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Improving Conceptual Knowledge and Soft Skills among Vocational Students through Inquiry-Based Learning in a Flipped Classroom

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ABSTRACT

This study investigated the efficacy of inquiry-based learning (IBL) in a flipped classroom in enhancing vocational students' conceptual knowledge and inquiry skills of vocational students. We conducted IBL interventions in a flipped classroom through a pre-experimental design (i.e., one-group pretest-posttest approach). A total of 14 second-year students of the HNTec in Agro-technology programme in one of the vocational schools in Brunei Darussalam were conveniently sampled. Data were collected through achievement tests and online interviews, and analysed using the paired sample t-test, the Wilcoxon-signed rank test, and thematic analysis. The findings showed that the IBL intervention in a flipped classroom improved the conceptual knowledge and inquiry skills of vocational students. There were significant differences (p=0.001<0.05) between the pretest and posttest scores of students' conceptual knowledge: declarative, procedural, and semantic, and the dimensions of inquiry skills: observation, questioning, hypothesising, investigation and interpretation. Students reported positive perceptions toward IBL in a flipped classroom although they faced accessibility and adaptability challenges. This study concluded that IBL in a flipped lesson environment enhances the conceptual knowledge and inquiry skills that are fundamental in developing soft skills among vocational students. Recommendations were made based on the need to ensure a simultaneous use of IBL and flipped pedagogical approaches in vocational education.

***Keywords**:*

Inquiry-Based Learning; Flipped Classroom; Conceptual Knowledge; Soft Skills; Vocational Education.

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ABSTRAK

Studi ini menyelidiki kemanjuran pembelajaran berbasis inkuiri (IBL) di kelas terbalik atau flipped classroom dalam meningkatkan pengetahuan konseptual dan keterampilan inkuiri siswa kejuruan. Kami melakukan intervensi IBL di kelas terbalik melalui desain pra-eksperimental (yaitu pendekatan pretest-posttest satu kelompok). Sebanyak 14 siswa tahun kedua program HNTec in Agro-technology di salah satu sekolah kejuruan di Brunei Darussalam dengan mudah dijadikan sampel. Data dikumpulkan melalui tes prestasi dan wawancara online, dan dianalisis menggunakan uji-t sampel berpasangan, uji peringkat bertanda Wilcoxon, statistik deskriptif, dan analisis tematik. Temuan penelitian ini menunjukkan bahwa intervensi IBL di kelas terbalik meningkatkan pengetahuan konseptual dan keterampilan penyelidikan siswa kejuruan. Terdapat perbedaan yang signifikan ($p=0.001<0,05$) antara nilai pretest dan posttest pengetahuan konseptual siswa: deklaratif, prosedural, dan semantik, serta dimensi keterampilan inkuiri: observasi, menanya, hipotesis, investigasi dan interpretasi. Temuan kami juga mengungkapkan bahwa siswa melaporkan persepsi positif terhadap IBL di kelas terbalik meskipun mereka menghadapi tantangan aksesibilitas dan kemampuan beradaptasi. Studi ini menyimpulkan bahwa IBL dalam lingkungan pelajaran terbalik meningkatkan pengetahuan konseptual dan keterampilan inkuiri yang mendasar dalam mengembangkan soft skills di kalangan siswa kejuruan. Rekomendasi dibuat berdasarkan kebutuhan untuk memastikan penggunaan IBL secara simultan dan pendekatan pedagogis terbalik dalam pendidikan kejuruan.

***Kata Kunci**:*

Pembelajaran Berbasis Inkuiri; Kelas Terbalik; Pengetahuan Konseptual; Keterampilan Lunak; Pendidikan kejuruan.

1. Introduction

Vocational education significantly contributes to the production of human resources and industrial growth (Wu et al., 2021). In Brunei Darussalam (hereinafter, Brunei), policymakers in postsecondary education have developed several courses in TVET aimed at equipping students with the practical skills needed for this 21st century. Several professional development programmes have also been implemented to improve the skills of TVET instructors to impart practical training and skills to students (Salleh et al., 2021). This is necessary because in vocational education, pedagogical instructions should emphasise the acquisition of practical skills relative to theory. Graduates from vocational schools should be critical thinkers and problem solvers, as they must ensure the practical use of their educational experiences.

Conceptual knowledge in the form of declarative, procedural and semantic improves students' understanding of STEM disciplines (Gardenfos, 2017). This kind of knowledge facilitates the acquisition of observational, questioning, hypothesising, investigative, and interpretative skills by students (Bell et al., 2010). The combination of conceptual knowledge and these skills enhances the critical thinking and problem-solving skills among vocational students. Previous studies have linked vocational success to the acquisition of soft skills (McClendon-Payton, 2021; Putra, 2021). The relevance of soft skills has also been corroborated by a survey conducted by the Institute of Brunei Technical Education (IBTE) on employers' satisfaction from 2018 to 2020. The findings indicated that employers prefer vocational school graduates who are problem solvers, critical thinkers, and those who can apply their knowledge practically. In the 4.0 industrial revolution, the workforce should be equipped with IT competencies and problem-solving skills, thus making a combination of vocational and soft skills quintessential (Saari et al., 2021).

The association between students' acquisition of knowledge and soft skills with teachers' pedagogical approaches has been established. Dinihari et al. (2021) reported that vocational students who received inquiry-based learning interventions and went through a series of inquiry activities constructed knowledge for themselves, which improved their reflections and level of understanding. This improves their learning outcomes, cognitive skills, analytical, and problem-solving skills (Deng et al., 2020). Conversely, traditional approaches to pedagogical instruction in vocational education limit students' creativity, motivation, and knowledge acquisition (Rahman et al., 2021; Suardana et al., 2018).

Although conventional pedagogies can help complete instructional content on or before time, they are less helpful in vocational education, where practicality and problem-solving skills are prioritised. However, we observed as teachers/mentors that most TVET instructors in the vocational schools under the IBTE in Brunei still resort to traditional pedagogies. From our classroom observations, the instructors mostly gave lectures to students while the students observed and listened. This affected the engagement of students, as they were not allowed to participate in the classroom discussion and could not answer higher-order thinking questions. Our interactions with the students also revealed that they were afraid to ask questions, lacked interest in the subject taught, which affected their level of understanding, creativity, and problem-solving skills.

Referring to the flipped-flopped approach to learning that characterise educational delivery in Brunei, there is the need to test the efficacy of instructional approaches such as the IBL using students from the Bruneian vocational institutions. The IBL approach comes to mind because existing studies (Deng et al., 2020; Sarwa et al., 2021) have confirmed its efficacy in flipped classrooms in vocational learning. Winn et al. (2019) stressed that IBL improves learners' cognitive skills to process information more deeply. This enhances their learning and knowledge retention. Villalba et al. (2018) confirmed from Spain, Hungary and the Czech Republic that flipped classrooms are effective in vocational education since it serves as a context for students' inquiry. According to Paristiowati et al. (2017), flipped lessons improve critical thinking and independent learning. This gives room for students to develop and apply conceptual knowledge and involve themselves in the instructional process (Chang & Hwang, 2018).

Previous studies on vocational education and skill acquisition in the Bruneian context have not considered the efficacy of IBL in flipped classrooms. Given this background, we hypothesise that IBL in a flipped classroom in the provision of vocational education can improve conceptual knowledge, problem solving, critical thinking, and practical skills of students. This study investigated the impact of IBL in a flipped classroom on vocational students' knowledge of instructional concepts and inquiry skills. We also sought to explore the perceptions and challenges of vocational students toward IBL in a flipped classroom. The three research questions guiding this study are as follows: What is the impact of the IBL in a flipped classroom on vocational students' knowledge of instructional concepts? What is the impact of IBL in a flipped classroom on vocational students' inquiry skills? What are the perceptions and challenges of vocational students in the implementation of IBL in a flipped classroom?

1.1 Literature Review

We framed this study on the constructivist learning theory and the technological, pedagogical, and content knowledge (TPACK) framework. The constructivist theory posits that students are active learners who construct knowledge based on prior experiences (Bruner, 1990). The flipped classroom allows students to be exposed to prior learning experiences and acquire knowledge by themselves. Students are exposed to instructional concepts at home before the actual learning. This study argues that IBL in a flipped classroom allows vocational students to become independent and active learners. Students can analyse, hypothesise, and form mental schemas that are relevant for physical interactions through flipped lessons. This promotes an inquiry into the pedagogical instructions. IBL in a flipped classroom is feasible when TVET instructors appreciate and apply the interaction between technology, pedagogy, and content knowledge (Koehler & Mishra, 2009). TVET instructors should be able to blend knowledge of technology and content, knowledge of pedagogy and content, and knowledge of technology and pedagogical in the flipped classroom to improve students' knowledge and inquiry skills. Although existing evidence (Chang et al., 2015) shows that the use of TPACK increases the acquisition of students' knowledge of instructional concepts, we sought to uncover how vocational students' knowledge of concepts and inquiry skills can be improved in a flipped context where the interplay between TPACK exists.

Today's teaching and learning require technological integration and innovation (Groff, 2013). One of such innovative instructional pedagogies is the "flipped classroom". The flipped classroom allows the delivery of instructional content through online videos before physical class sessions (Latif et al., 2017; Chang & Hwang, 2018). Students acquire knowledge in an online classroom before the physical class. The physical classroom is used for instructional dialogues. Students check their knowledge by reflecting on the feedback given by the instructor to confirm the knowledge acquired (Kakosimos, 2015).

The relationship between flipped lessons and students' conceptual knowledge has been established. According to Kong (2014), flipped approach leads to students' motivation, increases attendance and academic grades. Students studying in a flipped classroom are more likely to achieve learning outcomes (McLauglin & Rhoney, 2015). Meanwhile, Nouri (2016) stated that low-achieving students exhibited positive attitudes toward flipped classrooms, and this was strongly correlated with their motivation, engagement, and learning effectiveness. From a meta-analysis in health and vocational education, Hew and Lo (2018) found evidence to support that the knowledge and skills of students improved when flipped classrooms were used. Students reported a positive perception on flipped classrooms since they were able to access pre-recorded video before physical classes, making learning convenient (Hew & Lo, 2018). For Goedhart et al. (2019), the combination of personalised pre-class and peer-learning activities in flipped sessions facilitated deeper learning and practical skills among students. Other studies (Sarwa et al., 2021; Sadik & Abdulmonem, 2020: Villalba et al., 2018) have linked flipped instruction with knowledge acquisition and skills in vocational education.

Flipped classrooms have been linked to student acquisition of inquiry skills through IBL, especially in TVET and STEM disciplines. IBL is a holistic approach to teaching and learning. It facilitates students' decisions about how they are engaged in instructional content, grasp knowledge and apply the knowledge. It also makes students active in the classroom as they become more curious of the 'how' and 'why', relative to the 'what', which helps them to be more perceptive of learning goals (Rooney, 2009). Vocational students are expected to think critically, solve abstract problems, be innovative, and be self-reliant (Yussop et al., 2021). To this end, students who participate in inquiry-based activities should be able to coordinate the knowledge and skills they acquire simultaneously. We argue that this kind of knowledge acquisition and the concurrent application of inquiry skills are what is needed in vocational education.

Graduates from vocational schools should have practical knowledge on what they learn and how to transmit it to the field of work. Existing studies have shown how IBL leads to inquiry skills and practical knowledge. Conklin (2012), for example, contended that inquiry develops students' higher-order thinking skills and performance. IBL approach improved students' mean test scores on science and technology courses, and their positive resistance behaviours (Sever & Guven, 2014). It improves student participation and subject matter knowledge, investigative, and interpretative skills (Zafra et al., 2015). Students' understanding of observational and hypothesising skills in science-related disciplines improved through IBL (Ibrohim et al., 2020). To date, the positive impact of flipped classrooms and IBL has been treated in isolation in assessing the acquisition of conceptual knowledge and inquiry skills by students. Amid Covid-19, the integration of the two approaches is needful especially in vocational education concerning students' acquisition of inquiry skills and conceptual knowledge.

2. Methods

The one-group pretest-pottest pre-experimental design was used. This is because a single intact class was observed twice to check the efficacy of an intervention (Marsden & Torgerson, 2012). This design is considered suitable because no control group served as the standard of comparison in this study (Frey, 2018). We extended the design to using the mixed-methods approach, which allowed for the collection of both quantitative and qualitative data (Creswell, 2014). Although the pre-experimental design can affect validity due to the lack of a control group (Thyer, 2012), it is effective in conducting experiments using an intact group. This includes resource challenges such as internet connection and interruptions in face-to-face pedagogical instructions (Frey, 2018).

A total of 14 **(**5 males and 9 females) second-year students of the HNTec in Agro-technology programme were conveniently sampled. They were students specialising in food technology from one of the vocational schools under the IBTE in Brunei. The students were used because they were being prepared for a career as laboratory technicians and food technology researchers. They are readily available during the conduct of this study. Their ages ranged from 18 to 25 years.

Data were gathered through a structured interview guide and tests. The interviews were conducted online, on a one-on-one basis after the intervention. The purpose of the interviews was to explore student perceptions and challenges in the implementation of IBL in a flipped classroom. A total of six (6) students were conveniently sampled for the interviews. The tests were meant to collect data on, first, students' conceptual knowledge about food and microbiological growth since they majored in food technology, and, second, students' inquiry skills about food and microbiological growth. Conceptual knowledge focused on students' acquisition of declarative, procedural, and semantic knowledge (Gardenfos, 2017). Inquiry skills focused on students' acquisition of observation, questioning, hypothesising, investigation, and interpretation skills in the IBL intervention (Bell et al., 2010).

Both the pretest and posttests for the first cycle consisted of 20 selected-response questions (15 multiple choice and 5 true/false questions). For the second cycle, the pretest and posttest consisted of nine (9) constructed response questions (short answer questions). Questions on these two cycles were based on the cognitive level of 'remembering' and 'understanding' of Bloom's taxonomy. For the third cycle, the pretest and posttest consisted of both selected and constructed response questions (6 multiple choice and 5 short answer types). The questions for this cycle were based on all Bloom's learning taxonomies. This was to ensure problem-solving and critical thinking skills among the students. We developed a table of test specifications in line with Bloom's taxonomy to improve the validity of the test items. Questions that measured conceptual knowledge and inquiry skills in the tests were crafted based on all the dimensions of Bloom's taxonomy. Internal verification of the questions in the tests was conducted by two experienced TVET instructors of Agro Technology who had taught for four years.

Before data collection, ethical clearance was obtained from the Sultan Hassanal Bolkiah Institute of Education Research Ethics Committee. Other ethical issues such as informed consent, anonymity, and confidentiality were fulfilled. On the field, pretests on conceptual knowledge and inquiry skills of students were conducted. This was to assess the students' prior knowledge of food and microbiology. A posttest was also conducted two weeks after each cycle. It sought to assess the effectiveness of a particular cycle before convening the next cycle. We proceeded to the successive cycle when there was a significant improvement in the mean difference between pre and posttests scores. When no improvement was observed, we repeated the cycles until an improvement was seen. The cycles were conducted in a flipped classroom environment with a technology-enhanced IBL. For the interview, reliability and validity were determined based on trustworthiness, dependability, confirmability, transferability, and credibility (Morse et al., 2002).

Three IBL interventions were provided to uncover both conceptual knowledge and inquiry skills of the students. Since the IBL naturally should expose students to inquiry skills, we emphasised students' acquisition of conceptual knowledge. The first, second, and third intervention cycles focused on students' acquisition of declarative (why), procedural (how), and semantic (why). After each cycle of interventions, the students wrote their reflections on what they learned. They also shared their reflections in Microsoft Onenote with the instructor. Table 1 provides a summary of the intervention cycles based on the conceptual knowledge of the students, content, pedagogy and the technology used.

Table 1. Intervention cycles based on conceptual knowledge and TPACK

Conceptual Knowledge	Content	Pedagogy	Technology
Declarative (what)	Microorganism defined Types of microorganisms Features and structure of microorganisms	Flipped lesson (A) Confirmation IBL (B) - Students to confirm their previous knowledge. Structured IBL (C) - Students followed required procedures	Edpuzzle videos for A PowerPoint Presentation for A & B Microsoft OneNote for students' reflection
Procedural (how)	Growth of bacteria by binary fission Microbial growth curve Growing microorganisms in the lab	A, B, and C.	Edpuzzle video for A PowerPoint Presentation for B Online simulation via Labster for C Microsoft OneNote for students' reflection
Semantic (why)	Growth of microorganisms under extrinsic and intrinsic conditions	A Guided IBL – Students were given activity-based questions, searched, and presented answers in class.	Edpuzzle video for A Online simulation for guided IBL. Online simulation for guided IBL.

The students' responses to their pretest and posttests were marked using developed rubrics. The sores were coded into the Statistical Package for the Social Science (SPSS) Software Version 25 to aid the analysis. We checked for the normality assumption using Shapiro-Wilk (suitable for our sample size). We observed that data on conceptual knowledge (declarative, procedural, and semantic) were normally distributed over the test scores in all cycles. For the first cycle, skewness = 0.033, kurtosis = 0.110, and Shapiro-Wilk's value (p = 0.639), second cycle, skewness = 0.076, kurtosis = -0.648 and Shapiro-Wilk's value (p = 0.942), and last cycle, skewness = 0.298, kurtosis = 1.366, and Shapiro-Wilk's value (p = 0.541). The z-score was used to assess the skewness and kurtosis which shows values within ±2.58 for all three cycles of the intervention, with p>0.50 for all cases which fulfills the normal assumption (Tsagris & Pandis, 2021). For inquiry skills, we observed that the data collected were not normally distributed over the tests for the interventional cycles. The data collected were analysed using a paired sample t-test, a Wilcoxon-signed rank test, and a thematic analysis.

3. Results and Discussion

The first objective was to investigate the impact of the IBL approach in a flipped classroom on vocational students' conceptual knowledge. The research question formulated for this objective is: *What is the impact of the IBL approach in a flipped classroom on vocational students' knowledge of instructional concepts?* The summary of the results of the paired sample t-test analysis is presented in Table 2.

Table 2. Pretest and posttest results on conceptual knowledge

Conceptual Knowledge Dimensions	Pretest		Posttest		Mean difference	SD	*P*	*t(13)*	*d*
	Mean	SD	Mean	SD					
Declarative	47.1	11.2	70.3	13.5	23.2	13.9	0.001	6.226	1.66
Procedural	37.0	14.8	68.6	18.6	31.6	10.8	0.001	10.977	2.93
Schematic	40.4	19.7	62.6	18.4	22.2	15.9	0.001	5.237	1.40

Descriptions: SD is Standard Deviation; Significant at 0.05; d = effect size.

The results in Table 2 show a statistically significant mean difference in the pretest and posttest scores regarding declarative knowledge [t(13)= 6.226, p<0.05), CI (15.3, 31.3)], with a mean difference of 23.2 and an effect of size of 1.66. Similar results were found for procedural knowledge [t(13)=10.977, p<0.05), CI (25.4, 37.8)] with a mean difference of 31.6 and effect of size of 2.93, and semantic knowledge [t(13)=5.237, p<0.05), CI (13.1, 31.4)], with a mean difference of 22.2, and an effect size of 1.4. Students' declarative knowledge was higher in the posttest (M=70.3, SD=13.5) compared to the pretest scores (M=47.1, SD=11.2), as well as procedural knowledge, posttest (M=68.6, SD=18.6) compared to the pretest scores (M=37.0, SD=14.8), and their semantic knowledge, posttest (M=62.6, SD=18.4) compared to the pretest scores (M=40.4, SD=19.7). The results suggest that the students exhibited high levels of conceptual knowledge when the IBL intervention was provided in the flipped classroom. The large effect sizes mean that IBL in a flipped classroom explains more than 92% of students' declarative, procedural and semantic knowledge of the instructional concepts (Cohen, 1988).

Our second objective was to determine the impact of the IBL approach in a flipped classroom on vocational students' inquiry skills. The research question that was set for this objective is: *What is the impact of IBL in a flipped classroom on vocational students' inquiry skills?* The summary of the results of the Wilcoxon-signed ranked test is presented in Table 3.

Table 3. Pretest and posttest results on vocational students' inquiry skills

Type of Inquiry Skills	Median (pretests)	Median (Posttest)	Median Difference	*p*	*Z*
Observation	9.00	13.00	4.00	0.001	3.33
Questioning	4.50	8.50	3.50	0.001	3.31
Hypothesising	6.00	8.00	2.50	0.001	3.33
Investigation	13.00	18.00	5.00	0.001	3.32
Interpretation	9.00	13.50	4.00	0.001	3.32

Significant at 0.05

The results in Table 3 indicate that the student's inquiry skills were higher after the intervention through IBL in a flipped classroom. For observation skills, there was a statistically significant median increase in the pretest (Median = 9.00) and protest (Median = 13.00), with a median difference of 4.00. For questioning skills, there was a statistically significant median increase in the pretest (Median = 4.50) and the posttest (Median = 8.50), with a median difference of 3.50. Likewise, hypothesising skills, pretest (Median = 6.00) and posttest (Median = 8.00), with a median difference of 2.50, investigation skills, pretest (Median = 13.00) and posttest (Median = 18.00) with a median difference of 5.00, and interpretation skills, pretest (Median = 9.00) and posttest (Median = 13.00) with a median difference of 4.00. All the median differences for the dimensions of the inquiry skills were significant with p = 0.001, and z-values ranging from 3.31 to 3.33. This suggests that IBL in a flipped classroom improved the inquiry skills of vocational students.

The third objective was to explore the perceptions and challenges of vocational students in IBL in a flipped classroom. The research question that guided this objective is: *What are the perceptions and challenges of vocational students in the implementation of IBL in a flipped classroom?* Thematic analysis of the interview transcripts revealed two general themes. These are positive perceptions and challenges of IBL in flipped classrooms.

The students generally reported positive perceptions of IBL in the flipped class. They indicated that the IBL in the flipped classroom ensures early preparation and participation in instructional decisions. This motivated them and improved their performance.

In early preparation, S3 believed that through an online learning platform, he understood his learning expectations. He was well prepared before the actual lessons. He said that the Edpuzzle video helped him understand the content and prepared him for class. For S6, she was able to answer questions during the physical classes and this was due to the flipped lessons. She attributed this to her prior understanding. She shared that "*When I watch the video before physical classes, I am able to answer the questions from my instructor based on my understanding*".

The excerpts imply that IBL in the flipped classroom helps ensure early preparations of students and gives them the idea of what is expected in the lesson. Regarding student participation, S10 reported that "*The instructor asks the questions, makes us investigate to find answers. This helps us to have a deeper understanding of the subject*". S5 felt involved in the learning process, and confirmed this by indicating that she was more involved in the learning process.

The views of the students reiterate that they participated in the IBL in a flipped class, and that their participation helps them understand instructional concepts. The students were also motivated in the IBL and flipped class. S4, for example, saw the IBL and the flipped classroom as fun. This made him perceive that the classroom environment was positive in promoting his motivation. He confirmed and indicated that IBL activies are fun, creating positive study environment that motivated him to learn. S11 also shared that "*IBL in a flipped classroom motivates me to learn*". This was further corroborated by S10 who shared that "*It motivates us a lot to know more*".

From the students, IBL in flipped classrooms encourages them to learn and to know more. They reported that the approach comes with fun. The motivation expressed by students is helpful for their acquisition of knowledge. It was not surprising that students indicated that their performance as a result of IBL in a flipped classroom improved. S6, for example, shared that her performance after the intervention improved. This reiterates the efficacy of the IBL intervention in the flipped class. He confirmed: "*I can see an improvement in my previous test results*". S3 believed that there was improvement in her first performance due to the intervention she received. She confirmed "*I can see the improvement from the first test*". This was further corroborated by S4 who shared that "*IBL helps me to perform better*". The excerpts indicate that there was an improvement in the current compared to the previous performance of students.

The students had difficulty accessing instructional documents. They also reported adaptability problems. Regarding accessibility challenges, S4 admitted that he had challenges in accessing the video lessons for the flipped class. He was not sure if this challenge resulted from his internet connection. For S11, she had accessibility problems. She was not able to do the reflection that was required after the lesson because she could not access it. She confirmed this in her comment "*At times I do not do the self-reflection sessions because I cannot access it*". S6 shared that she encountered adaptability challenges in the early stages of the flipped lessons integrated with the IBL activities.

The excerpts from the students regarding accessibility and adaptability show that they are faced with such problems in their flipped classrooms. This can be detrimental to lesson delivery using IBL and flipped approaches.

The findings of this study shed light on the effectiveness of IBL in a flipped classroom in improving conceptual knowledge and inquiry skills among vocational students. Our findings show that students majoring in food technology had better declarative, procedural, and semantic knowledge of instructional concepts after IBL interventions. They were able to understand what, why, and how of instructional concepts through the inquiry instructions conducted in a flipped classroom. They also improved their observational, questioning, hypothesising, investigative, and interpretative skills. These skills and knowledge through IBL instructions in a flipped context help develop critical thinking and problem-solving skills among vocational students. IBL and flipped interactions promote students' inquiry and the self-construction of knowledge (Chang & Hwang, 2018).

Our findings confirm the effectiveness of IBL and flipped instruction in enhancing vocational students' knowledge and inquiry skills that have been reported in the literature (Dinihari et al., 2021; Villalba et al., 2018). We believe that the use of technology in flipped lessons and the integration of IBL triggered vocational students' knowledge acquisition and inquiry. Consistent with the TPACK framework, the interplay among technology, pedagogy, and content knowledge is key in enhancing instructional delivery, knowledge acquisition, and inquiry skills (Chang et al., 2015). Through technology and the integration of IBL in flipped lessons, vocational students had positive perceptions of conceptual knowledge and inquiry skills as evidenced in the literature (Nouri, 2016). This led to the positive attitudes they exhibited toward flipped lessons, which predicted their motivation, engagement, and learning effectiveness. Consistent with the constructivist learning theory, our findings show that vocational students were active, constructed knowledge, and inquired about learning based on their prior knowledge (Bruner, 1990). This prior knowledge was enhanced through IBL and flipped interactions.

The positive perceptions shared by vocational students on IBL and flipped lessons should lead to better conceptual knowledge and inquiry skills as justified in the literature (Chang et al., 2018; Hew & Lo, 2018; Paristiowati et al., 2017). It is, therefore, not surprising that they exhibited higher performance after they have been exposed to IBL interventions in a flipped class. There were challenges that are associated with IBL and flipped lessons. There were accessibility and adaptability challenges. However, we confirm the effectiveness of IBL and flipped instruction in enhancing the acquisition of inquiry skills and conceptual knowledge by vocational students in the literature (Ibrohim et al., 2020; Sarwa et al., 2020; Sadik & Abdulmonem, 2020; Zafra et al., 2015). This study adds that the conceptual and inquiry skills that accompany the use of IBL and flipped lessons are fundamental in ensuring critical thinking and problem-solving skills among vocational students. The acquisition of these skills by vocational students will indicate their readiness and fit for the job market of the 21st century.

4. Conclusion

We set out to investigate the effectiveness of IBL in a flipped classroom in enhancing vocational students' conceptual knowledge and acquisition of inquiry skills. We found that IBL in flipped lessons improves the conceptual knowledge and inquiry skills of vocational students. This applies to all the dimensions of knowledge and iquiry skills. Although there were challenges in using these instructional approaches, students shared positive perceptions of the approaches. This study contributes to the literature on the efficacy of integrating IBL with a flipped classroom to determine students' conceptual knowledge and inquiry skills in vocational education. We have presented evidence that both pedagogical approaches can be integrated to improve the knowledge and inquiry skills of vocational students. This study concludes that IBL in a flipped classroom plays an important role in improving students' knowledge and understanding of instructional concepts, and inquiry skills for learning. Our findings imply that IBL and flipped lessons are natural partners in pedagogical instructions. Hence, integrating the two approaches improves vocational students' soft skills such as critical thinking and problem-solving.

The main limitations of this study is using a relatively small intact class without a control group. This was possible through the pre-experimental design we used in this study. It would have been better to use a control group as a standard of comparison to strengthen the validity of our findings. Irrespective of this limitation, we gathered data through various approaches, such as tests and interviews. This enhanced the validity and consistency of information gathered through triangulation. The following research recommendations are made. First, relevant educational agencies are recommended to develop strategies to ensure that vocational education instructors largely resort to IBL in a flipped context. This can be done by strengthening the organisation of in-service training for the instructors. Secondly, steps should be taken to address the challenges of vocational students in utilising IBL and flipped instructions. Efforts should be made to address accessibility and adaptability challenges. Future research should also consider extending the effectiveness of IBL in a flipped classroom to other vocational education majors, and other dimensions of conceptual knowledge (i.e., strategic knowledge). Future studies may also consider using larger samples consisting of both control and treatment groups to improve the generalisation of the effectiveness of IBL in flipped lessons in vocational education.

5. References

Bell, T., Urhahne, D., Schanze, S., & Ploetzner, R. (2010). Collaborative inquiry learning: Models, tools, and challenges. *International Journal of Science Education, 32*(3), 349-377. https://doi.org/10.1080/09500690802582241.

Bruner, J. (1990). *Acts of meaning.* Cambridge, MA: Harvard University Press.

Chang, S. C., & Hwang, G. J. (2018). Impacts of an augmented reality-based flipped learning guiding approach on students' scientific project performance and perceptions. *Computer and Education, 125*, 226-239. https://doi.org/10.1016/j.compedu.2018.06.007.

Chang, Y., Jang, S. J., & Chen, Y. H. (2015). Assessing university students' perceptions of their Physics instructors' TPACK development in two contexts. *British Journal of Educational Technology*, *46*(6), 1236-1249. https://doi.org/10.1111/bjet.12192.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Conklin, W. (2012). *Strategies for developing higher-order thinking skills, grades 6-12.* Huntington Beach, CA: Shell Educational Publishing.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative and mixed methods approaches* (4th ed.). Thousand Oaks, CA: Sage.

Deng, X., Wang, M., Chen, H., Xie, J., & Chen, J. (2020). Learning by progressive inquiry in a physics lesson with the support of cloud-based technology. *Research in Science & Technological Education, 38*(3), 308-328. https://doi.org/10.1080/02635143.2019.1629408.

Dinihari, P., Effendy, E., Rahayu, S., Dasna, I. W. (2021). Evaluation of learning cycle 4E-RE to improve chemistry learning of vocational high school students. *Journal of Technical Education and Training, 13*(2), 108-114. https://doi.org/10.30880/jtet.2021.13.02.010.

Frey, B. B. (2018). Pre-experimental designs. *The Sage Encyclopedia of Educational Research, Measurement, and Evaluation*. https://dx.doi.org/10.4135/9781506326139.

Gardenfors, P. (2017). Semantic knowledge, domains of meaning and conceptual spaces. In P. Meusburger, B. Werlen and L. Suarsana (Eds.), *Knowledge and Action. Knowledge and Space*, pp. 203-219. Springer, Cham. https://doi.org/10.1007/978-3-319-44588-5_12.

Goedhart, N.S., Blignaut-van Westrhenen, N., Moser, C. et al. (2019). The flipped classroom: supporting a diverse group of students in their learning. *Learning Environment Res, 22,* 297–310. https://doi.org/10.1007/s10984-019-09281-2

Groff, J. (2013). Technology-rich innovative learning environments. *OCED CERI Innovative Learning Environment project*, 2013, 1-30.

Hew, K. F. & Lo, C. K. (2018). Flipped classroom improves student learning in health professions education: a meta-analysis. *BMC Medical Education, 18*(1): 38. doi: 10.1186/s12909-018-1144-z

Ibrohim, I., Sutopo, S., Muntholib M., Yayuk P., & Imro'atul M. (2020). Implementation of inquiry-based learning (IBL) to improve students' understanding of nature of science (NOS). *AIP Conference Proceedings 2215*, 030005 https://doi.org/10.1063/5.0000632

Kakosimos, K. E. (2015). Example of a micro-adaptive instruction methodology for the improvement of flipped-classrooms and adaptive-learning based on advanced blended-learning tools. *Education for Chemical Engineers 12,* 1-11. https://doi.org/10.1016/j.ece.2015.06.001.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)?. *Contemporary Issues in Technology and Teacher Education, 9*(1), 60-70.

Kong, S. C. (2014). Developing information literacy and critical thinking skills through domain knowledge learning in digital classrooms: An experience of practicing flipped classroom strategy. *Computer & Education, 78,* 160-173. https://doi.org/10.1016/j.compedu.2014.05.009.

Latif, S. W. A., Matzin, R., Jawawi, R., & Mahadi, M. A. (2017). Implementing the flipped classroom model in the teaching history. *Journal of Education and Learning, 11*(4): 373-380. DOI: 10.11591/edulearn.v11i4.6390

Marsden, E., & Torgerson, C. J. (2012). Single group, pre-and post-test research designs: Some methodological concerns. *Oxford Review of Education, 38*(5), 583-616. https://doi.org/10.1080/03054985.2012.731208.

McClendon-Payton, K. S. (2021). *Vocational education: CNA students' perspectives of soft skills in training and the workplace*. Unpublished doctoral dissertation, Brandman University, Walnut Creek, California, United States. https://digitalcommons.brandman.edu/edd_dissertations/391.

McLaughlin, J. E., & Rhoney, D. H. (2015). Comparison of an interactive e-learning preparatory tool and a conventional downloadable handout used within a flipped neurologic pharmacotherapy lecture. *Currents in Pharmacy Teaching and Learning, 7,* 12-19. https://doi.org/10.1016/j.cptl.2014.09.016.

Morse, J. M., Barrett, M., Mayan, M., Olson, K., & Spiers, J. (2002). Verification strategies for establishing reliability and validity in qualitative research. *International Journal of Qualitative Methods, 1,* 1-19. http://www.ualberta.ca/~ijqm/.

Nouri, J. (2016). The flipped classroom: For active, effective, and increased learning – especially for low achievers. *International Journal of Educational Technology in Higher Education, 13*(1). https://doi.org/10.1186/s41239-016-0032-z.

Paristiowati, M., Fitriani, E., & Aldi, N. H. (2017). The effect of inquiry-flipped classroom model toward students' achievement on chemical reaction rate. *AIP Conference Proceedings, 1868*. https://doi.org/10.1063/1.4995105.

Putra, R. (2021). Soft skill development in vocational schools to produce competent graduates needed by the business/industry world. *Budapest International Research in Exact Sciences Journal, 3*(1), 77-81. https://doi.org/10.33258/birex.v3i1.1520.

Rahman, A. A. K., Jalil, N., Arsad, M. M., Hashim, S., Rahim, B. M., Yunus, A. F. N., Razali, R., & Ismail, E. M. (2021). Development of mobile application framework based on competency-based education for technical and vocational education. *Journal of Technical Education and Training, 13*(2), 44-52. https://doi.org/10.30880/jtet.2021.13.02.005.

Rooney, C. (2009). How am I using inquiry-based learning to improve my practice and to encourage higher-order thinking among my students of mathematics? *Educational Journal of Living Theories*, *5*(2), 99-127. http://ejolts.net/drupal/node/200.

Saari, A., Rasul, M. S., Yasin, R. M., Rauf, R. A. A., Ashari, A. M. Z., & Pranita, D. (2021). Skills sets for workforce in the 4th industrial revolution: Expectation from authorities and industrial players. *Journal of Technical Education and Training, 13*(2), 1-9. https://doi.org/10.30880/jtet.2021.13.02.001.

Sadik, A. E., & Abdulmonem, A. W. (2020). Improvement in student performance and perceptions through a flipped anatomy classroom: Shifting from passive traditional to active blended learning. *Anatomical Sciences Education, 0,* 1-9. https://doi.org/10.1002/ase.2015.

Salleh, S. M., Musa, J., Jaidin, J. H., & Shahrill, M. (2021). Development of TVET teachers' beliefs about technology enriched instruction through professional development workshops: Application of the technology acceptance model. *Journal of Technical Education and Training, 13*(2), 25-33. https://doi.org/10.30880/jtet.2021.13.02.003.

Sarwa, R., Triatmojo, W., & Priyadi, M. (2021). Implementation of flipped classroom on experiences in online learning during pandemic covid-19 for a project-base vocational learning guide. *Journal of Physics: Conference Series, 1842.* https://doi.org/10.1088/1742-6596/1842/1/012019.

Sever, D., & Guven, M. (2014). Effect of inquiry-based learning approach on student resistance in a science and technology course. *Educational Sciences: Theory & Practice, 14*(4), 1601-1605. https://doi.org/10.12738/estp.2014.4.1919.

Suardana, I. N., Redhana, I. W., Sudiatmika, A. A., & Selamat, I. N. (2018). Students' critical thinking skills in chemistry learning using local culture-based 7E learning cycle model. *International Journal of Instruction, 11*(2), 399-412. https://doi.org/10.12973/iji.2018.11227a.

Thyer, A. B. (2012). Quasi-experimental research designs. *Oxford Scholarship Online*, 1-37. https://doi.org/10.1093/acprof:oso/9780195387384.003.0002.

Tsagris, M., & Pandis, N. (2021). Normality test: Is it necessary? *American Journal of Orthodontics and Dentofacial Orthopedics*, *159*(4), 548-549. https://doi.org/10.1016/j.ajodo.2021.01.003**.**

Villalba, M. T., Castilla, G., & Redondo-Duarte, S. (2018). Factors with influence on the adoption of the flipped classroom model in technical and vocational education. *Journal of Information Technology Education: Research, 17,* 441-469. https://doi.org/10.28945/4121.

Winn, A. S., DelSignore, L., Marcus, C., Chiel, L., Freiman, E., Stafford, D., & Newman, L. (2019). Applying cognitive learning strategies to enhance learning and retention in clinical teaching settings. *MedEdPORTAL*, *15*(10850). https://doi.org/10.15766/mep_2374-8265.10850.

Wu, M., Cassim, F. A. K., Masrul, S., & Kesa, D. D. (2021). Challenges of collective inertia and scarcity to technological and vocational education universities. *Journal of Technical Education and Training, 13*(2), 95-107. https://doi.org/10.30880/jtet.2021.13.02.009.

Yussop, M. A. H., Shahrill, M., & Latif, S. N. A. (2021). Self-reliant learning strategy in vocational and technical education: Insights from group collaboration. *International Journal of Social Learning*, 1(3), 283-303. https://doi.org/10.47134/ijsl.v1i3.73

Zafra-Gómez, J. L., Román-Martínez, I., & Gómez-Miranda, M. E. (2015). Measuring the impact of inquiry-based learning on outcomes and student satisfaction. *Assessment and Evaluation in Higher Education*, *40*(8), 1050-1069. https://doi.org/10.1080/02602938.2014.963836.