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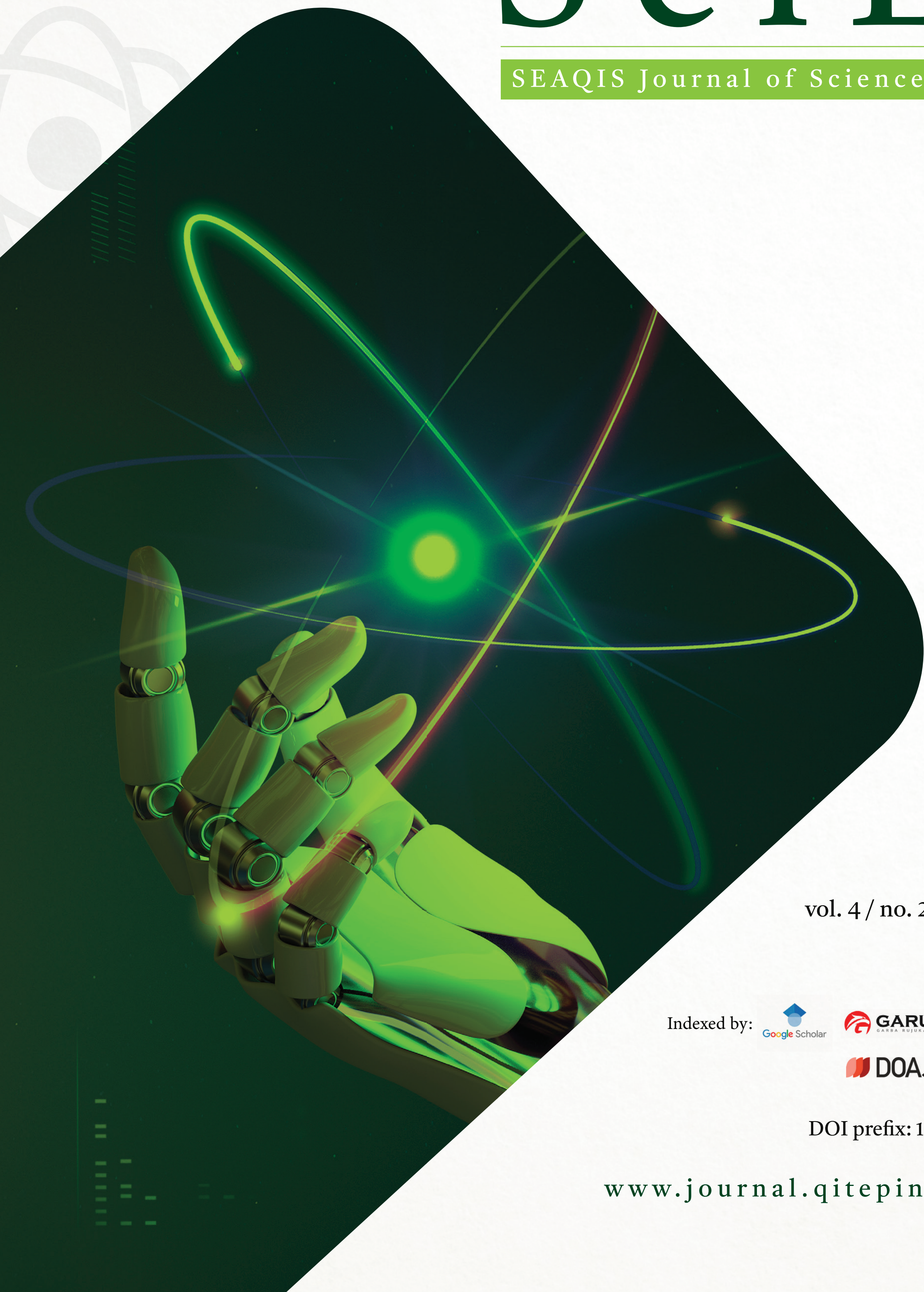
SEAQIS Journal of Science Education



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SEAMEO Regional Centre for QITEP IN SCIENCE

SciEd

SEAQIS Journal of Science Education

Acting Director's Message

Dear valued readers,

I am pleased to welcome you to the latest SEAQIS Journal of Science Education (SciEd) edition, Volume 4, Issue 2. As we continue to advance in our mission, SEAQIS remains committed to promoting innovation in science education across Southeast Asia. Through SciEd, we offer a platform for educators and researchers to share their insights and groundbreaking work, contributing to the progress of science education in the region.

SEAQIS, as a centre for professional development, thrives on collaboration. We work closely with authors, researchers, and practitioners to bring you high-quality and relevant content that reflects the latest trends and advancements in science education. This publication is a testament to the dedication of all our contributors.

I would like to express my sincere gratitude to the authors, our SEAQIS team, and all partners involved in making this issue possible. Your tireless efforts help ensure that we continue to provide a meaningful platform for those passionate about science education.

Looking ahead, I encourage educators, researchers, and readers of SciEd to embrace innovation and research. Together, let's move forward and create new pathways for growth and learning in science education.

Sincerely,

Zuhe Safitra
Acting Director, SEAMEO QITEP in Science

From the Editor-in-Chief

Greetings and welcome to the 4th volume, issue 2, in SEAQIS Journal of Science Education (SciEd). It is my great honor to present this collection of thought-provoking articles and research that reflect the diversity of science education. I would also like to express my gratitude to all the authors, the Editorial Board, the designer, the Publishing Office Staff, and everyone who has contributed to this publication. The hard work and tireless efforts have been made.

At SciEd, we believe in the power of ideas and the strength of diverse perspectives, which are reflected within these pages to encourage the curiosity of our dear readers. From cutting-edge research studies to thought-provoking essays, we strive to offer content that challenges assumptions, sparks dialogue and inspires meaningful change.

This journal is more than a collection of articles; it is a forum where ideas meet, evolve, and contribute to a better understanding of our world. We invite you to engage deeply with these works, reflect, question, and share your own insights. Your voice and perspectives are vital to this ongoing journey of discovery.

Thank you for being an integral part of the SEAQIS community. We hope you find this edition as inspiring and enriching as it was to create.

Warm regards,

Dr Elly Herliani
Editor-in-Chief

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The Desk

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

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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.

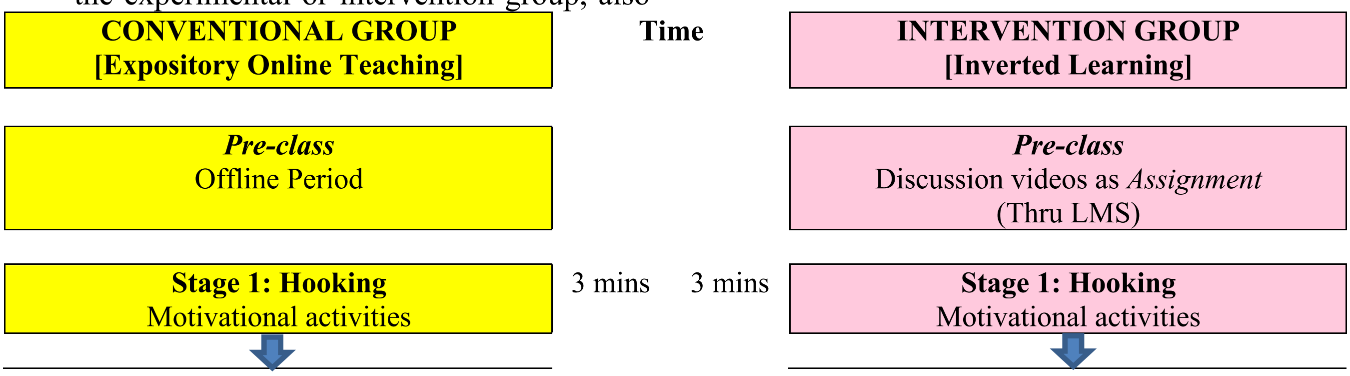
Locale and sample

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.



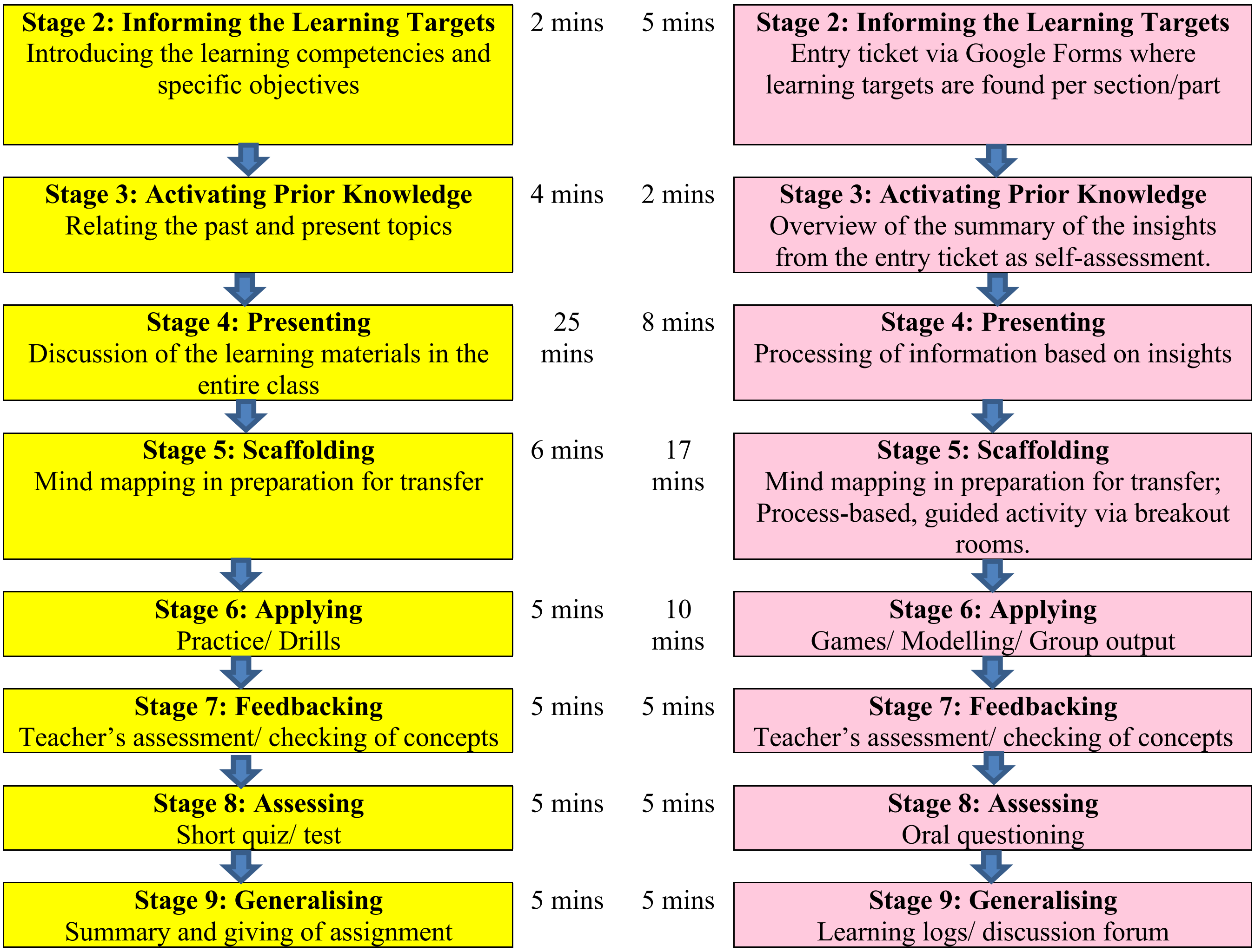


Figure 1. Comparative Flowchart of the Events for the EOT and ILA Groups

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.

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Research Paper

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Student Learning Satisfaction and Academic Performance in Philippine Science High School Chemistry: A Prediction Model Building Study for Online Learning

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Abstract

Learning satisfaction is a key indicator of enriching student learning whether it is face-to-face or online mode of delivery. Learning has shifted more to remote online learning due to the Covid-19 pandemic. This study aimed to identify the determinants of Student Learning Satisfaction (SLS) in online learning and develop a model that represented the relationship of the determinants to SLS. The study explored both internal and external determinants hypothesised to influence SLS among 169 students in grades 9-12 taking Chemistry at the Philippine Science High School Cordillera Administrative Region Campus (PSHS CARC). The internal factors included gender, academic self-concept (ASC), academic motivation (AM), interest to learn (IL), and mental well-being (MW), while the external factors comprised teacher-related indicators (Teacher), assessment-related indicators (Assessment), learning guide-related indicators (LG) and Knowledge Hub-related indicators (KHub). The study utilised Structural Equation Modelling (SEM) with SmartPLS software to develop the SLS model and Academic Performance (AP) model. Both online learning platforms used by PSHS CARC, the LG, and KHub, were found to influence SLS. The external determinants (LG, KHub, Teacher, Assessment) dominated the SLS models while internal determinants (ASC, AM, IL, MW) dominated the AP model for the PSHS CARC Chemistry students. The external determinants influenced the student's learning satisfaction while the internal determinants influenced the AP of the Chemistry students. Assessment indirectly affected SLS. Another finding was that gender, LG, and ASC directly influenced AP. The results validate that online learning tools (LG and KHub) were crucial determinants in ensuring learning satisfaction and academic success in the online learning of PSHS CARC Chemistry students. The models (SLS and AP) can be utilised to evaluate and enhance the quality of online learning and the development of effective online learning strategies and policies especially regarding the use of online tools like LG and KHub.

Keywords: Academic Performance; High School Chemistry; Learning Satisfaction; SmartPLS; Structural Equation Model (SEM)

Introduction

The Covid-19 pandemic has rendered online learning as the default mode of learning. Before the pandemic, online learning was considered merely an alternative or a complementary learning mode to the traditional classroom face-to-face learning. The issue of student satisfaction is a crucial factor in determining the success of learning for educational institutions and educators to guarantee that they are meeting the needs of students and delivering satisfying learning experiences in online or face-to-face modes. The need to study and determine the factors that contributed to student satisfaction in online learning was important for assessing the effectiveness of online learning strategies. The concept of learning satisfaction captured the attention of educational researchers after the implementation of online learning. Learning satisfaction is the feelings and attitudes of the learner which reflect the level of fulfilment during the learning processes (She et al., 2021). Learning satisfaction focuses on the level of learner's fulfilment in the learning process, and more importantly on the quality of the learner's output. The new challenges of maintaining quality education, including learning satisfaction and determining the factors that affected the quality of education, were the most pressing issues during the implementation of online learning. This study was conducted at the Philippine Science High School Cordillera Administrative Region Campus (PSHS CARC) during the school year 2021-2022. 169 students from grade 9 to grade 12 enrolled in Chemistry courses participated in this study. The challenge presented to the PSHS administration is on how to maintain the high standard quality of graduates despite the challenges in the implementation of online learning. Hence, the important element of this study is building a model that best represents the learning satisfaction and academic performance of PSHS CARC Chemistry learners with the aid of Structural Equation Modelling (SEM). SEM combines two statistical methods: confirmatory factor analysis and path analysis. This study aims to assess the influence of identified external and internal determinants of Student Learning Satisfaction (SLS) and Academic Performance (AP). This research was undertaken to come up with SLS models and AP models which best represent the PSHS Chemistry learners in the context of online learning.

Methodology

The participants were requested to submit accomplished assent/consent forms before implementing the survey. Those who submitted the forms were asked to answer a series of Five-point Likert scale survey questionnaires on student satisfaction, academic self-concept, academic motivation scale, interest to learn questionnaires, and mental well-being scale. The modified student satisfaction survey by Fieger (2012) was employed to gather data on PSHS students' satisfaction levels in relation to learning determinants such as teachers, assessments, learning guides, and KHub. To explore students' attitudes, feelings, and thoughts about themselves in relation to learning, the Academic Self-concept survey questionnaire originally developed by Raynor & White (2013) was modified. The Academic Motivation survey questionnaire, adapted from Ansari et al. (2021), was used to measure students' motivation levels specifically in the context of learning chemistry. To evaluate students' interest in learning chemistry, the researchers created an Interest to Learn survey based on a sample derived from the Student Interest and Learning Style Survey for Social Studies. To assess students' mental well-being, the researchers employed the Mental Well-being survey questionnaire, which was adapted from The Warwick-Edinburgh Mental Well-being Scale (WEMWBS) and the literature by Tennant et al. (2007).

The instruments, including the questionnaires, underwent content validation by experts to ensure their relevance and effectiveness. Quantitative statistical computations were performed using a spreadsheet and a specific statistical software called SMARTPLS (SEM-PLS). This combination of tools enabled the researchers to accurately analyse the data, including descriptive statistics, correlation analyses, regression analyses, and structural equation modelling. SmartPLS is a software with a graphical user interface for variance-based Structural Equation Modelling (SEM) using the Partial Least Squares (PLS) path modelling method. It is a software used when the analysis is concerned with testing a theoretical framework from a prediction perspective and in building a model relationship. Using SmartPLS, path models with latent variables (in this study the latent variables are the determinants) were estimated or determined whether there was a significant influence of the determinants on learning satisfaction using the PLS-SEM algorithm. The software computes standard results assessment criteria (e.g., for the formative measurement models, the structural model, and the goodness of fit) and it supports additional statistical analyses such as the preliminary testing of the validity and reliability of the questionnaires based on the responses.

The Bootstrapping PLS feature of the SmartPLS software calculates statistical p-values that were used to determine if the correlation between two variables was significant. Significant paths are kept while non-significant paths are removed until the structural model for learning satisfaction is completed. All possible connections among the variables are considered. The SmartPLS uses multivariate analysis. The multivariate analysis takes into consideration as many factors as possible and determines important relationships and structures among multivariate data. All correlation tests were two-tailed and p-values less than 0.05 were considered statistically significant. Data analysis was automatically done by the SmartPLS once the data was encoded into the software.

Results and Discussion

The External Determinants

Teacher Satisfaction

Teachers at PSHS were not only expected to possess deep subject knowledge but also to maintain a high level of student satisfaction on their teaching performance. The result of the teacher satisfaction survey clearly demonstrated the high level of student satisfaction on their teacher performance which included the teacher's knowledge, philosophy of teaching, attitude, and teaching performance as observed through their conduct of learning and interactions with students. The students across all grade levels were highly satisfied with their teachers' contributions to their learning experiences. The respondents in this study emphasised the importance of the teacher's classroom management and attitude, as they significantly influenced students' satisfaction with their Chemistry learning experiences.

Assessment Satisfaction

Assessments such as exams and quizzes have long been recognised as a significant source of stress and anxiety in the academic lives of students. However, it is important to acknowledge that assessments play a crucial role in evaluating students' learning and understanding. Consequently, it is imperative for students to find satisfaction in the assessment process. The student respondents reported relatively high levels of satisfaction with their assessments. Among the various aspects of assessment, the level of difficulty criterion received the lowest satisfaction rating across all grade levels. This finding is not surprising considering that Chemistry is widely regarded as one of the most challenging subjects. Assessments in Chemistry often require students to demonstrate not only knowledge but also their analytical and problem-solving skills. Hence, the complexity of these assessments contributed to the lower satisfaction ratings in terms of difficulty.

Learning Guides (LGs) Satisfaction

In the absence of a physical classroom and face-to-face interaction with teachers, PSHS-CARC implemented Learning Guides (LGs) as a solution. LGs served as asynchronous learning materials, allowing students to learn at their own pace and convenience. However, the satisfaction ratings revealed some areas that need improvement. Students' expectations included more visual elements and a userfriendly approach in the design of LGs. It appears that students may prefer more visual illustrations and less technical discussions in their LGs to enhance their learning experience.

KHub Satisfaction

KHub was implemented by the PSHS system as a learning management system to complement the learning guide in the online learning experience of the students. The features of KHub play a crucial role in assisting students with their online learning, which can ultimately lead to either satisfaction or dissatisfaction among students. Overall, the respondents reported relatively high levels of satisfaction on the use of the KHub. The students find KHub accessible and easy to use. However, students seem to be relatively unsatisfied with the notification features and response time of KHub.

The Internal Determinants

Academic Self-Concept (ASC)

How the students perceive themselves in their learning activities is a very important aspect of how a student would learn. Learning starts with a correct mindset. A positive self-concept will result in better learning, whereas a negative self-concept will spell failure in learning even before the learning process is started. The Academic self-concept survey result indicated that the PSHS student respondents exude optimism in their academic self-concept. Among those with high ratings across all grade levels are ASC item 1 (If I try hard enough, I will be able to get good grades) and ASC item 26 (I would like to be a better student than I am now). Meanwhile, ASC item 24 (I am good at scheduling my time) and ASC item 35 (I have a very good study habit) had relatively low ratings. In other words, the students do not find themselves having the self-discipline to schedule their study time and have good study habits.

Academic Motivation (AM)

Academic motivation encompasses the driving factors behind behaviours that impact academic performance and achievement. These factors include the level of effort students invest, their ability to manage their workload effectively, the pursuits they choose to engage in, and their perseverance in the face of challenges (Usher & Morris, 2012). While all grade levels are motivated by earning high grades in Chemistry, they seem to be "demotivated" by the problem-solving requirements of Chemistry courses. In other words, their difficulty in solving problems decreases their academic motivation toward Chemistry. PSHS students have been observed to be competitive in their academics in general but maybe not in Chemistry as the result of this survey shows. Another implication is a demotivation of the students to have a career in Chemistry. The students do not find motivation in having a career in Chemistry and hence the low motivation to learn.

Interest to Learn (IL)

Interest in learning is a personal inclination and desire that promotes active engagement in the learning process. When individuals are genuinely interested in a subject, they exhibit enthusiasm, curiosity, and a willingness to invest time and effort to expand their understanding. This intrinsic motivation not only enhances the learning experience but also improves knowledge retention and application. At all grade levels, students displayed enthusiasm for acquiring new knowledge in Chemistry, demonstrating a positive attitude for learning. Nevertheless, the data also uncovered areas where students showed less inclination: reading in advance before a Chemistry topic is discussed in class and engaging in research activities related to Chemistry. These aspects received the lowest ratings in the survey. The student ratings across all grade levels indicate a relatively low level of interest in learning Chemistry.

Mental Well-being (MW)

Enhancing the mental well-being of learners is crucial, especially in the context of the pandemic, where students face unique challenges in their learning. The mental well-being of learners refers to their ability to cope with the demands of learning under pandemic conditions and their capacity to concentrate on their studies. The study by Ranadewa (2021) showed that mental well-being affects learners' satisfaction. The mean score of the students on mental well-being survey question shows an alarming signal that the students' mental well-being should be a concern while they are in the online learning process. The students' own self-rating on their ability to think clearly, dealwith problems, and feelng confident are relatively low.

Academic Performance (AP)

Academic performance in online learning refers to how well students perform academically within virtual educational settings. It encompasses achievements, grades, and overall learning outcomes. The student's AP is solely dependent on their final Chemistry course grades. The Chemistry grades of each student respondent were recorded confidentially. Table 1 summarises the average grades per grade level of the student-respondents. The grading system is as follows: 1.0; 1.25; 1.50; 1.75; 2.0; 2.25; 2.50; 2.75; and 3.0, with 1.0 as the highest grade.

Table 1. Average Chemistry Grade per grade level.

GRADE LEVEL	Average Chemistry Grade		
	MALE	FEMALE	ALL
Grade9	1.72	1.97	1.85
Grade10	1.57	1.30	1.43
Grade11	1.25	1.17	1.20
Grade12	1.20	1.32	1.29

The SLS Models

Figure 1 shows the SLS Model for each grade level to easily see direct and first-degree indirect determinants to the SLS for each Grade level resulting from the procedure described in the section Methods with the SmartPLS.

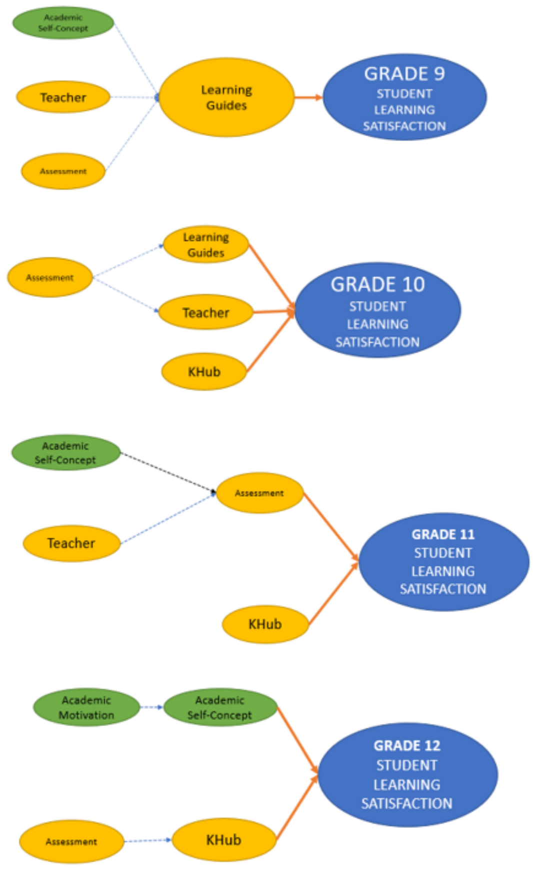

Figure 1. SLS Model for each Grade Level showing direct and indirect determinants.

Interpretation of resulting SLS model per grade level are as follows:

1. LG showed direct significance to the SLS in Chemistry for Grade 9 and 10. This can be explained by the high reliance of the younger students on the LG during the academic year 2021-2022. As the students were expected to be independent learners, the interaction between students and teachers became less frequent. This was due to the fact that the LGs had become the main source of "personal" contact between the students and teachers which instructions on what topics to study as well as activities and problems to solve are stated and explained. LGs became the manual for students in their learning process, particularly for the younger learners. PSHS-CARC Chemistry students in all grade levels agreed that clarity of the directions in the LG along with the completeness of the LG followed by creativity we're the most

important. These factors or features should have been taken advantage of designing the LG aimed at the learning satisfaction of the students. On the contrary, based on the students' responses, the LG became a negative determinant to learning satisfaction if they were too lengthy in content and the time allotted to complete the modules was insufficient.

2. Assessment showed indirect significance to the SLS of the students in Chemistry for all grade levels. Interestingly, Assessment was significantly related to LG and KHub. LGs gave directions to the students on which assessment activities to do. Hence, it is not a surprise that LG and assessment were closely and significantly related to each other. The KHub was also used for online assessment activities. Assessments were found to influence learning satisfaction if timely feedback was given. Based on the students' qualitative responses, the students found the time allotted to complete the assessment, the type of assessment and the number of assessments required in the Chemistry course reasonable. The students appreciated the flexibility of setting deadlines for the assessments. However, the Grade 9 students complained about the level of difficulty of assessments, the Grade 10 students complained about unclear instructions in assessments, the Grade 11 students complained about inconsistent intervals of giving assessments, and the Grade 12 complained about the assessment outputs that replace quizzes and exams such as PowerPoint and video presentations, infographics, and other creative outputs.

3. The Knowledge Hub (KHub), an online learning support system, was directly significant to Self-Regulated Learning Strategies for all grade levels except Grade 9. Learning Management Systems (LMS), such as KHub, were essential for online learning. However, for KHub to enhance learning satisfaction, it needed to be developed to ensure ease of use, usefulness, and navigation. Qualitative feedback highlighted KHub's ease of access and navigation across various digital devices. Dissatisfaction arose mainly from internet speed and stability issues, causing erratic notifications and hindering learning. This result aligns with Alenezi's (2018) study, which identified barriers to LMS adoption such as limited internet access and infrastructure. Despite these challenges, students using KHub for online learning at PSHS reported a level of learning satisfaction.

4. The Teacher Determinant had different effects on each grade level. Grade 10 students viewed their Teacher Satisfaction as directly related to their learning satisfaction, while Grade 9 and 11 students showed their learning satisfaction to be indirectly related to their teacher satisfaction. The Grade 12 students did not perceive teacher satisfaction influencing their learning satisfaction. This may have been attributed to the fact that higher grade level PSHS students were taught to be more independent learners. Assessments were found to influence learning satisfaction if timely feedback was given (Dziuban et al. 2015; Bahati et al. 2019).

PSHS teachers are experts and masters of the courses they teach. The PSHS Chemistry curriculum is at the same level as those taught in university-level courses. Based on the students' responses, while the students did not complain about the requirements demanded of the courses, they appealed for consideration of teachers' expectation that they should easily understand the lesson taught and that they should strictly follow deadlines of submissions of the course regardless of the circumstances. The students seemed to appeal more time for them to absorb the lesson and enough reasonable time to complete requirements. The late return of their outputs and feedback on their completed activities was a source of teacher dissatisfaction for the Grade 9 Chemistry learners.

5. Among the internal determinants, ASC showed a direct effect on SLS for Grade 12

students and indirect effect on SLS for Grade 9 and 11 students. The factors IL and MW did not show any influence on the learning satisfaction of students. AM only indirectly affected the learning satisfaction of Grade 12 students. However, the relatively low ratings on these internal factors signalled that possible intervention might be needed for the PSHS students on these determinants. It is interesting to note that the ASC is significantly connected to the LG. One possible explanation might be that the LGs were meant for self-study. The study by Hassan et al. (2021) showed that positive academic self-perceptions were found to strongly influence satisfaction in the course. Hence, a high self-perception of the student's academic self-concept that they can learn on their own with minimum supervision through the LG was important.

The Academic Performance (AP) Model

Figure 2 showed the final AP Model to easily see direct and indirect determinants to the academic performance/grade of the Chemistry students.

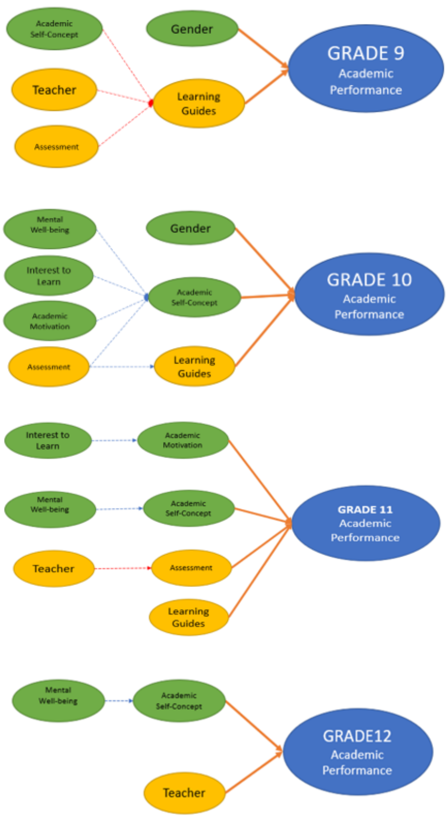

Figure 2. AP Model for each Grade Level showing direct and indirect determinants.

The resulting AP Model per grade level is summarised as follows:

1. Gender appeared to be a factor in the AP of Grade 9 and Grade 10 students but not for Grade 11 and Grade 12. Based on the results, Grade 10 male learners have higher Chemistry grades than their female counterparts. Meanwhile, Female PSHS-CARC Chemistry Grade 9 students have higher grades in Chemistry than the male Grade 9 students. However, the contrasting results for Grades 9 and 10 mean that it is not conclusive to infer which gender has a better AP in Chemistry. The study of Yu and Deng (2022) which investigated gender differences in e-learning outcomes globally, focusing on self-efficacy, satisfaction, motivation, attitude, and performance, concluded that, in general, there are no significant gender differences in e-learning outcomes across most countries.

2. The external factors (Teacher, Assessment, and LG) have varying effects on AP at different grade levels.

Teacher satisfaction directly influenced the Grade 12 AP and indirectly influenced the Grade 10 and 11 students. The findings of this study suggest that teacher communication orientations and student communication preferences can impact student performance. Effective communication between teachers and students is therefore essential for fostering better academic outcomes.

KHub does not show any effect on the student's AP or grades. KHub is not a significant determinant of the student's academic performance/grade for all grade levels.

3. The internal factors (ASC, AM, IL, and MW) also showed varying effects on the academic performance of the Chemistry learners.

ASC showed direct significant effect on the AP for all grade levels except Grade 9.

This means that a high ASC is an important factor for the students to have higher academic performance or grades in Chemistry. Zhan and Mei (2013) reported that both ASC and social presence significantly impact students' learning achievement and satisfaction, However, the general average rating for ASC of the PSHS-CARC students is relatively low compared to the other internal determinants. There may be a need in helping the students improve their ASC. MW, IL, and AM have an indirect effect on the AP of Grade 10 students. However, AM, IL, and MW do not show a significant effect on Grade 9 AP. For the Grade 11 and 12 learners, MW shows an indirectly significant effect on AP. These results collectively reveal that mental well-being plays a significant and often underestimated role in determining the academic outcomes of Grade 11 and 12 students. The emotional state of students directly influences their attitudes towards learning and ultimately impacts their academic performance. Furthermore, the prevalence of heightened stress levels further supports the notion that MW indirectly affects academic success in a positive way.

While the SLS model is dominated by external determinants (LG, KHub, Teacher, and Assessment), the AP Model is dominated by internal determinants (ASC. AM. IL and MW). This means that the SLS is influenced by external factors and the AP of the Chemistry students is affected by internal factors.

Conclusion

The PSHS CARC Chemistry learners are found to be satisfied with all the external determinants: Teacher, Assessment, LG and KHub. The two remote learning tools had the lowest ratings. However, it is interesting to note that both LG and KHub have a significant influence on the learning satisfaction of the PSHS CARC Chemistry students.

The PSHS CARC Chemistry learners have relatively low ratings on their internal determinants: ASC, AM, IL, and MW. While they have a relatively low assessment of themselves as learners, they appear to perform well as evidenced by their high Chemistry grades. The results indicate that PSHS CARC Chemistry students can cope and perform academically well despite relatively low perceptions of their internal (mental and psychological) aspects.

On the SLS Model

The result of the study showed indirect relation between SLS and academic performance. SLS and academic performance are indirectly related through one determinant, the LG. This means that specifically for the PSHS education system, student satisfaction, and academic performance are entirely separate matters.

In general, internal determinants have no direct influence on the SLS. This means that the students get their learning satisfaction from the external determinants. SLS is derived directly from LG and KHub and indirectly through Teacher and Assessment. In other words, external determinants (LG, KHub, Teacher, Assessment) dominate the model. Only one internal determinant, academic self-concept, is indirectly related to SLS.

External and internal determinants are independent of each other. Internal determinants do not influence the external determinants. While it is expected that students who get higher grades tend to have better learning satisfaction, the result of the PSHS Chemistry learners' perceptions showed a different picture. Their goal of attaining high grades is not tied directly to their learning satisfaction.

On the relationship of Student Learning Satisfaction and their Academic Performance

For the young learners (Grade 9 and Grade 10), the result of the study showed that the learning satisfaction of the students does not directly influence the AP. In addition, for these young Chemistry learners, this study showed that the AP is indirectly related to the learning satisfaction through the LG determinant. For the older Grade 11 and 12 learners, there was no significant connection between the learning satisfaction and their academic performance.

On the Academic Performance Model

Academic Performance is important for PSHS because it is an indicator of the student's academic achievement rather than their learning satisfaction. A stark contrast to the SLS model, which is dominated by external determinants, the AP Model is clearly dominated by internal determinants. The AP Model highlights the lack of emphasis on SLS. It confirms that the focus of the students is primarily on achieving high grades rather than valuing their learning experience. While learning satisfaction and academic performance are distinct objectives for PSHS Chemistry students, it appears that the students prioritise the latter over the former.

The Student Learning Satisfaction (SLS) Model and Academic Performance (AP) Model as Predictive Models for Online Learning

In this study, the developed SLS and AP models can be used as predictive models of student behaviour and their Chemistry grades, respectively. The SLS Model can be used to predict the likelihood that the students will enjoy and find satisfaction in learning the lessons in a difficult subject like Chemistry. The AP Model can be used to predict the likelihood of students getting a high grade in their Chemistry subject. Furthermore, the SLS and AP Models as prediction models for online learning can help educators and administrators to provide targeted support to students, leading to improved outcomes and success in online learning environments.

The AP model predicts that students with high ASC would have higher grades. Also, from the AP model, ASC is influenced by the student's perception of their mental well-being, interest to learn the subject, and academic motivation. In other words, high MW, IL, and AM lead to high ASC which in turn leads to a higher grade in Chemistry. The AP model also indicated that the LG predicts the Chemistry grade, which is expected because all assessment and grading requirements are incorporated in the LG.

In summary, one of the important results of this study was that both online learning platforms used by PSHS CARC, the LG, and KHub, were found to be effective tools for online SLS. PSHS CARC may need to improve more on these two determinants towards more positive learning satisfaction experiences for their Chemistry learners. This result (especially for LG) is further reinforced by the fact that learning satisfaction and academic performance are indirectly related to each other through LG. This means that the LG used by PSHS CARC was an effective tool for their online mode of learning. PSHS CARC must take advantage of the use of the LG for the students to enjoy independent online learning because learning satisfaction translates to better academic performance for their Chemistry learners.

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Infusing Vibrancy into Science Learning through Weismann: An Educational Game for Learning Plants and Animals' Reproduction Systems

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Abstract

This research endeavours to develop an educational game, Weismann, designed to enhance the engagement and effectiveness of teaching and learning about plants and animals' reproduction systems. Named after August Friedrich Leopold Weismann, the pioneering scientist behind the germplasm theory, the game aims to infuse vibrancy into the learning experience. Adopting a Research and Development (R&D) framework, the study employs sourced data from multiple channels, including expert validation assessment scales as well as science teachers and their students' feedback on their practical experiences as users. The findings reveal Weismann to be highly valid, scoring 91.2, and remarkably practical, with teachers and students rating it at 95.9 and 83.9, respectively. These results affirm the game's efficacy as a valuable tool for science education, offering a dynamic and effective approach to learning.

Keywords: Educational Game; Science Learning; Reproduction Systems

Introduction

Planning, implementation, and evaluation of learning are three important things in the learning process (Panigoro, 2018). This is the reason learning evaluation is an activity that is as important as knowledge transfer. Educational evaluation involves 3 stages: input, process, and outcome; evaluation of student learning is a method used to monitor the process, progress, and revision of learning outcomes (Rokhim et al., 2021). The student evaluations and student learning assessments serve as an important lens through which to examine the teaching (Fisher, 2019). In his book "Becoming a Critically Reflective Teacher", Stephen Brookfield (1995) makes the case that critical reflection on one's own teaching is a crucial component of growing as a teacher and enriching students' learning experiences.

During the observation, some information was collected: (1) The lack of willingness, interest, enthusiasm, motivation, and enthusiasm of students to do the evaluation tests. That is because the evaluation model tends to be the same from time to time, which affected most of the students who did not complete the evaluation test; (2) The test question models without pictures or animations force students to imagine something abstract. Furthermore, evaluation tests also tend to make students tense and nervous; (3) In the pandemic era, the time for one hour of face-to-face lessons has been reduced, resulting in students not having enough time to do evaluation tests; (4) In general, students have the ability to operate digital technology; and (5) Students generally have a high interest in digital games. Maki (2002) states instructors assist students in "understanding their strengths and shortcomings and reflecting on how they need to progress over the course of their remaining courses" by examining their performance through formative assessment and sharing the results with them.

Based on observations, it is known that junior high school students are Digital Native Students (DNS). DNS are the generation that was born when technology was already in their environment (Dingli & Seychell, 2015). This fact can facilitate the implementation of evaluations in the era of the pandemic, considering that everything must be done with the help of digital technology. One of the evaluation methods that can be used is game-based learning. An educational game needs to be developed as an evaluation tool. Previous research related to game-based learning includes: (1) Sasongko and Suswanto (2017) found that the games developed were valid to be used as learning evaluation tools; (2) Naimah et al. (2019) proved that the developed science adventure game can improve the problem-solving skills of junior high school students in science learning; (3) Rohwati (2012) found that educational games can increase student activity in the learning process, apply ICT in learning, and have a good impact on language acquisition; (4) Indra et al. (2018) said that the instructional game with the Luther Model was effective in improving science learning outcomes.

This study aimed to develop a valid and practical game as an evaluating tool for science learning by adopting the principle of "Stealth Assessment". Stealth Assessment is a method that utilises digital games to discreetly assess students' level of conceptual understanding (Georgiadis et al., 2021). Thus, students feel that they are only playing a game, not taking a test. Students can play educational games without worrying about the availability of storage space on their smartphones. In this case, the game was developed based on a web browser by utilising Google Sites. This game was named "Weismann", derived from the name of the scientist who created the germplasm theory, August Friedrich Leopold Weismann.

Methodology

The type of research conducted is Research and Development (R&D) with the Plomp development model. The Plomp model developed by Tjerd Plomp consists of three stages: preliminary research; prototyping stage; and assessment phase (Plomp, 2013). The preliminary research stage involves the needs of student, curriculum, and concept analysis; the prototyping stage involves formative evaluation (self-evaluation, expert review, one-to-one evaluation) and small group evaluation. This study is limited to practicality testing through small group evaluation. The data came from two sources: first, testing the validity of the product by experts, which involves three Science Education lecturers at Universitas Negeri Padang; and second, involving four junior high school science teachers and 30 junior high school students for a practicality questionnaire. The expert validation questionnaire covers three aspects: the learning design; the visual communication; and the device. The product assessment questionnaire by users includes four aspects: usability; ease of use; attractiveness; and clarity.

Results and Discussion

The product developed in this study was the educational game "Weismann" based on Google Sites, which contained the concept of the Breeding System in Plants and Animals for Junior High Schools. Product development was based on the lack of availability of digital evaluation tools for students on the product concept. This game was expected to help visualize evaluation test objects that were difficult to observe directly, which could be in the form of images, animations, and sounds. In addition, the evaluation system also allowed for deep interaction between multimedia and students as users. With this two-way interaction and supported by appropriate media types, learning activities will be more interesting, the learning environment more dynamic, and learning more effective (Asyhar et al., 2012).

1. Preliminary Research

Interviews conducted with science teachers revealed significant concerns regarding students' motivation and enthusiasm for participating in evaluation tests. Students often displayed a lack of willpower, interest, and passion when it came to completing assignments and quizzes. This disengagement frequently led to incomplete work and negatively affected students' overall academic performance. Furthermore, evaluation tests often induced anxiety and nervousness among students, which contributed to scores falling below the average mark. When asked, students identified repetitive and unchanging teaching methods as primary reasons for their lack of interest, indicating that the monotony led to feelings of boredom.

The research also involved an in-depth analysis of the Kompetensi Dasar (KD) outlined in the standard science curriculum, which served as a foundation for developing an educational tool called "Weismann." Focusing on the concept of the Reproductive System in Plants and Animals for Grade 9, the analysis delineated several key competency indicators. These include:

1. Classifying angiosperm plants based on vegetative reproduction,
2. Interpreting the roles of different pollination intermediaries,
3. Describing various seed dispersal mechanisms,
4. Sequencing the life cycles of angiosperms, gymnosperms, ferns, and mosses,
5. Categorizing animals based on reproductive strategies,
6. Grouping animals by their life cycles,
7. Sequencing the life cycle of jellyfish, and
8. Identifying different types of reproductive technologies in both plants and animals.

This curriculum mapping ensures that the educational tool aligns with the competencies required for Grade 9 science, with a strong emphasis on visualization to aid students' comprehension of complex concepts.

Junior high school students, typically aged between 12 and 15 years, are in a developmental stage known as the formal operational phase, characterized by heightened emotional sensitivity and rapidly shifting enthusiasm for learning. According to Muhibbin (2007), these students require learning experiences that support critical thinking and cater to their emotional and cognitive development. They are drawn to vivid, harmoniously contrasting visuals and benefit from interactive and engaging learning methods. Given their psychological and cognitive profiles, this age group also thrives on having a degree of freedom and experience-based learning opportunities.

The Reproductive Systems chapter includes multiple life cycles—such as those of angiosperms, gymnosperms, ferns, and mosses—that are conceptually abstract and difficult to internalize through traditional verbal explanations. Incorporating visual aids into evaluation tools, such as diagrams and animations, can enhance students' understanding and retention. Visual content serves to create longer-lasting mental images, making complex information more accessible and memorable.

An analysis of students' needs and preferences provided crucial insights into designing an effective evaluation tool. Understanding the characteristics and interests of students highlighted the necessity for an engaging, game-based, and mobile-friendly evaluation format. Asyhar et al.

(2012) noted that students in this age group often prefer digital games, which informed the decision to create a mobile-based assessment tool. This approach capitalizes on students' enthusiasm for gaming and leverages it to increase motivation and improve academic performance.

Game-based evaluations have several advantages. According to Smaldino (2011), games are highly effective at capturing students' attention and fostering motivation, leading to the development of targeted skills in an engaging way. Additionally, the curriculum analysis and feedback from students indicated that traditional methods of quizzes and assignments were perceived as monotonous and abstract. Tools that integrate games and visual content can clarify and simplify complex scientific concepts, preventing overly verbal or text-heavy presentations and making learning more appealing (Arief & Sadiman, 2009).

2. Prototyping Stage

a. Self-Evaluation

Table 1 showed the self-evaluation result of the educational games product. There are only two aspect which does not meet the qualification, that are some errors of the part of the product and the display of the image and text on the product. Those parts are become suggestion to revising the product.

Table 1. Self-Evaluation Results

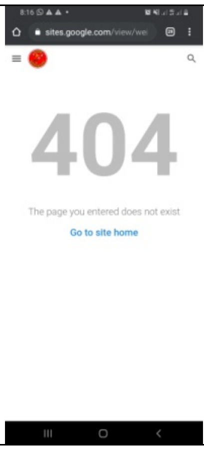
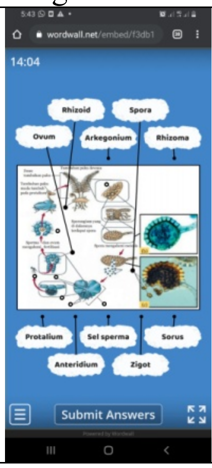
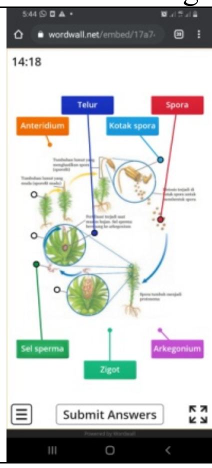
No	Statement	Evaluation	
		Yes	No
A	Navigation		
	1. There are guides	✓	
	2. Can be operated on all smartphone brands	✓	
	3. Button function works fine	✓	
	4. Consistent button placement	✓	
	5. Not easy to error		✓
B	Test Questions		
	1. The questions presented are in accordance with KD	✓	
	2. Questions are presented sequentially	✓	
	3. If there is a question that involves something abstract, then it is simulated with pictures and animation	✓	
	4. Game contains questions on essential concepts	✓	
	5. Questions tailored to the growth of students	✓	
C	Graphics		
	1. The animation is according to concepts of the breeding system in plants and animals.	✓	
	2. Images and text are correct and legible		✓
	3. Colour according to the characteristics of students	✓	
	4. Animation can run well	✓	
	5. Using communicative sentences	✓	

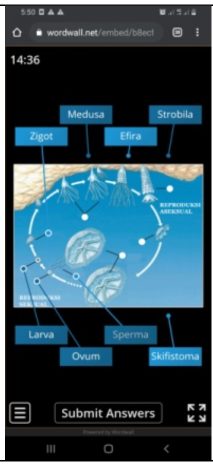
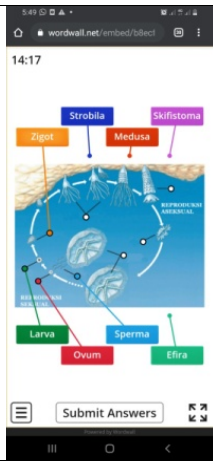
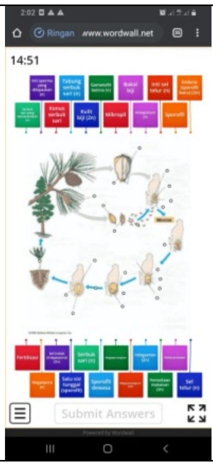
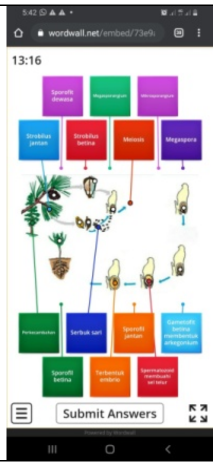
a. Expert Review

At this stage the educational game “Weismann” was tested and assessed by the experts. The product was validated by three experts who are competent in their fields. There are some errors on the product and the result of the test is in line with the result of the self-assessment process. So, the revision was conducted based on those test results.

The appearance of the product before and after revision is shown in table 2.

Table 2. Revision Result based on Expert Review

<table>
<tr><th>No</th><th>Before Revision</th><th>After Revision</th></tr>
<tr><td rowspan="2">1</td><td>
</td><td>
</td></tr>
<tr><td colspan="2">There was an error display when accessing the game on stage 10. This problem was because there was an error in entering the code, so it failed to run.</td></tr>
<tr><td rowspan="2">2</td><td>
</td><td>
</td></tr>
<tr><td colspan="2">Stage 10 was constantly displaying the loading icon. This results in the user not being able to start the game because it was only stuck until the initial loading.</td></tr>
<tr><td rowspan="2">3</td><td>
</td><td>
</td></tr>
<tr><td colspan="2">Stage 6, which had the same appearance as stage 5. This happened because of the wrong code entered. The code used to build stage 6 was copied from the previous code, which was stage 5.</td></tr>
</table>

4		
	Changing the background colour of the game on stage 9. This was because the initial design had the same colour as the drag line in the answer. It was feared that it could cause doubt for users.	
5		
	Enlarging the resolution of the stage 4 image. This was because the initial image had a blurry appearance.	

Besides testing the function of the product, the experts also do the validation of the product. The validation process used a questionnaire and consisted of three components: learning design (D), visual communication (K), and devices (P). The validation result of each aspect can be seen in figure 1.

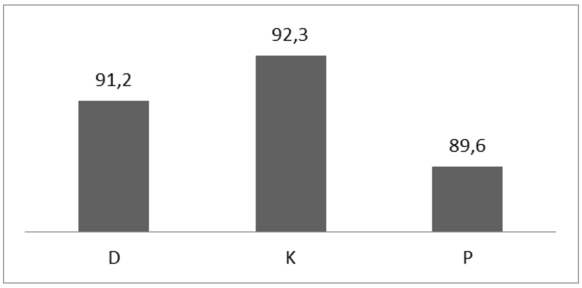


Figure 1. Result of Validity Assessment

The average score on the instructional design component was 91.2. This showed that its validity score was in the 'very good' category. An average score of 92.3 was obtained for the visual communication component. Similarly, this shows that the validity of the display component was in the 'very good' category. The last was the device component. If averaged, it had a score of 89.6. This shows the validity score of the system components was in the 'very good' category.

The results of the product validity assessment in the learning design aspect were included in the very valid category. Based on this, the game developed by the goals and learning indicators that had been set. In addition, the games developed could also measure the achievement of competence and were in accordance with the direction of learning. This game could make the evaluation process more interesting and interactive. Most importantly, the games developed were in accordance with students' ability level and could also train students to think fast, be creative, and work independently. Thus, based on the value obtained, it could be concluded that the product developed had met the valid criteria for the learning design aspect.

In the aspect of visual communication, product validity is in the very valid category. Based on this, it can be concluded that the language used in the game is easy to understand, the game contains good and correct language rules, the sentences are communicative, effective, and efficient, and the vocabulary used is correct. In addition, the images, layouts, menu designs, and animations used have been included in the good category. Based on the score, it can be concluded that the product developed has met the valid criteria in the aspect of visual communication.

In the aspect of the device, the validity of the product is included in the very valid category. Based on this, it can be concluded that the game does not make errors when played. The game can also run well even without certain applications.

Moreover, the game can be used on all smartphone brands and does not interfere with other systems on the smartphone used. In addition, the operation of the game is relatively easy and simple, can be used repeatedly, and does not require a large amount of RAM. Most importantly, the games developed have met the principle of originality.

The conclusion that can be drawn from the validator's validation of the three aspects of product validity is that the game developed is included in the valid category. Validation is the process of requesting approval or ratification of the suitability of the product developed so that the product developed is feasible and suitable for use in learning evaluation (Asyhar, 2012).

b. One-to-One Evaluation

The last part of prototyping stage is one-to-one evaluation. On this part the product was tested by random users. They give some suggestions for improving the user interface, accessibility, and the function of the product. The revision result based on the on-to-one evaluation process was shown on table 3.

Table 3 Revision Results based on One-to-One Evaluation

No	Before Revision	After Revision
1		
	There were too many buttons. The solution offered was to eliminate buttons that have dual functions, such as the back button, because it has the same function as the back button on the user's smartphone.	

		
2	Provide animation at the beginning, middle, and end of the game to raise interest and attention of the players.	
		
3	The background colour was too dark. The solution offered was to make animal and plant images into watermarks on several game pages to enhance visual appeal.	

3. Small Group Evaluation

Four junior high science teachers and 30 grade 9 students evaluated the practicality. Aspects of the assessment included usefulness (MA), ease of use (MD), attractiveness (KM), and clarity (KJ). From this assessment, the game products developed are included in the very practical category.

a) Practical Test Results by Teachers

The usefulness (MA) aspect received an average score of 95.5, indicating 'very good' category. For ease of use (MD) obtained a score of 93.3, while attractiveness (KM) had a score of 96.9. The clarity (KJ) component averaged 95.8. All placing them in the ‘very good’ category. The overall practicality of the educational game “Weismann” was determined by these four assessment components that had been analysed. The results of the practicality assessment by the teacher can be seen in figure 2.

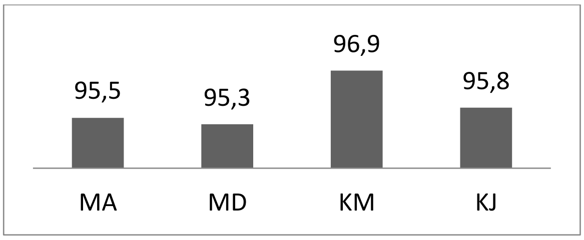


Figure 2. Practicality Assessment Result by Teachers

The average teacher practicality score was 95.9. This showed that the practicality score of using the educational game “Weismann” based on Google Sites was in the ‘very good’ category.

b) Practical Test Results by Students

The usefulness (MA) received an average score of 82.3, the ease of use (MD) component scored 84.8, attractiveness (KM) averaged 83.8, and clarity (KJ) received 86.7. All components were rated within the ‘very good' category. The practicality of the educational game "Weismann" could be obtained by determining the average of the four components that had been analysed. The results of the practicality score plot according to students can be seen in Figure 3.

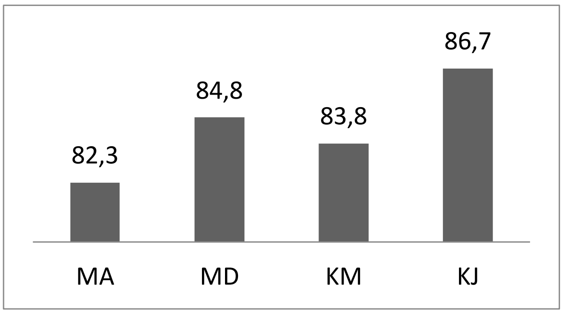


Figure 3. Components of Practicality Assessment by Teachers

The average score of students' practicality was 83.9. This showed that the practical score of the educational game "Weismann" based on Google-based was in the 'very good' category.

Based on the aspect of usefulness, both teachers and students consider this game can hone independence in learning. Because the game is designed for self-evaluation, teachers and students also strongly agree that this game can hone independence in learning and train users to think creatively. In addition, according to teachers and students, this game can also improve memory, boost thinking power, and train the mind to think quickly.

Based on the aspect of ease of use, if the product practicality assessment is carried out by teachers and students, there are no significant obstacles. The game can be run on each student's smartphone properly if there are no errors or stops suddenly. In addition, the game also has an uncomplicated display so that both teachers and students can play it easily even though it is their first time playing it.

This game is designed to be operated without an application, addressing a common issue among gadget users which is limited storage space for running applications. One of the criteria for a good learning media is that it be practical, flexible, and durable. This criterion requires the teacher to choose an existing media that is easy to obtain, can be used in all conditions, and is easy to carry everywhere (Asyhar, 2012).

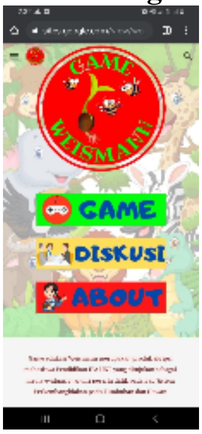
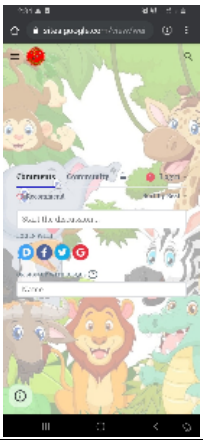
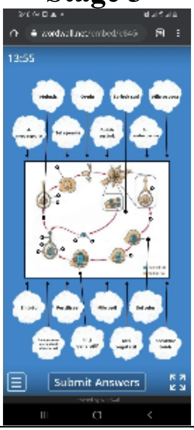
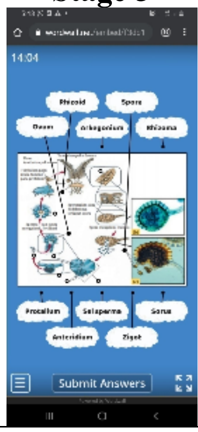
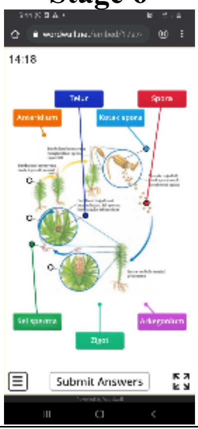
Based on the attractiveness aspect, the teacher and students said that the "Weismann" game has an attractive appearance and gameplay and stimulates students' interest in continuing playing. Students, as users, also admit that this game can foster their curiosity and interest in learning the concept of the breeding system in plants and animals. This can be seen from their enthusiasm when playing this game.

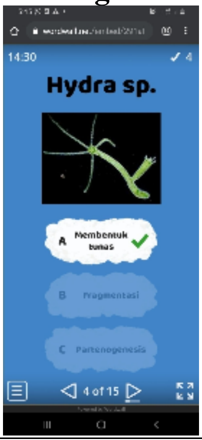
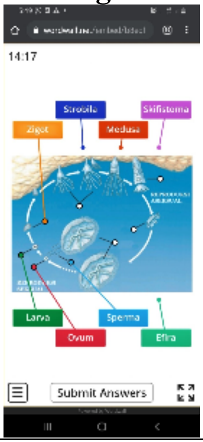
Based on the aspect of clarity, teachers and students stated that they could easily understand the flow of the game. This is because each stage provides game instructions. In addition, this game also contains images and high-quality animations. The conclusion that can be drawn from the user's assessment of the practicality of the product is that the games developed are included in the practical category.

4. The Final Product

Based on all of test, evaluation, and revision process, the product then reaches the final version that ready to be used in the learning process. The sample appearance of the final product can be seen in table 4.

Table 4. Appearance of Final Product

Home Page	Game Menu	Discussion Menu	About Game
			
Play and Guide	**Guide view**	**Stage 1**	**Stage 2**
			
Stage 3	**Stage 4**	**Stage 5**	**Stage 6**
			

Stage 7	Stage 8	Stage 9	Stage 10
			

Conclusion

The educational game "Weismann," designed based on an extensive analysis of student needs and the Grade 9 science curriculum, has been rated in the 'very good' category by both experts and users, confirming its effectiveness and validity for use in science learning. The game addresses significant issues identified with traditional assessments, such as a lack of student motivation and engagement due to repetitive methods that often resulted in incomplete assignments and lower scores. By incorporating interactive and visually appealing elements, "Weismann" makes complex concepts like plant and animal reproductive systems more accessible and engaging. The game aligns with *Kompetensi Dasar* (KD) standards, utilizing animations and pictorial aids to enhance understanding and retention. Moreover, its design caters to the developmental characteristics of junior high students, who benefit from game-like, digital learning experiences. This integration of educational content and engaging game mechanics ensures that the tool not only captures students' interest but also effectively supports their learning outcomes.

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ClassPoint to Classroom Learning Enhancement: An Interventional Tool Integrated in PowerPoint Presentations

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Abstract

This research investigated the effectiveness of interactive ClassPoint presentations in enhancing students' engagement and understanding of Science concepts in Grade 8. A quasi-experimental design with a quantitative follow-up survey was employed in this study. The participants were the 50 Grade 8 students who were divided into control and experimental groups, each comprising 25 learners. The control group was exposed to regularly-used teaching modalities,including PowerPoint presentations. Meanwhile, the experimental group was employed with ClassPoint presentations. A pre-test/post-test was used to measure effectiveness, and a survey questionnaire was used to gather students' feedback on ClassPoint. The gathered data was analysed using the Wilcoxon signed-rank test, Mann-Whitney U test, and Frequency distribution. Findings revealed that the utilisation of ClassPoint presentations has significantly improved the scores of the students and is a better teaching modality when compared to the other learning modalities used. In addition, over half of the students strongly agreed that ClassPoint has increased their motivation (64%) and their engagement in the class (56%). This feedback aligned with their strong agreement that lessons were lively and interesting (64%), andClassPoint's display slides helped them to focus and follow the teacher's presentation better (68%). Nearly half (48%) also found these activities helpful for self-reflection on their learning progress. These findings suggested that ClassPoint can be employed as an alternative learning strategy for Science 8.

Keywords: ClassPoint; Interactive Learning; Instructional Strategy

Introduction

Keeping students engaged in class can be a challenge. Traditional teaching methods, like lectures and slides, might not always capture their attention. This can lead to students feeling bored and having trouble understanding the material. To counter this, active teacher-student interactivity is essential.

Active student participation in the classroom is a strong indicator of learning progress. When students participate, they can build on what they know, show that they understand the material, gain confidence, and apply what they've learned (Susak, 2016). Many studies have shown that students who participate actively in class tend to do better in school. In the study of Konold, et al. (2018), where more than 60,000 students participated, they discovered that class participation had a significant impact on how well students learn. This was supported by Bekkering and Ward (2020) who concluded that students who participated more tended to have better scores. The research findings from Akpur (2021) also indicated that taking part in class activities is a significant variable in promoting academic achievement. All these studies highlight that when students engage, it positively influences their academic performance.

However, when face-to-face classes resumed after a two-year closure of schools, it was often observed that many students were hesitant to participate in class discussions. It was also noted that these students tended to score lower on assessments, which contributed tolowering the Mean Percentage Score (MPS) of the class. For the first and second quarters of school year 2022-2023, the average MPS in Science 8 for the two classes handled by one of the researchers was around 83%. The heterogeneous nature of the classes could have contributed to this situation since each class was composed of students with different learning styles, academic abilities, and socio-economic backgrounds. Other reasons that could have limited them from participating include fear, low self-confidence, and being unprepared. The students mentioned that they felt shy about participating because they were worried their answers might be wrong.

Given the pivotal role of Science in fostering essential skills like scientific inquiry, objectivity, curiosity, and critical thinking, which are crucial for personal, professional, and lifelong development (DOST-SEI, 2011), there is a need to enhance teaching strategies to improve students' participation and at the same time improve their academic performance. Enhancing teaching strategies can be achieved by integrating technology, such as using mobile phones through ClassPoint presentations, into Science lessons. Since mobile phones are now equipped with various functionalities, they can facilitate knowledge sharing, encourage interactive as well as participatory learning, and support both online and offline learning (Ananayo, 2022).

ClassPoint, integrated into Microsoft PowerPoint, transforms teaching by making learning interactive. With ClassPoint, advanced annotation and teaching tools could be used to highlight key points during live class presentations. Additionally, interactive activities and quizzes – such as quick poll, word cloud, multiple choice, short answer, image upload, fill in the blank, audio upload, video upload, and draggable objects – are integrated to make the class engaging. All of these activities can be included in any part of the lesson. Furthermore, a gamified reward system has been embedded to reward students for their participation through the awarding of stars, levels, badges, and leaderboards.

The use of ClassPoint presentations as a teaching approach aligns with the department's vision of holistically developing learners, utilising Information and Communication Technology (ICT) as a powerful tool in delivering curriculum content as well as employing differentiated approaches (DepEd Order No. 21, 2019). In addition, this strategy is anchored on the e-learning theory. This theory is built on cognitive science principles that demonstrate how the use and design of educational technology can enhance effective learning. These principles include: (1) Multimedia principle. It uses two formats of audio, visual, and text instead of using one; (2) Modality principle. It explains visual content with audio narration instead of on-screen text; and (3) Learner control principle. It allows the learner to control their learning pace (He, n. d. as cited in Ananayo, 2022).

While studies have explored the effectiveness of ClassPoint in online learning, its impact on face-to-face learning, particularly in Science, remains largely unexplored. Therefore, the researchers explored the impact of maximising the use of mobile phones through ClassPoint presentations to enhance students' participation and learning outcomes in a purely face-to-face classroom setting, specifically in Science.

Methodology

Research Design

This study employed a Quasi-experimental design with a quantitative follow-up survey utilising Likert scales. A quasi-experimental **design** is a type of research design that resembles an experimental design but lacks random assignment to treatment or control groups (Creswell & Creswell, 2017).

This type of design was chosen for the study because it was difficult to randomly assign participants to be part of the control and experimental groups. This is due to the fact thatthe two sections involved in this study were formed at the beginning of the school year and have different schedules for Science classes. Despite the situation, this design still allowed the researchers to investigate the effectiveness of the intervention (ClassPoint) in enhancing mastery and class participation as well as establishes a cause-and-effect relationship between the intervention and learning outcomes.

Participants

The participants in this study were the students enrolled in Grade 8 Sapphire and Amethyst classes at San Antonio Integrated School in Diffun, Quirino, Philippines, during the 2022-2023 school year, when classes returned to in-person learning. The study utilised the total enumeration technique, also known as universal sampling, a type of purposive sampling technique that involves selecting every single member of a defined population for inclusion in a study (as defined by Australian Bureau of Statistics, n.d.). Through this sampling technique, all the students from the two sections were taken as respondents. The researchers preferred to use this technique in selecting respondents due to the small population of Grade 8 and because they are currently handled by one of the researchers. The researchers believed that the students could provide valuable information for testing the research hypothesis.

The two sections were both composed of students who possess and do not possess mobile phones. To ensure equivalence between the experimental as well as the control group and to eliminate other factors that might affect the validity of research results, their General Weighted Average (GWA) for the first and second quarters were considered. The two groups have almost the same quarterly GWA based on the teacher's class record. The control group and experimental group were identified after the administration and analysis of the pre-test.

Instrument

The test questions were adapted from DepEd textbooks and modules aligned with the competencies. Science experts assessed the tool's validity, resulting in an Individual Content Validity Index of 0.93, indicating strong validity. A grammarian also reviewed the instrument for grammatical accuracy. After revising items with low validity scores, the instrument was pilot-tested with a Grade 8 class from Cabarroguis National School of Arts and Trades, achieving a Cronbach's Alpha of 0.85, indicating good reliability.

Data Collection

Before the study was conducted, approval was sought from the school head, district, division and regional leaders. Then, the researchers ensured consent from the parents for the participation of the students in the study. After which, the learners were oriented. A pre-test was administered to both the control and experimental groups to assess their initial ability and identify any potential confounding variables that might affect the objectivity of the study. After the conduct of the pre-test, ClassPoint was applied to the experimental group. At the same time, regularly-used modalities, including PowerPoint presentations, were employed in the control group during the given period for Science 8. This setup took place for the whole three weeks duration of the implementation of the intervention. Two weeks after the intervention period, all learners were subjected to a post-test to find out if there is a significant change in their scores.

A post-experiment survey using Likert scales was also conducted to gather students' feedback on the intervention. This method was applied in this study to describe the students' perception on the intervention and provide valuable insights into their experiences. The learners from the experimental group answered a survey questionnaire adapted from the study of Bong & Chatterjee (2022), which was slightly revised to suit the needs of this study. The five-statement survey employed a four-point Likert scale to quantify student perceptions.

Results and Discussion

The data distribution was first assessed for normality using the Shapiro-Wilk test with a significance level of 0.05 (Van den Berg, n. d.).

Table 1. Result of Data Normality Test

	Group	df	p-value	Analysis
Pre-test	Control	25	.041	Not normally distributed
	Experimental	25	.042	
Post-test	Control	25	.008	
	Experimental	25	.000	

Examining the table revealed that in the pre-test, the control group had a Sig. value of .041 whereas the experimental group obtained .042. In the post-test, the control group achieved a Sig. value of .008, while the experimental group obtained .000. These findings indicated that the data from both the control and experimental groups, in terms of pre-test and post-test scores, do not exhibit a normal distribution.

Table 2. Mann-Whitney U Test for the pre-test

	N	Median	Mann-Whitney U	Z	p-value	Interpretation
Control	25	10	298.500	.274	.784	Not Significant
Experimental	25	10				

α = .05

The results of the pre-test showed no statistically significant difference (Z=.274, p=.784) between the average initial ability of the students in the control and experimental groups. This suggests that the two groups were comparable in terms of their cognitive level before the intervention, making them suitable for comparison after the ClassPoint implementation.

Table 3. Significant difference between the pre-test and post-test scores of students in each group

Group	N	Mean Rank	Sum of Ranks	Z value	p-value	Interpretation	Effect Size (r)
Control Group							
Pre-test	25	13.00	325.00	4.376	.000	Significant	0.618 (large)
Post-test	25						
Experimental Group							
Pre-test	25	13.00	325.00	4.377	.000	Significant	0.619 (large)
Post-test	25						

r: small effect (<0.3), medium effect (0.3-0.5), large effect (>0.5) *α =.05*

Table 3 presented the results of the Wilcoxon signed-rank test, examining the significant differences between the pre-test and post-test scores among students in each group. In the control group, a Z-value of 4.376 and a p-value of .000 indicated a statistically significant difference, with the post-test scores exceeding the pre-test scores (as implied by the positive Z-value). Furthermore, the r value of 0.618 indicated a large effect size, suggesting that the use of PowerPoint and other regularlyused teaching methods had a substantial impact on learning outcomes. The combination of PowerPoint presentations and other traditional teaching methods, such as class discussions, proved to be an effective approach in enhancing student understanding. This result is consistent with the study by Shigli, et al. (2016) who concluded that PowerPoint presentation is an effective tool for improving knowledge regarding gerontology. This observation also aligns with the findings of Hadiyanti and Widya (2018), who emphasized that students perceived PowerPoint presentations as advantageous for learning and understanding lessons due to their structured format, and focus-retaining features. However, Hadiyanti and Widya (2018) also found that some students were not motivated to attend classes with PowerPoint presentations, as it made them feel bored and did not allow them to participate in classroom discussions.

For the experimental group, the Wilcoxon signed-rank test also indicated a statistically significant difference between the pretest and posttest scores (Z = 4.377, p = .000). The effect size was large (r = 0.619), suggesting that ClassPoint has a great impact also on learning outcomes, reflecting its effectiveness in enhancing student performance. This result supports the findings of Yusi (2023) who concluded that ClassPoint has a positive effect on students' performance, as it increased their achievements on the mathematics test.

Table 4. Significant difference between the posttest scores of students from the experimental and control groups

	N	Median	Mann-Whitney U	Z	p-value	Interpretation	Effect size (r)
Control	25	36	198.500	2.151	.026	Significant	0.315 (medium)
Experimental	25	39					

r: small effect (<0.3), medium effect (0.3-0.5), large effect (>0.5) *α =.05*

The Mann-Whitney U test was used to compare the scores of the students who were exposed to ClassPoint (experimental) and those who were exposed to regularlyused teaching method (control). The experimental group exhibited a higher median score of 39 compared to the control group (Mdn=36). The statistical analysis also revealed a significant difference between the two groups (Z=2.151, p=.026). These results suggest that the experimental group performed better than the control group and that it could be attributed to the intervention used. Moreover, the effect size (r=0.315) was determined to be of medium magnitude, which means that the difference between the two groups is not small, but it is not large either. This indicates that ClassPoint has a moderate impact on student performance compared to the regularlyused teaching methods.

The superiority of ClassPoint over PowerPoint and other teaching methods used when it comes to enhancing student performance could be due to the interactive and gamified features of ClassPoint which is absent in a mere PowerPoint presentation. As studies have proven, the integration of interactive activities (Yusuf, 2015; Mallari & Lumanog, 2020) and gamified features (Ng & Lo, 2022) into instruction could significantly improve students' academic performance. This could be because employing interactive tools and technologies promotes participation and inclusive learning, resulting in enhanced student engagement and interest during classroom activities (Ullah & Anwar, 2020). Furthermore, Nasu and Alfonso (2018) highlight that interactive game-based activities not only reduce boredom but also facilitate active learning, leading to better retention and understanding of material. However, Phungphai and Boonmoh (2021) concluded that implementing rewards can serve as positive reinforcement to encourage students' desire to learn. When Leftheriotis et al. (2017) explored the potential of gamified interactive display technology to enhance knowledge consolidation and student engagement, their findings revealed that incorporating gamified interactive display applications into learning activities can effectively support the learning process because students found the game enjoyable, making them participated actively. Additionally, the students performed significantly better on a cognitive test administered after playing the game.

Table 5. Students' Perception of Learning Experiences with ClassPoint

Statements	Frequency/Percentage			
	Strongly Disagree	Disagree	Agree	Strongly Agree
I experienced greater interaction and engagement with my peers and my teacher when ClassPoint was used in the class.	0/0	2 / 8%	9 / 36%	14 / 56%
The ClassPoint has motivated me to participate in the activities more often in the class.	2 / 8%	0/0	7 / 28%	16 / 64%
The interactive activities in ClassPoint helped me to self-evaluate how well I was learning during classes.	2 / 8%	0/0	11 / 44%	12 / 48%
The lessons are lively and interesting when my teacher runs the class using ClassPoint than a class without the use of ClassPoint.	0/0	0/0	9 / 36%	16/ 64%
ClassPoint's display slide allows me to follow along and pay more attention to the teacher's presentation.	0/0	0/0	8 / 32%	17 / 68%

N=25

A survey of 25 students from the experimental group revealed positive feedback about ClassPoint's impact on learning. Over half (56%) strongly agreed that they found the lessons more engaging and interactive, with 64% reported increased motivation to participate due to ClassPoint's engaging activities. Nearly half (48%) found these activities helpful for self-reflection on their learning progress, and 64% found the lessons lively and interesting. Notably, 68% felt ClassPoint's display slide helped them focus and follow the teacher's presentation better. These feedback suggest that ClassPoint has the potential to significantly enhance students' engagement, self-evaluation, and focus in the classroom.

One factor that could have contributed to the notable engagement of students during classes with ClassPoint is the anonymity feature during interactive sessions. This sense of anonymity, wherein students can actively participate without revealing their identity, serves to boost their confidence. Students may feel more at ease expressing their thoughts, contributing answers, and engaging in class activities, as they are free from concerns about potential judgment and embarrassment. They could actively participate without the fear of being ridiculed for giving incorrect answers. This is supported by Stanley (2021), who mentioned that anonymous platforms can boost student confidence, engagement, and inclusivity.

Conclusion

The scores of the group employed with ClassPoint and the group without ClassPoint increased significantly after the implementation, demonstrating effectiveness of both strategies in enhancing learning outcomes in Science 8. However, ClassPoint is superior or better compared to other modalities used when it comes to enhancing students' academic performance. This advantage of ClassPoint is not solely reflected in scores. Over half of the students strongly agreed that ClassPoint has enhanced their engagement and focus on the classroom, while almost half strongly agreed that ClassPoint has enhanced their self-evaluation. Over half also strongly agreed that lessons are lively and interesting with ClassPoint and that it has motivated them to participate more often in the class. These positive student perceptions further underscore the effectiveness of ClassPoint in fostering a more enriching and impactful learning environment.

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Analysing a Chemistry Lesson on Ionic Bonding: Insights from a Learning Study

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Abstract

The aim of this paper is to report the insights gained from analysing an online Chemistry lesson on ionic bonding as part of a learning study conducted during the COVID-19 pandemic in 2021. The lesson was collaboratively developed by a group of seven high school Science teachers supported by two facilitators. Data collected includes the lesson plan, the transcript from the virtual lesson, and teacher reports. Insights were drawn from each phase of the learning study cycle – Study, Plan, Teach, Reflect. In the Study phase, the teachers came up with several presumed critical aspects based on responses to a two-part pre-test. In the Planning phase, a pattern of variation was used. In the online Teaching phase, we found potential critical aspects emerged when the students interacted with the object of learning, but this was not picked up by the teacher. The critical aspects identified from the learners' point of view include the number of shells for each atom and the number of electrons in each shell. In the Reflect phase, we consider the role of facilitators in guiding the lesson to focus on the discernment of critical aspects. The insights gained can potentially support teachers on how to plan and analyse lessons using the variation theory of learning, particularly in the context of online teaching.

Keywords: Chemistry; Ionic Bonding; Lesson Study; Research Lesson; Variation Theory; Online Teaching

Introduction

This paper reports on insights gained from analysing an online Chemistry lesson on ionic bonding as part of a learning study conducted during the COVID-19 pandemic in 2021. Ionic bonding was identified by the teacher group as one of the top three most difficult topics to teach and learn in Chemistry. Chemistry is one of three components in the Combined Science subject (subject code 5129), alongside Biology and Physics. Combined Science is studied by all Brunei senior secondary students who do not qualify for the pure science stream. These students sit for the externally assessed Ordinary Level examination in Year 11, at the age of 16-17 years.

Learning Study is derived from Lesson Study, a form of collaborative, practice-based professional learning that originated in Japan, that consists of cycles of experimentation and reflection on classroom instruction (Lewis *et al*, 2022). Like Lesson Study, Learning Study follows the "Study-Plan-Teach-Reflect" process, but with a key difference: it incorporates an explicit theory of learning in the design of teaching. According to Wood and Sithamparam (2021), being explicit about theory retains the potential to transform teacher education and professional development. In a learning study, the focus is on an object of learning, defined by Marton and Pang (2006) in their seminal work as a specific insight or skill that teachers wish to develop in students over a period or sequence of periods. The object of learning has two aspects: the direct and indirect objects of learning. The direct object of learning refers to the content while the indirect object of learning refers to the capability of using that content.

In analysing teaching and learning, it is important to differentiate between the intended, enacted, and lived objects of learning. The intended object of learning refers to what is planned, as outlined in the lesson plan. The plan details the sequence of activities designed to help students discern the critical aspects of the object of learning, which are typically identified through carefully crafted pre-tests or interviews. The enacted object of learning refers to what students can potentially learn in the classroom through the pattern of variation and invariance that was constituted jointly by both the teacher and the students. In other words, what varies and what remains constant in the lesson both constrains and enables learning. The lived object of learning refers to what is learnt. For example, what students learn depends on what aspects they discern and what dimensions of variation are made explicit during the teaching.

In addition to the concept of the object of learning, the concept of critical aspects is also synonymous with learning study and variation theory. Pang and Ki (2016) argue that critical aspects are not necessarily the things that students most often get wrong, overlook or forget. They assert that critical aspects should be defined from the learner's alternative ways of experiencing the object of learning and not necessarily based on the subject discipline or curriculum. Thorsten and Tvarana (2023) identified five different conceptions of critical aspects in their study. The highest conception is one in which critical aspects are seen as focal points for teaching the object of learning. They focus on what students need to discern in order to experience the object of learning in a certain way. The critical aspects are discerned as a specified description of the object of learning that can be the base for teaching it.

As facilitators, we used the lesson study variant called the learning study (Marton and Pang, 2006) as the professional development approach to support the Combined Science teachers. In a learning study, teachers focus on an object of learning and use the variation theory of learning to plan and analyse lessons to enable students to discern critical aspects (Kullberg et al, 2024). Previous studies on the use of variation theory in Chemistry can be found in the works of Vikstrom et al (2013) where for example, in analysing enacted patterns of variation, a frequently asked question was: What was possible for the students to discern and learn, and what was not?

Bergqvist and Chang Rundgren (2017) reported a list of students' alternative conceptions of, and difficulties understanding chemical bonding. These include:

- the use of the octet rule,
- focus on electronic configurations,
- lack of explanations for why bonding occurs and failure to explain that chemical bonds are due to electrostatic forces.

Thus, this study seeks to explore and answer the following question: What insights are gained from the four phases of learning study: Study, Plan, Teach, Reflect?

Methodology

A learning study essentially conducts "Study-Plan-Teach-Reflect" focusing on an object of learning as the point of departure. The first cycle of the learning study, which is the focus of this paper, consists of five meetings and one research lesson as shown in Table 1.

Table 1. Schedule and tasks for the learning study

Session	Phase	Tasks
#1	Study	Introduction to the PD. Selecting a topic for study. Identify tentative object of learning. Setting the pre-test.
#2	Study	Diagnose students' learning difficulties. Confirm the object of learning and its critical aspects.
#3	Plan	Plan the research lesson.
#4	Plan	Plan the research lesson (continued)
School-based	Teach	Research lesson in school (online).
#5	Reflect	Evaluation of learning outcomes.

The participants in this study came from five different schools across Brunei Darussalam. Through our experience as facilitators, we observed that guiding teacher groups to focus on the object of learning and designing lessons around critical aspects can foster a rich environment for systematic teacher action research, such as Learning Study.

Data collected for this research included the collaboratively developed lesson plan and the transcription of the online research lesson, which was conducted via Microsoft Teams. The steps involved in our analysis were as follows:

1. Downloading the video of the lesson from Microsoft Teams.
2. Transcribing the lesson.
3. Preparing an analysis template, consisting of three columns: time during lesson, description of activity and analysis
4. Conducting independent analyses of the lesson and sharing these findings with one another.
5. Watching video of the lesson together, pausing at key points of the video to consider what we saw from the enactment.

These methods provided a comprehensive understanding of how the lesson was delivered and where critical aspects were addressed.

Results and Discussion

The Study Phase

In this phase we present the outcomes of the pre-test analysis and discuss the possible critical aspects of learning ionic bonding. The pre-test question is as follows:

> The pre-test:
> (a) Describe the formation of ionic bonds in NaCl and $MgCl_2$.
> (b) Use cross and dot diagrams for the formation of ionic bonds in NaCl and $MgCl_2$.

Table 2 outlines suggested answers from the teachers' point of view. Note that these are in the terminology used by Thorsten and Tvarana (2023, p5) on "presumed critical aspects", based on teachers' disciplinary and curriculum knowledge as well as their knowledge and familiarity of content and students.

Table 2. Answer rubric for the pre-test question

Level	(a) Describe the formation of ionic bonds in NaCl and $MgCl_2$.	(b) Use cross and dot diagrams for the formation of ionic bonds in NaCl and $MgCl_2$.
1	Incorrect answer	Incorrect answer
2	Partially correct answer that states: 1) electron transfer from Na atom to Cl atom (for NaCl) and Mg atom to Cl atoms (for $MgCl_2$); 2) full 8 e^- in valence shell (stable); 3) NaCl: Na atom lost 1 e^- to form Na^+ ion while Cl atom gains 1 e^- to form Cl^- ion and $MgCl_2$: Mg atom lost 2 e^- to form Mg^{2+} ion while 2 Cl atoms gain 1 e^- each to form 2 Cl^- ions;	Partially correct answer that shows at least 3 out of 5 points listed below.
3	Fully correct answer that states ALL of these points: 1) ionic bonds formed between metal and non-metal; 2) electron transfer from Na atom to Cl atom (for NaCl) and Mg atom to Cl atoms (for $MgCl_2$); 3) full 8 e^- in valence shell (stable); 4) NaCl: Na atom lost 1 e^- to form Na^+ ion while Cl atom gains 1 e^- to form Cl^- ion and $MgCl_2$: Mg atom lost 2 e^- to form Mg^{2+} ion while 2 Cl atoms gain 1 e^- each to form 2 Cl^- ions; 5) strong force of attraction between the oppositely charged ions formed the ionic bond.	Fully correct answer that shows: 1) a dot is used to show e^- in one atom while a cross is used in the other atom; 2) correct number of e^- in the shells of both atoms; 3) correct electronic configurations before and after ionic bond is formed; 4) correct arrow(s) from metal to non-metal atoms; 5) square brackets drawn with correct numerical charges at top right of the bracket for ions.

There are three different levels of understanding for each part question, with level 1 as the lowest and level 3 as the highest. For part (a), five critical aspects related to ionic bonding were identified:

1) ionic bonds formed between metal and non-metal;
2) electron transfer;
3) full 8 electrons in valence shell;
4) loss and gain of electrons to form ions;
5) electrostatic force of attraction between oppositely charged ions.

For part (b), the five critical aspects are:

1) the proper use of dot and cross on atoms;
2) correct number of electrons in the shells of both atoms;
3) correct electronic configurations before and after ionic bonds is formed;
4) correct arrow(s) from metal to non-metal atoms;

square brackets with correct numerical charges.

The Plan Phase

The planning incorporated a sequence of patterns of variation, particularly in the ratio of metal to non-metal in ionic bonding. For example, lithium fluoride (LiF) forms when a lithium atom donates one electron to a fluorine atom, allowing lithium to achieve the electronic configuration of the noble gas helium. Similarly, calcium fluoride (CaF_2) is formed when calcium transfers two electrons to fluorine, resulting in calcium achieving the electronic configuration of the noble gas neon. In this design, the non-metal (fluorine) was kept constant,

The Task
Describe and draw the formation of ionic bonding for lithium fluoride (LiF), calcium fluoride (CaF_2) and an unknown compound X_2Y.

while the metal element was varied from lithium to calcium, in terms of the number of outermost electrons donated to fluorine. Prior to the first research lesson, the group decided to develop asynchronous learning materials that students could access and interact with at their own pace. These materials included two videos explaining ionic bonding and a collaborative task for students to complete with their peers.

During the research lesson, students were expected to present their answers, while the teacher's role was to probe gaps in the students' understanding and clarify any misconceptions.

The Teach Phase

Potential critical aspects not picked up by the teacher

In the research lesson the teacher covered four out of the five critical aspects of the object of learning ionic bonding formation. The aspect that was not covered was the electrostatic force of attraction between oppositely charged ions. Interestingly, a critical aspect that had not been anticipated emerged during the lesson, reflecting the dynamic nature of teaching, as described by Lo (2012): "Critical features cannot be uncovered in pre-lesson interviews (or pre-test) but only emerge when the students interact with the object of learning during the lesson" (p. 78).

Below is an extract from the lesson that illustrates the unfolding of this unexpected aspect.

Teacher: *"So how many electrons are there in lithium and fluorine? You can check this from your Periodic Table."*

Teacher typed the question on chat box in Teams: *"How many electrons are there in Li and F? How are they arranged in their shell?"*

Student: *"Lithium have 3 electrons. And fluorine there is 9 electrons. The electrons are arranged with 2 in the first shell and the rest 8 all above."*

Teacher: *"Ok just to clarify that it's actually for other shell it would be 8 electrons. Ok so how many electrons are there in lithium, the outer shell of lithium?"*

SILENCE

Teacher: *"How many electrons are there in the outer shell of lithium and how many in fluorine?"*

SILENCE

Student: *"Lithium have 2, 8, 3."*

Teacher: *"Yes, lithium has got 3 in total but how about the outermost shell?"*

Student: *"Only 2 electrons."*

Teacher: "Only 2?"

SILENCE

Student: *"1 only Teacher. 1."*

Teacher: *"Ok lithium has got 1 and fluorine has got?"*

Student: *"7"*

Teacher: *"7. Ok so in this case lithium will transfer one electron to fluorine."*

In this interaction, the student struggled with the correct electronic configuration. The student initially implied that lithium has three shells and incorrectly identified the configuration as 2, 8, 3 instead of the correct electronic configuration, 2, 1. This demonstrated a misunderstanding about how electrons are arranged in different shells and the concept that each shell can hold a certain number of electrons.

To clarify:

- **Lithium** has 3 electrons, with a configuration of **2, 1** (2 in the first shell, 1 in the second).

- **Fluorine** has 9 electrons, with a configuration of **2, 7** (2 in the first shell, 7 in the second).

This misunderstanding highlights a critical aspect that was not fully discerned: the number of shells for each atom, the number of electrons in each shell, the arrangement of electrons across different shells and the rule that shells must be filled sequentially. The general rule is that the innermost shell is filled first. This shell can contain a maximum of two electrons. The second shell can hold a maximum of eight electrons, and when this shell is filled, electrons will go into the third shell, which also holds a maximum of eight electrons. Then, the fourth shell begins to fill.

In another part of the discourse, the class was asked to predict the elements in the ionic compound X_2Y with atomic numbers of X and Y given as 11 and 8, respectively. A student incorrectly identified X as hydrogen because the diagram only showed one electron in the outer shell (Figure 1). Although the electronic configuration was written as 2, 8, 1, only one shell was shown. It is not clear if the student who wrote this is aware of the existence of three shells in X and that the electrons are placed from the inside out. The first two electrons are in the first shell, the next eight electrons are in the second shell and the last one electron is in the third shell, which is the outermost shell for X.

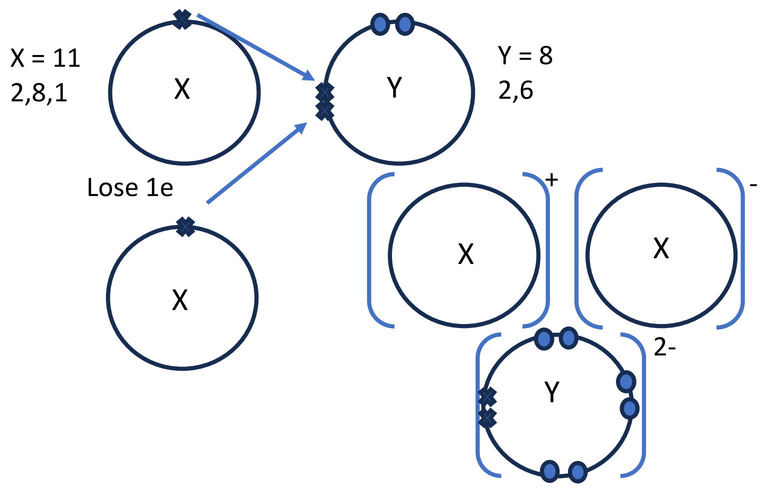

Figure 1. A group's drawing of an ionic bond formation (redrawn for clarity)

Below is the extract:

Teacher: *"Maybe you can have a guess on what is X and what is Y? On the Periodic Table."*

Student: *"Hydrogen, Teacher."*

Teacher: *"Hydrogen. Which one is hydrogen?"*

Student: *"X."*

Teacher: *"Hydrogen. Why do you think it is hydrogen?"*

Student: *"Because have only one electron."*

Teacher: *"Hmmm, if it is only 1 electron, it will be hydrogen. In this case, X has 11 electrons. So, it is stated in the question X has 11 electrons."*

At this point, another student correctly identified X as sodium and Y as oxygen. The teacher was satisfied with this correct response but missed the opportunity to address the confusion about X being hydrogen. It was only after a facilitator alerted the teacher that the teacher revisited the issue.

Teacher: *"Someone said X could be hydrogen just now. So, there might be some* *confusion here because if you look at the drawing here, there is only 1 electron on X. Ok, so you might think this is the hydrogen but what is happening here actually these two students are drawing only the valence shells. Ok so, this is the most outermost shell 2,8,1. The outermost shell has only 1 electron. But it doesn't mean that this atom has got 1 electron only. Ok? So, if you draw, everything, it will be three shells originally. It is my bad that I didn't tell you to draw full shells at first."*

The teacher made the number of electron shells for element X explicit, which was a critical aspect for students who had not yet discerned this concept. This clarification is essential because identifying an element cannot be based solely on just the number of electrons in its valence shell. Students must also discern the total number of electron shells for each atom. The students' drawings in Figure 1 further suggest that depicting only the valence shell may be insufficient. We tentatively conclude here that it is critical to draw the electron shells in full and show how the electrons are arranged when illustrating ionic bonding. Drawing only the valence shell or outermost shell can lead students to conclude the wrong identity of the element.

The role of the facilitators

Facilitators played a crucial role during the research lesson, offering guidance to the teacher via WhatsApp when potential gaps in student understanding emerged. During the research lesson, the facilitators prompted the teacher at least twice through WhatsApp to consider what the students were trying to say. In the previous instance, we shared one example of the facilitator prompting the teacher to explore why a student believed X to be hydrogen, leading to a valuable clarification on electronic configuration and shell arrangement.

In this second example, following a prompt from the facilitators, the teacher referred to a student's answer and asked:

"As we can see from your diagram, so what happen here is calcium, the electronic configuration is 2, 8, 8, 2 and you said from what I understand here, 2 of these electrons are transferred to fluorine. One each to each one, right? Why is the calcium transferring the electrons away? Why is Ca losing 2 electrons? Why is F gaining 1 electron?"

A student responded in the chat box. The teacher read out the answer.

"Fluorine becoming a full shell."

"Only 1 electron."

The student's answer was correct. The teacher then raised a question which was open to all students. It appeared to be a good question, a question of contrast, and it seemed to have been prompted by the discussion so far.

"Why does Li lose only 1 electron, but Ca loses 2 electrons?"

The teacher showed two groups' answers on the screen (Figure 2). This was not in the lesson plan but rather impromptu. It appeared to motivate some students to respond.

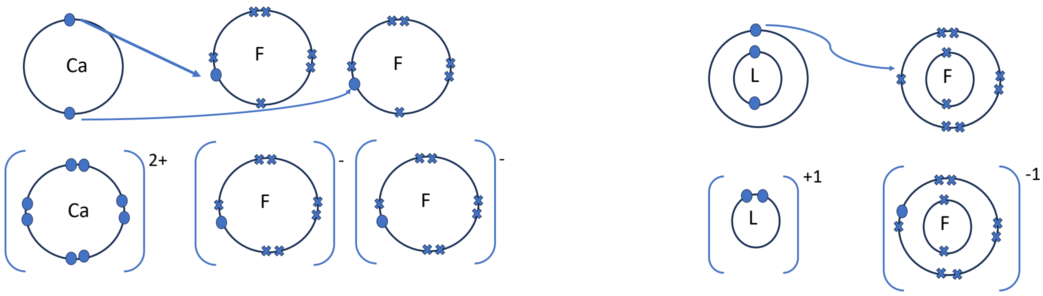

Figure 2. Two groups' drawings of ionic bond formation for CaF_2 and LiF

"So, one of you said just now said fluorine is gaining 1 electron to have full electron shell. Then what is the purpose of calcium and lithium losing electrons?" A student replied:

"Because lithium to make the shell full … Lithium have 2, 1 electrons. That's why he lose one electron – to make the shell full."

The teacher asked:

"How about calcium?"

A student said:

"Calcium is 2, 8, 2 then he must lose 2 electrons to make the shell full."

Here the student's response was missing one part of the shell. However, losing 2 electrons is correct hence the teacher helped clarify the concept:

The teacher continued:

"Ok. That's good. Let me rephrase. Lithium as one of you has said has got the configuration of 2, 1 so it removes 1. Whereas calcium has 2, 8, 8, 2, it removes 2. Ok so when that happens, we say they have full shell so that's good."

This part of the lesson demonstrated the teacher's ability to foster deeper student understanding, driven by facilitators' interventions. Additionally, the use of students' diagrams to visualise the contrasting behaviours of lithium and calcium in ionic bonding was highly effective.

The Reflect Phase

The research team noted a significant challenge in student participation, as only four out of nineteen students attended the online lesson. Of those who attended, one student demonstrated a more advanced understanding of ionic bonding concepts. The teacher facilitating the lesson also reflected that the asynchronous part of the lesson did not work as well as intended. It appeared that students struggled in engaging with their peers to complete the asynchronous tasks assigned to them. They were also unfamiliar with engaging in peer discussions in an online environment. According to the teacher, the students may need more guidance on how to lead and participate in peer discussions.

More critically, the facilitators identified two new critical aspects of student learning during the lesson that had not been captured in the initial lesson design or reported in existing literature. The teachers' presumed critical aspects, while necessary, were insufficient to address the real gaps in student understanding. The critical aspects identified during the lesson include the number of electron shells for each atom and the arrangement of electrons within these shells. Through student dialogue, it became clear that focusing solely on the valence shell—the outermost shell of an atom—was misleading for some learners. Instead, drawing the full arrangement of electron shells proved vital for helping students accurately discern the structure of atoms involved in ionic bonding. These aspects are critical for these learners and may not be critical for other learners.

The facilitators also reflected on the value of learning from students' alternative conceptions. Identifying what students have not yet discerned is just as informative as understanding what they do know. In this case, alternative conceptions about atomic structure were not anticipated in the pre-lesson phase but became clear through student responses. These unanticipated critical aspects serve as powerful teaching moments, offering educators the opportunity to reshape their strategies in real time to better meet the students' needs.

Discussion

The learning study reported in this paper provides further evidence of the usefulness of the variation theory of learning to plan and analyse lessons (Kullberg et al, 2024). Through the lens of variation theory, the critical aspects of the object of learning were identified from the lesson transcript, focusing on the number of electrons in each shell and the number of shells for each atom.

These critical aspects, as far as we are aware, have not been previously reported in the literature, making them noteworthy discoveries from the learners' perspective in this study. They are students' alternative ways of experiencing the object of learning.

Pang and Ki (2016) argue alternative ways of experiencing the object of learning have to be considered and addressed during the teaching. The timely intervention by the facilitators during the lesson was crucial in enabling the teacher to recognise and address these alternative perspectives. This allowed for an in-the-moment adjustment of the teaching approach to better meet the students' needs. However, it is important to acknowledge that we do not have sufficient data to confirm whether the learners fully grasped the critical aspects at the end of the lesson. Facilitator interventions during a learning study are rarely reported in the literature. However, we argue that the purpose of a research lesson is to help learners discern the critical aspects and if these can be done during the lesson through a gentle nudge, it provides the opportunity for reflection-in-action (Schon, 1983).

In future studies, the findings from this lesson could inform a more systematic approach, particularly in teaching ionic bonding. For instance, showing the full electronic configuration of each element—not just the outer shell—could provide a clearer foundation for students to understand how bonds are formed. A more structured exploration of electron shells and their arrangement might address the alternative conceptions observed in this study, which students struggled to fully discern the nature of ionic bonding by focusing solely on valence electrons.

It is important to acknowledge the limitations of this study, particularly in relation to student participation during the COVID-19 pandemic. Only four out of nineteen students attended the lesson online, significantly reducing the sample size and, consequently, the breadth of data available for analysis. Additionally, the asynchronous learning activity did not work as effectively as intended. According to the teacher, this was largely due to students being unfamiliar with leading and participating in online discussions.

Conclusion

This study seeks to find out the insights gained from the four phases of a learning study on ionic bonding. In the Study phase, teachers initially identified presumed critical aspects based on their analysis of a two-part pre-test question. These aspects guided the lesson planning, but did not fully align with what students ultimately needed to discern. During the Planning phase, a pattern of variation was carefully designed to bring out these aspects. In the Teaching phase, potential critical aspects emerged as students engaged with the object of learning, but this was not picked up by the teacher. The critical aspects identified from the learners' point of view include the number of shells for each atom and the number of electrons in each shell—key concepts that the students struggled to grasp. In the Reflect phase, the role of facilitators in guiding the teacher to focus on the discernment of critical aspects was essential. The presumed critical aspects identified by teachers at the outset differed from those that arose from the learners' actual experiences. This discrepancy underscores the importance of addressing students' alternative conceptions during teaching and adapting instructional strategies accordingly. The study also emphasised the significance of facilitator interventions during the lesson. Facilitators provided timely nudges to help the teacher notice and address students' alternative conceptions, allowing for reflection-in-action. This approach is not commonly reported in research studies but proved to be a valuable part of the learning process here.

In conclusion, this learning study not only affirms the usefulness of variation theory in both lesson planning and analysis but also highlights the need for flexibility in teaching to accommodate learners' diverse perspectives. While challenges such as limited student attendance due to the COVID-19 pandemic affected the overall outcome, the findings suggest that future lessons could benefit from a more explicit focus on critical aspects like the full electronic configuration of atoms, rather than just the outer shell. By recognising and addressing students' alternative conceptions, teachers can enhance understanding and support deeper learning. Further research is needed to assess the long-term impact of such strategies and to refine approaches for both in-person and online learning environments.

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