.01$) than those of their EOT counterparts.

Table 1. *t-test Results of Direct Concept Understanding between EOT and ILA Students*

Group	Mean	Std. Deviation	t	p-value	Decision	Interpretation
EOT	25.8	6.91	-2.8538	0.00237	Reject Ho	Significant
ILA	28.5	8.28				

Note: $p < 0.05$ is significant

The results of the study could be attributed to the ability of the ILA to introduce many core concepts outside of the classroom; hence, it can be adopted to address the challenge of improving the academic performance of learners (Silva & Galembeck, 2014; Goff et al., 2018). Although Shim & Inti (2022) stated that flipping is not effective for online courses, Hew et al. (2020) discovered that participants in fully online flipped classes performed as effectively as participants in traditional set-up. The significant difference between the test scores of the two groups can imply that the ILA has successfully made the in-class discussions more inclusive, interactive (Ahmad & Arifin, 2021) and focused (Morris & McDermott, 2022); thus, students were able to grasp the concepts discussed in class more easily.

As such, the ILA can possibly help in the transition from traditional in-person instruction to a fully online learning. In addition, students had mixed feelings about the effectiveness of the ILA model.

This is why Azmin et al. (2021) warned that the ILA can result in ineffective online learning if it is not carefully designed. Morris and McDermott (2022) also suggested that teachers, as curriculum designers, must be more innovative and responsive to dispel the stigma that online learning is a weaker option compared to in-person learning.

On Deferred Concept Understanding

Retention is not only limited to recalling facts and information, but also a way in developing critical thinking, creativity, relationship between concepts, and transfer understanding (Adiansyah et al., 2021; Haniah et al., 2020; Sholihah & Lastariwati, 2020). The ILA group comparably had higher mean score of 28.41 ± 7.77; while the EOT group had 17.53 ± 6.62. Furthermore, Table 2 presented the comparative analysis of the retention test results between the students who were taught using the EOT and those students exposed to ILA.

Table 2. *t-test Results of Deferred Concept Understanding between EOT and ILA Students*

Group	Mean	Std. Deviation	t	p-value	Decision	Interpretation
EOT	17.53	6.62	-11.10	P <0.001	Reject Ho	Significant
ILA	28.41	7.77				

Note: $p < 0.05$ is significant

Through a two-sample t-test (pooled variance), using T distribution (df=216), it shows that there was a significant difference between the retention test scores between the two groups; specifically, that the mean of the EOT group is significantly lower than the ILA group (t= -11.10, p<0.01). The p-value generated was less than the significance level of 0.05, which suggests that there was statistical evidence to support that the mean difference between their deferred concept understanding is significant. In addition, the observed effect size d is 1.50, which implies that the magnitude of the difference between the two means is large. The result implies that inverted learning can influence deferred learning since the retention test results of students were observably and significantly better than those taught using the expository online teaching.

On Test Improvement (Pre-Post-Retention Tests Analysis)

Results from the Analysis of Variance, using F distribution df (2,315) comparing the means in the pre-test (Mean= 13.63 ± 3.96), post-test (Mean= 25.82 ± 6.91), and retention (Mean= 17.53 ± 6.62) test of students who were taught using the expository online teaching (EOT) revealed that the groups' means were not equal as shown in Table 3. The same results were observed in Table 4 showing the performance of ILA group in the pre-test (Mean= 14.37 ± 3.83), post-test (Mean= 28.8 ± 8.28), and retention (Mean= 28.41 ± 7.77) through the Analysis of Variance, using F distribution df (2,333).

Table 3. *ANOVA Results – EOT Test Improvement*

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
Groups (between groups)	2	8215.328	4107.664	114.8445	< 0.001
Error (within groups)	315	11266.6609	35.7672		
Total	317	19481.9888	61.4574		

Note: P < 0.05 is significant

The differences between the means of some groups under EOT and ILA were statistically significant, with F values of 114.84 (p < .001) and 158.01 (p < .001), respectively. Both groups generated a p-valueless than the significance level of 0.05 with large effect sizes of 0.85 for EOT and 0.97 for ILA. These suggested that both instructional interventions were equally effective for students as per Hew et al. (2020). Thus, post-hoc analyses were conducted to further understand the differences between the tests per group.

Table 4. *ANOVA Results – ILA Test Improvement*

Source	DF	Sum of Square	Mean Square	F Statistic	P-value
Groups (between groups)	2	15122.0426	7561.0213	158.0104	< 0.001
Error (within groups)	333	15934.5175	47.8514		
Total	335	31056.5601	92.7061		

Note: P < 0.05 is significant

Post Hoc Analysis – EOT vs ILA

After running a post hoc analysis using Tukey HSD / Tukey Kramer in Table 5 for students exposed to EOT and Table 6 for those taught using ILA, there were significant differences between the pre-test and post-test means, the pre-test and retention test means, and post-test and retention test means. The only difference in the results were observed in the ILA group, where post-test and retention test results did not significantly vary.

This suggests that ILA can sustain concept understanding over time since retention test was administered after four weeks later. The post-hoc analysis further supports the idea that ILA can improve students' deferred understanding of concepts in Biology.

Table 5. *Post hoc Analysis Results – EOT*

Pair	Difference	SE	Q	Lower CI	Upper CI	Critical Mean	p-value
X1-X2	12.1887	0.5809	20.983	10.2542	14.1232	1.9345*	1.306e-10
X1-X3	3.8962	0.5809	6.7074	1.9617	5.8307	1.9345*	0.000009535
X2-X3	8.2925	0.5809	14.2756	6.358	10.2269	1.9345*	1.307e-10

Note: X1- Pre-test; X2- Post-test; X3- Retention test

Table 6. *Post hoc Analysis Results – ILA*

Pair	Difference	SE	Q	Lower CI	Upper CI	Critical Mean	p-value
X1-X2	14.4107	0.6536	22.0469	12.2345	16.5869	2.1762*	1.325e-10
X1-X3	14.0446	0.6536	21.4868	11.8684	16.2209	2.1762*	1.325e-10
X2-X3	0.3661	0.6536	0.5601	-1.8102	2.5423	2.1762	0.9172

Note: X1- Pre-test; X2- Post-test; X3- Retention test

On Self-Efficacy Analysis

With the adoption of digital learning and the development of educational technologies (Tsai et al., 2017) especially in this new normal, inverted learning approach would be highly recommended for improving students' self-efficacy. This is supported by Table 7, which details the results of the comparative analysis in students' levels of self- efficacy in Bioenergetics of students between the two groups under study, using two-sample Mann-Whitney U test.

Table 7. *Comparison of Students' Level of Self-Efficacy- EOT vs ILA*

	Mean	SD	p-value	U	p-value	Decision	Interpretation
EOT	7.61	1.26	0.033	4870.5	0.0110	Reject Ho	Significant
ILA	7.95	1.44					

Note: $p < 0.05$ is significant

Students who have high self-efficacy and are affectively and cognitively engaged perform better in science classes (Uçar and Sungur, 2017). The results showed that the EOT students' self-efficacy level was lower than the ILA students' and such difference is enough to be statistically significant (U=4870.5; Z= -2.2888; p=0.03307). Therefore, ILA enables students to attain self-efficacy in virtual learning environments, as supported by Heaperman & Sudweeks (2001). The ILA encourages deeper learning than expository online teaching (Algarni, 2023; Arante & Castro, 2022). It gives students more time to learn, empowers them to be more independent and responsible, fosters their creativity, and improves their knowledge and skills across varying levels of achievement (Paul et al., 2023).

Based on the self-efficacy results, ILA provides students the flexibility of "anytime and anywhere" learning (Martin et al., 2010) by revolutionising the learning platform through development of learning management system (LMS) or adopting multiple learning modalities in the new normal set-up. ILA is more reasonably considered purposeful maximization of technology or digital resources in education (Drozdikova-Zaripova, & Sabirova, 2020).

Conclusion

Results revealed a significant difference in the direct concept understanding (P= 0.00237) between the ILA group (28.5± 8.28) and the EOT group (25.8± 6.91). Regarding deferred concept understanding (P <0.001), ILA group (28.41± 7.77) also had significantly higher mean score than the EOT group (17.53± 6.62). In view of their self-efficacy, ILA group (7.95± 1.44) had significantly higher self-efficacy level compared with the EOT group (7.61± 1.26). Such difference is big enough to be statistically significant. Thus, it can be concluded that ILA could significantly and positively affect students' direct and deferred concept understanding and self-efficacy.

The ILA offers several advantages that can make it a more effective instructional approach for teachers to consider, such as it 1) makes students become more self-directed thinkers and doers; 2) fosters deeper understanding of concept by students as they interact with the content ahead of time, which can lead to better retention of knowledge and learned inquisitiveness; 3) leverages students' differential needs and interests; 4) gives chance to students to succeed through flexible learning space and time; and 5) cultivates important skills for their future academic endeavours.

The findings suggest for investigating the long-term effects of ILA on students' academic performance. Longitudinal studies could evaluate how long-term exposure to ILA affects their academic trajectory and concept retention. Additionally, further research could examine how ILA can be applied to other STEM subjects. This would not only provide information regarding its transferability but also contribute to the development of best practices for its implementation across diverse educational contexts.

Acknowledgements

The author gratefully acknowledges the financial support provided by the Department of Science and Technology - Science Education Institute (DOST-SEI)- CBPSME for this research. Additionally, the author expresses sincere appreciation to the University of the Philippines- Open University (UPOU) and Mindanao State University- Maguindanao for furnishing the essential educational resources and support that facilitated the completion of this study.

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