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Research Article

A Mixed-Method Approach to Investigate the Effect of Flipped Inquiry-Based Learning on Chemistry Students Learning

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ABSTRACT

This study investigated the effects of flipped inquiry-based learning approach (FIBL) on chemistry students' academic performance and learning experiences. This study utilized a mixed research methods approach with a quasi-experimental design. A convenient sampling technique was used to identify pre-service teachers studying chemistry at the college of education in Ghana. Quantitative data was obtained using a chemistry academic achievement test and critical thinking skills test. Qualitative data was obtained through a focus group conducted in the experimental class. Results from the quantitative data analysis showed a significant increase in students' academic performance and critical thinking skills in the pre-and post-test scores in experimental classes. Female pre-service teachers performed better with higher scores in chemistry learning outcomes than their male colleagues. In addition, the focus group results showed that students had positive views on learning in the FIBL environment in terms of learning convenience, peer collaboration, conceptual understanding, and learning skills. The study provides insight into flipped and inquiry-based learning as effective pedagogical approaches for delivering chemistry instructions. Overall, the results show that flipped inquiry-based learning is an effective pedagogical approach enabling students to develop learning potentials in chemistry.

Keywords: flipped learning, inquiry-based learning, academic achievement, collaboration, critical thinking skills

INTRODUCTION

Chemistry is one of the major subjects that are of importance to humans. Teaching and learning such a subject entails adequate teaching resources and preparation. In chemistry education, adequate knowledge of organic chemistry units is considered helpful to students learning for their future in the chemical industry (Roy, 2016). However, it is considered one of the most challenging units for students, especially IUPAC naming and writing structures of aliphatic hydrocarbons (Adu-Gyamfi et al., 2017; O'Dwyer & Childs, 2017; Sarkodie & Adu-Gyamfi, 2015). This difficulty relates to students' inadequate understanding of correctly identifying carbon atoms, positions of substituents, and functional groups (Akkuzu & Uyulgan, 2016).

One critical reason for the students' poor understanding and performance in nomenclature is ineffective pedagogical approaches (Adu-Gyamfi et al., 2017). Studies have revealed that some teachers deliver nomenclature teaching with traditional lecturing and give few examples to students (Adu-Gyamfi et al., 2017). Most often, students do not understand the content thoroughly and need more time on their own to acquire the knowledge (Akkuzu & Uyulgan, 2016). Researchers have argued that nomenclature entails drill-and-practice exercises and follow-up reviews with educators and recommend its use (Shaw & Yindra, 2003).

Using teacher-centered instruction involves educators transferring knowledge to students without the latter's adequate understanding of application concepts (Addae & Quan-Baffour, 2018; Maphosa & Ndebele, 2014). Many concerns have been raised about the ineffectiveness of teacher-centered instruction due to a lack of student engagement and motivation (Addae & Quan-Baffour, 2018; Ibrahim et al., 2018) and poor understanding of scientific concepts (Bagheri et al., 2013; Maphosa & Ndebele, 2014). In addressing this challenge, teachers need for teachers to use learning practices to help students construct meaning from observation and phenomena experience (Berland et al., 2016). Further, recommendations and advocacy are made to shift science instructions towards student-centered instructional practices to enhance students' effective communication, increase achievement, creativity, and problem-solving skills (MoE, 2007; T-TEL, 2015).

Educators have used instructional strategies emphasizing student engagement and active learning for students' collaboration (Mulvey et al., 2016). Inquiry-based and flipped learning are examples of active learning pedagogies that support student-centered learning. According to the constructivist learning theory, inquiry-based and flipped learning are two effective learning approaches that support students' construction of new knowledge. The constructivist argues that students discover their understanding from the experience and guidance from instructors or guided instruction in learning new things (Applefield et al., 2000). This imply constructivism emphasizes students experiences in active learning experiences and prior knowledge to the present and future learning, which are the components of inquiry-based and flipped learning approaches. The remaining session discussed the literature on the positive aspects of inquiry-based learning (IBL) and flipped learning (FL).

LITERATURE REVIEW

Inquiry-Based Learning

Inquiry based learning relates to the constructivist approach, where students construct knowledge on their own. Inquiry-based learning is a classroom activity model that involves seeking knowledge and new understanding in a practice-based format (Holbrook et al., 2014). In IBL, a series of student-centered strategies, where students take more control of their learning and construct knowledge through interactions (Pedaste et al., 2015) and apply knowledge in solving real-life problems (Heindl, 2018). Through the active learning activities, students develop 21st- century skills such as critical thinking, problem-solving, and creativity from the group work or independent learning process (El Mawas & Muntean, 2018).

Researchers have broadly endorsed IBL in science education due to its ability to inspire and engage students in scientific investigations to find solutions to social-scientific problems (Riga et al., 2017; Van Uum et al., 2016). As a result, IBL has received much attention regarding its effectiveness on students learning outcomes. Many studies have found that IBL enable students to explore, communicate and discover knowledge and gain a deeper understanding of the subject matter (de Dieu Kwitonda et al., 2021; Hofer et al., 2018; Li et al., 2022), increases academic performance (Azizoglu et al., 2022; Bodner & Elmas, 2020; Singh, 2020) and enhance the development of critical thinking and problem-solving skills (Arsal, 2017; Duran & Dokme, 2016; Herawati et al., 2020).

Flipped Learning

The flipped learning approach is an active student-centered pedagogical approach where students are engaged with individual computer-based pre-instructions outside the classroom leading to quality interactive group learning in class (O'Flaherty & Phillips, 2015). Researchers have found flipped learning to involve blending face-to-face and online learning activities to engage and support students learning using technology (Abeysekera & Dawson, 2015; Bergmann & Sams, 2012). In the flipped learning technology, students are engaged in out-of-class instructions, allowing them to take responsibility for learning the material at their convenience (Garcia-Ponce & Mora-Pablo, 2020; Sointu et al., 2022). Moving aspects of lecture instructions outside the classroom create space for peer discussions and collaborative learning, with the educator facilitating the learning activities (Fuchs, 2021). During the student engagement in the activities, instructors guide students and facilitate their learning to understand and comprehend knowledge from learning materials (Bergmann & Sams, 2012).

Studies show that flipped instruction increases students' active learning roles in constructing their own knowledge (Awidi & Paynter, 2019). Many empirical studies on the effectiveness of the flipped learning as an instructional approach found increased student academic achievement in chemistry (Olakanmi, 2017; Oppong et al., 2022; Rohyami & Huda, 2020), development of critical thinking skills (Boateng et al., 2022; Munzil et al., 2020) due to the active engagement and interactive nature of the approach.

One crucial component of flipped learning is the inquiry learning activities involving students engaging in collaborative activities, including IBL. In the FIBL environment, learners watch video lectures to prepare for interactive, collaborative, IBL activities and discussions (Seery, 2015). The combined FIBL pedagogy involved students watching video clips on open-ended problems and were required to use their own experiences to build knowledge during the face-to-face sessions. Using inquiry with a flipped-classroom approach to introduce learning concepts to students frees up space for in-class activities for engagement and exploration (Love et al., 2015). Students use individual and collaborative learning among peers in the flipped inquiry-based learning (FIBL) environment. Research has emphasized the benefits of collaborative learning in a flipped classroom, enhancing students learning (Asiksoy & Ozdamli, 2016). While engaging in collaborative learning activities in FIBL, students build new knowledge to integrate more effectively into the learning process. It is possible that building new knowledge through flipped inquiry-based classroom activities increases student learning outcomes. This assertion supports our hypothesis that a flipped inquiry-based classroom is an effective approach to teaching chemistry.

Effects of a Flipped Inquiry-based classroom on chemistry students' learning

FIBL involves the combination of active, direct face-to-face instruction and inquiry-based activities delivered asynchronously online (Bishop & Verleger, 2013). FIBL approach emphasizes engaging students in active learning activities to improve their conceptual understanding, critical thinking, and problem-solving. To be competent in critical thinking, one requires mastery of gathering, selecting appropriate information, analyzing data, hypothesizing, and solving a problem (Molitor & George, 1976). Students develop critical thinking knowledge and experience from engaging in active learning activities. The curricular policies should be shifted from content knowledge or content based to developing learners' critical thinking skills. Hence, learning through FIBL experiences creates opportunities for learners to improve their learning and critical thinking skills.

Several researchers have documented the effects of IBL and flipped classrooms on students' chemistry learning outcomes. For instance, Paristiowati et al. (2017) used quasi-experimental method to examine the effect of inquiry-based flipped learning activities on students' chemistry achievement. The results showed students in the inquiry-flipped learning classroom recorded higher scores compared to those in the traditional class session. The active learning activities enhanced knowledge acquisition makes students developed positive attitudes towards the approach. In a study researchers utilized a flipped guided learning (FGIL) model to support first-year undergraduate general chemistry students learning. The results indicated that the FGIL model enhanced students' understanding of the chemistry concepts. Also, students had positive views of the model as it effectively enhanced their understanding of conceptual knowledge and increased interest in learning (Aumi & Mawardi, 2021). Similarly, another study qualitative methods were used to analyze the

Table 1. Demographic information of group participants

Variables	Group demographics	
	Control	Experimental
Gender		
Male	32	38
Female	16	14

effects of the flipped problem-based solving model on high school students' learning skills in a chemical course. The analysis of the results showed the learning model enabled students to become independent, active learners. The authors concluded that the model enhance students' collaborative, communication, creativity, and critical thinking skills (Karyadi et al., 2020).

While few research or studies on the combination of flipped learning and IBL in chemistry education have been documented, no research is found on chemistry teacher education. Based on this perspective, the study sought to investigate the effect of FIBL on pre-service teachers' chemistry learning. In addition, interviewing students on their views of learning in chemistry courses would provide practical information on the FIBL approach.

Research Questions

To achieve the purpose of this study, the following research questions guided the study:

1. What are the effects of flipped and IBL on students' academic achievement?
2. What are the effects of flipped and IBL on students' critical thinking skills achievement?
3. What views do students have about learning in flipped inquiry based learning environment?

METHOD

The design of this study was explanatory-sequential mixed-method involving quantitative and qualitative approaches (Creswell & Clark, 2017). The quantitative aspect of the study utilized a true quasi-experimental design pre-test/post-test with a comparison group to determine the effect of the use of flipped learning and IBL in students' chemistry learning. The qualitative approach used a phenomenological method to elicit students' opinions about the effects of combined FIBL. Data triangulation from different sources was used to strengthen the study results. Quantitative results were used to increase the generalization of the study, and qualitative data was used to explain the context of data triangulation (McMillan & Schumacher, 2010). This enabled the researchers to understand participants' learning experiences in the FIBL environment.

Study Group and Participants

The study was conducted on pre-service teachers taking general chemistry course in the teacher education program. A convenient sampling technique was used to select two classes taking the course. The target population was all pre-service chemistry teachers in the Eastern Region of Ghana. A purposeful convenient sampling technique was used to identify and assign the 100 pre-service teachers into two classes as control (n=48) and experimental (n=52) classes, as shown in **Table 1**. The classes were intact, which were already assigned by the university, so the researchers had no control. However, these classes were assigned randomly as control and experimental classes based on their course major. Before the intervention, a pre-test was conducted to explore the students' level of knowledge in chemistry. The study was conducted over four weeks during the academic year's 2021-2022 first semester. The concept of naming and structures of aliphatic hydrocarbons was taught this time of the research by an experienced chemistry tutor employed for the study. The pre-service teachers attended 80mins lessons weekly in three different sessions over the research period. The study covered compulsory general chemistry course content designed and delivered through online instruction and face-to-face. None of the participants have prior experience in flipped classroom approach.

Data Collection Procedures

The researcher and tutor prepared course materials comprising video lectures, PowerPoint slides, reading materials, and tasks and shared them on the Google Classroom and WhatsApp groups for the pre-service teachers in the experimental class. The same materials were given to the control class during the study, excluding the videos and online materials. The same educator presented instructions on the content, assignments, tasks, and quizzes to both classes, using the control class's traditional lecture approach. In contrast, the experimental class received instructions with the flipped-IBL approach. At the beginning of each week, pre-service teachers reviewed 10-15mins videos on the hydrocarbon content and other reading materials. They took short quizzes as homework tasks and preparatory tasks for classroom activities. In the classroom, educators used the think-pair-share method to engage pre-service teachers to discuss the video content and reading materials to explain the concept. Pre-service teachers are then given class exercises to build up the basic concepts through reflection on the content either as group work or individually. Pre-service teachers are given tutorials to further assess their understanding of the content as tasks or homework using individual and group presentations. At the end of the intervention, pre-service teachers were assessed on their learning outcomes through academic achievement test, critical thinking skill test and interview. Before the study, the pre-service teachers approved ethical clearance procedures and permission with informed consent. In determining pre-service teachers' views on the flipped-inquiry-based learning approach in chemistry learning, a focus group discussion was conducted with 10 volunteered participants from the experimental class. After explaining the purpose of the focus group and seeking participants' consent, the discussions was conducted and audio-recorded via WhatsApp and Zoom meetings which lasted for 60mins.

Data Collection Instruments

At the end of the intervention, a chemistry achievement test (CAT) on organic chemistry was developed. Questions were selected from the previous questions in the chemistry curriculum of the Diploma of education to evaluate the pre-service teacher's academic achievement. These questions were appropriate as they were a standardized national test for the teacher training curriculum for the diploma in basic education program at the Institute of Education, University of Cape Coast. A critical thinking skills test (CTST) was also developed to assess the pre-service teachers' critical thinking levels during intervention. The test items comprised of multiple-choice and open-ended questions used to measure pre-service teachers critical thinking level. The CTST contained items that involves knowledge, application and reasoning thinking levels in the cognitive domain of the chemistry curriculum. The knowledge thinking level measures students' ability to recognize and recall basic concepts or fact. The application level involves students' ability to use knowledge to perform a task solution using previous knowledge gained from a familiar test. The synthesis test items consisted of ideas that involve the use of complex cognitive skills such as making inference with intuitive and inductive thinking to perform a task (Bloom, 1956; Krathwohl, 2002). The knowledge thinking level test items consisted of six multiple choice questions, four application items consisting of open-ended questions and the reasoning items consisting of 10 open-ended questions. Finally, Qualitative data were collected using focus group discussions.

Data Analysis

To assess the content and face validity of the instrument, the test items were inspected by one expert in science education who recommended some parts amended. Jamovi statistical software version 2.25 was used to analyze the quantitative data, and the significance level for the statistical tests was set at 0.05 in all the analyses. Quantitative data (i.e., pre-test, post-test, and critical thinking skills) were analyzed using descriptive statistics, e.g., means standard deviations. An independent sampled t-test was conducted to determine the differences between the control and experimental groups participants in terms of academic achievement, gender, and critical thinking skills. A discrimination index, facility index, and instrument reliability were performed. The facility index used to determine the difficulty or simplicity of the test items was in the range of 0.4-0.71, and the discrimination index used to distinguish between low and achievers was ≥0.4. According to Mok (1994), a facility index range of $0.3 \leq A \leq 0.8$ is admissible, and a discrimination index of ≥0.4 is considered a very good item. A Cohen's d effect size was used to determine the degree of practical significance of using FBIL approach on students' achievement. The qualitative data was transcribed, categorized, and analyzed with content analysis method.

Table 2. Independent t-test on chemistry achievement between groups

Groups	Pre-test		Post-test		Mean diff	t	p
	Mean	SD	Mean	SD			
Control	11.10	3.43	12.13	2.19	3.52	-9.54	<0.05
Experimental	10.90	2.94	15.65	1.44			

Table 3. Independent t-test on chemistry achievement based on gender

Groups	Pre-test		Post-test		Mean diff	t	p
	Mean	SD	Mean	SD			
Male	11.02	1.79	11.26	1.77	1.88	-2.55	0.012
Female	11.13	1.51	13.14	1.57			

Table 4. Independent t-test on critical thinking skills scores in post-test between groups comparison

Groups	Pre-CTST		Post-CTST		Mean diff	t	p
	Mean	SD	Mean	SD			
Control	9.72	1.99	13.60	2.18	1.62	-4.09	<0.05
Experimental	9.69	2.18	15.22	1.77			

RESULTS

Effects of Flipped Inquiry-Based Learning on Students' Achievement

The achievement test was used to compare differences in the pre-test and post-test scores. The results of the descriptive statistics and test are shown in **Table 2**.

The independent samples t-test was used to determine when students' achievement changed between the pre-test scores of the control and experimental classes. The results showed a normal distribution in the pre-test data sets with no significant differences between the two groups' mean scores (t=-1.128, p=0.262). In the post-test scores, students in the experimental group obtain higher scores (M=15.65, SD=1.44) than the control group (M=12.13, SD=2.19). The independent t-test conducted on the post-test scores in the control and experimental groups revealed a significant difference between the two mean scores (t=-9.544, p<0.05). From the results of this study, a Cohen's d value of 0.89 indicates a high degree of practical significance of using FIBL approach on students learning outcomes.

The results in **Table 3** shows a significant difference in chemistry academic achievement in favor of females (t=-2.55, p=0.012). The mean achievement score difference of the females (1.21) was higher than that of the male counterparts with 0.84. The difference in learning outcomes indicates gender influences students' chemistry with females achieving higher than males.

Effects of Flipped Inquiry-Based Learning on Students' Critical Thinking Skills

Analysis of the critical thinking skills results showed a normal distribution in the pre-test data sets with no significant differences between the two group mean scores (t=0.413, p=0.681).

As shown in **Table 4**, the analysis of the critical thinking skills showed a normal distribution, with students in the experimental group obtaining higher scores (M=15.22, SD=1.77) than the control group (M=13.60, SD=2.18). An independent t-test showed significant differences between the control and experimental classes scores (t=-4.088, p<0.05) and a high effect of 0.81.

Students' Views on Learning in a Flipped Inquiry-Based Learning Environment

The results obtained from the focus group with students (six males and four females) showed they had a positive attitude about learning in the FIBL environment. Most of the students had a favorable view of the approach. Some of the positive views were:

> The ability to review the videos by pausing and rewinding them many times (P9, female).

> Being able to learn at our own convenient time and pace (P3, male).

> There is more opportunity to work and learn with peers (P5, female).

> Tutors were always available to answer students' questions for clarification (P4, male).

When asked how the approach contributed to their learning, the students mentioned the approach impacted their learning, thinking skills, and collaboration with peers. Three participants believed the FBIL enhanced their conceptual understanding. Some comments expressed by the students are, as follows:

> The learning activities helped in the understanding of content and deepening knowledge construction (P8, female).

> It helps students to gain a deeper understanding of content rather than memorizing the ideas from the learning materials and knowledge gained (P10, male).

Further, the students stated that working on tasks independently and with peers in the learning process enhanced their skill development, e.g., problem-solving, and critical thinking. Some comments explaining the development of skills are shown below:

> FIBL approach help students internalize the conceptual process and interpret what they have learned in real-life situations, and solve problems (P3, female).

> The approach is helpful as students could use learning experiences to critically think when solving daily life problems (P9, female).

DISCUSSION

This study investigated the effect of FBIL approach on pre-service teachers' achievement in chemistry and examined their views on the FIBL approach. In our study, pre-service teachers studied the course materials before class and discussion sessions, promoting students' independent learning. The results of our study are consistent with the literature on effective combined flipped learning and inquiry-based learning models on students' learning. For instance, several previous studies have reported that students engaging in collaborative learning and face-to-face and online interactions enhance students' knowledge experiences, engagement, achievement, and thinking skills (Murillo-Zamorano et al., 2019; Shih & Tsai, 2017; Ye et al., 2019). The benefits of flipped and inquiry-based learning suggest that students' engagement in collaborative work and task reflection improves their ability to construct knowledge and develop thinking skills.

The main findings of this study revealed that students' academic achievement in the experimental group was higher than students in the control class. The results of the pre-test analysis in the control and experimental classes before the intervention show pre-service teachers in both classes had identical achievement scores. After the intervention, the findings show a statistically significant difference in academic achievement between the control and experimental groups, with students in the flipped-inquiry-based class scoring higher on each assessment than in the control class. This can be attributed to pre-service teachers' better understanding of the content by spending much time in discussions, problem-solving activities, and practicing theoretical knowledge. In agreement with this finding, prior studies indicate the FIBL approach help increase students' academic achievement in chemistry (Aumi & Mawardi, 2021; Bokosmaty et al., 2019; Paristiowati et al., 2017). This study confirms previous studies that the flipped inquiry learning activities are more effective and directly affect students' deeper learning and increase academic achievement than the lecture approach (Cay & Karakus, 2022; Tsai et al., 2015). Similarly, other studies in the literature have concluded that students in FBIL environments are more likely to perform better as the approach positively enhances students' conceptual understanding of the subject or content (Ye et al., 2019). Unlike the didactic approach of teaching, students are passive which leads students' disengagement in the learning process. As pointed out, students in conventional class lack the capacity to ask questions for ideas clarification and leads to inadequate understanding of concepts (Addae & Quan-Baffour, 2018).

This study showed that gender has significant influence on student chemistry learning outcomes, with females outperforming the male counterparts. This finding is in line with other studies that found female students achieve higher in chemistry than males (Boz et al., 2016; Eugene & Ezeh, 2016). This finding did oppose other studies that report male students achieve higher scores in chemistry than females (Tenaw, 2013; Yewande, 2015). On the other hand, other studies have found non-significant differences between male and females test scores in chemistry (Oladejo et al., 2021; Shehu, 2015). These findings present an inconclusiveness in gender achievement in chemistry in learning context.

It is believed that employing effective instructional approaches that creates opportunities for students to be highly engaged in the learning process enhances the development of learning skills. Also, students taught with a more collaborative learning approach in a context-based teaching promote the development of critical thinking and problem-solving skills. In the flipped inquiry based learning environment, students are engaged in collaborative learning activities that involve applying and analyzing content learned. Students build new knowledge to enhance their thinking skills and abilities through constant engagement and collaborative learning. This study showed pre-service teachers in the experimental class scored higher in the critical thinking skills in the post-test than in the control class. Through the active engagement, pre-service teachers in the experimental class developed more conceptual understanding and developed thinking skills that enabled them to move beyond understanding to knowledge application and synthesis. The finding is similar to previous studies that find FIBL could promote creativity, critical thinking and problem-solving skills in chemistry (Karyadi et al., 2020; Paristiowati et al., 2019). It can be concluded that flipped classroom and inquiry-based learning are effective learning approaches that enhance knowledge development of new skills that facilitate learning real-life problems.

Further, previous studies have found students develop positive attitudes toward learning in the flipped-inquiry-based learning environment (Love et al., 2015). Results from the focus group revealed that pre-service teachers had expressed positive attitudes and views about learning in a flipped inquiry-based environment than the didactic approach. Since students were provided with activities to learn at their own pace, they can practice and engage more on the tasks. Self-study and independent learning improve students' learning outcomes by enabling them to control and engage more with learning materials. In line with previous studies, students in the flipped inquiry environment work at their own pace, enabling them to take responsibility for their learning and become active learners (Awidi & Paynter, 2019). Some participants responded that flipped-inquiry-based instructions enabled students to apply their knowledge in everyday life, review the video lectures, and learn at their own pace. Against this fact, it is likely to conclude that pre-service teachers in the flipped class gained more opportunities to reflect and learn the materials independently at their convenience. These findings confirm that the FIBL approach substantially impacts students learning. In FIBL settings, lectures are moved from in-class to create a free space for discussions and collaborative learning activities among peers and the educator. This finding is in the literature that the collaborative aspect of the FIBL approach helps students nurture their passion and interest in the content, resulting in positive experiences and attitudes toward the approach (Capaldi, 2015; Loizou & Lee, 2020).

Limitations

This research has some limitations. Firstly, the sample consisted of only 100 pre-service teachers selected from only one college of education in Ghana; therefore, the findings cannot be generalized in a broader context. Another limitation was that from the observation participants face challenges with to inadequate resources, e.g., lack of digital tools and poor internet connectivity. This resulted in some participants not adequately prepared for pre-class activities, e.g., watching videos. Again, since the pre-service teachers were from the same college of education, researchers cannot verify whether there was any communication among themselves.

CONCLUSION

This study has revealed that combining flipped classroom and inquiry-based learning models has positive benefits, e.g., improving students' performance, critical thinking and developing good learning experiences fostering critical thinking skills. Even though pre-service teachers had difficulty in IUPAC naming and writing structures of hydrocarbons, they could overcome this challenge with FIBL approach to enhance their conceptual understanding. Findings from this study that a combined flipped-inquiry-based model could effectively be used to deliver IUPAC naming concepts to students to improve their learning attitudes, academic performance, and critical thinking skills. This current study recommends chemistry educators to use the IBL and FL approach to stimulate students' chemistry learning and achieve desired learning objectives. Chemistry educators and researchers could design and implement the curriculum materials to suit the model for teaching organic chemistry concepts. Gender difference in chemistry learning outcome was in favor of females and does not infer the number of females outnumbering the males contributed to the difference in performance. This shows that despite the gender imbalance in the population, chemistry educators could employ effective pedagogical approach that can promote chemistry knowledge, skills and values to attain the goal of building capacity for female scientists. Future research is needed to study students' perceptions of using IBL and FL models in K-12 education. It is also recommended that future studies be conducted to explore teachers' views on using a combine flipped inquiry based learning approach in higher education.

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