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ORIGINAL ARTICLE

High School Students' Statistical Literacy Changes in a Flipped Classroom Environment: A Quasi-Experimental Study

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ABSTRACT
Statistics in the 2018 Vietnam General Education Curriculum for Mathematics is emphasized from Grade 2 to Grade 12, helping develop students' competences and qualities. However, students still struggle to connect and apply statistical concepts to real-life situations. This study used a flipped classroom model to teach 10th-graders statistics to develop their statistical literacy. Using a quasi-experimental design, we evaluated how the students' statistical literacy developed as they participated in the flipped classroom. The results show that the flipped classroom improves students' statistical literacy. All four categories of statistical literacy increased statistically significantly, including graphical displays, measures of central tendency, measures of variability, and using statistical knowledge to solve problems. The results are explained by the opportunities embedded into the program. Time outside of class was used for the students to review content and access new concepts, along with questions to demonstrate their statistical knowledge and reveal shortcomings. The students spent the most of their interaction time in class on activities to understand concepts and applied them to real-life situations. Some lessons learned from the study are discussed.

1. INTRODUCTION

The Vietnam 2018 Mathematics General Education Curriculum aims to develop learners' competence and qualities, focusing more on statistics. At the high school level, statistics focuses on analyzing and processing data, measures of central tendency, and measures of variability for ungrouped data samples (Grade 10) and grouped data samples (Grade 10, 11, 12). From there, students can draw a statistically meaningful conclusion, understand the meaning of typical statistics in practice, and recognize the relationships between statistics and knowledge of other subjects in the curriculum. Thus, it is apparent that statistical literacy is the central goal of statistics in the current high school program, helping students interpret the meaning of statistics in real life through describing, representing, analyzing, and processing data or assisting students in developing statistical literacy.

Statistical literacy has kept an important role in statistics education over the past 20 years (Callingham & Watson, 2017). In today's data-driven technological society, understanding and applying statistical knowledge in daily life and work is essential for all citizens. Citizens without statistical knowledge will have difficulty distinguishing between reliable and unreliable information and face challenges in understanding, interpreting, evaluating, and making intelligent decisions with information (Watson, 2014). However, statistical literacy is often overlooked in schools, focusing primarily on procedural and computational aspects rather than developing conceptual understanding. Therefore, students struggle to connect and apply concepts to situations where they must draw conclusions related to real life (Nguyen & Tran, 2024).

To overcome this difficulty and develop statistical literacy for students, it is necessary to use teaching strategies that help students understand statistical concepts and apply them to solve real-life problems. A flipped classroom (FC) model is a potential strategy to help achieve the above goal. Strayer (2012) and Wilson (2013) compare the effectiveness of a flipped classroom with a traditional classroom when teaching statistics at undergraduate level. Their results show that FC enhances learning motivation and leads to learning more meaningful statistics. Furthermore, Winquist and Carlson (2014) asserted that one year after completing an introductory statistics course taught through the FC model, students in the FC class outperformed students in traditional classes. However, studies evaluating the effectiveness of FC in teaching statistics at the high school level are still limited. This study addresses the question: How does students' statistical literacy develop when participating in an FC model?

2. LITERATURE REVIEW

2.1. Statistical literacy

In today's data-driven technological society, statistical literacy is critical for everyone (Watson, 2014). Research claims and reports appear frequently in the media, and to make informed decisions, we must rely on statistical literacy instead of emotions and beliefs (Frost, 2013). According to Wallman (1993), statistical literacy is the ability to understand and critically evaluate statistical results that appear in everyday life and use statistical thinking to make decisions related to personal, professional, and social life. This definition requires that students have mathematical skills to understand statistical information and the social context in which the data are located. Nearly a decade later, Gal (2002) expanded and introduced a definition of statistical literacy, including (a) the ability to interpret and evaluate statistical information, reason based on data or random phenomena in different contexts; (b) the ability to express reflections on statistical information, such as opinions about the meaning of the information or concerns about the acceptability of the conclusions. Watson (2006) defines students' statistical literacy as using statistical tools, contextual knowledge, and critical skills to make appropriate decisions in unfamiliar situations. Watson (2006) further suggests different components of statistical literacy, such as graphical displays, measures of central tendency, and measures of variability.

Thus, statistical literacy includes the use of basic statistical concepts, terms, and symbols, as well as the ability to organize data and work with different forms of data representation to understand, interpret, and evaluate the real world around them (Garfield et al., 2010). Watson and Callingham (2003) argue that statistical literacy develops when students are exposed to various contexts. Watson and Callingham also propose a three-level model of statistical literacy consisting of (a) understanding basic statistical concepts, (b) understanding statistical concepts as they appear in real-world contexts, and (c) the ability to question statements made in contexts that lack appropriate statistical interpretation.

Statistical literacy is crucial for society in general and helpful for everyone in making decisions based on data. The NTCM mathematics teacher community (2002) offers four steps to solve problems in statistics, as follows:

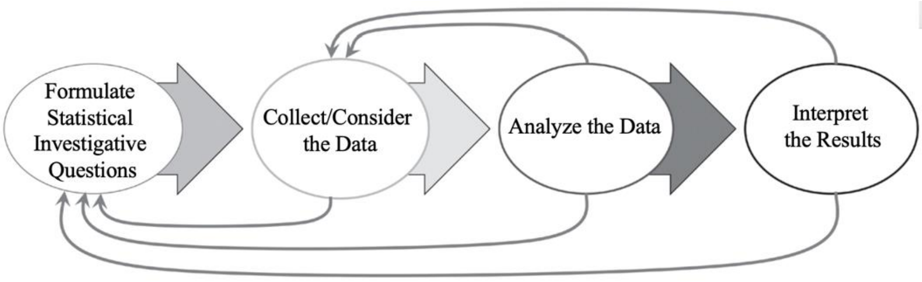

Figure 1. Diagram of statistical problem-solving process

Statistical literacy plays a crucial role and connects the above steps. To solve a problem, students must collect and analyze the data to answer and explain their reason. Students need to recognize related, connected statistical concepts and apply their understanding in situations, such as measures of central tendency and variability of the data sample.

2.2. Flipped classroom model

The flipped classroom (FC) is a learning model that combines online and face-to-face learning (Cevikbas & Kaiser, 2022). Students watch online lectures before class, and class time is reserved for active learning, such as problem solving, group work, and quizzes, with teachers' support. Although FC still relies on lectures assigned for students to preview at their own pace, the lectures need to be designed to be easier to understand, avoiding cognitive overload (Karaca & Ocak, 2017). Then, active participation in the classroom is maximized, increasing learners' autonomy and enjoyment (Dove, 2013). The teacher's role also shifts from imparting knowledge to guiding and organizing learning activities, creating opportunities to better assess students' understanding (Farmus et al., 2020).

The results based on the analysis of 97 research articles on FC in mathematics teaching demonstrate that FC is a promising pedagogical method that brings many benefits to mathematics teaching and learning (Cevikbas & Kaiser, 2022). Similarly, a systematic review by Lo et al. (2017), analyzing FC model studies in the context of college and secondary mathematics education to examine its effects on learners, finds that FC brings more effective learning than traditional classrooms.

Besides, students' attitudes change more positively (Brooks & Weaver, 2017); students are free to interact with the learning context at their own pace and are more responsible for learning (Leavy & Hourigan, 2016). The FC model encourages students to improve their critical thinking abilities, clarify the goals of cooperative learning, and think about mathematical problems before participating in classroom activities (Voigt et al., 2020). The FC model helps teachers make the most of their time outside the classroom and carry out learning activities effectively in the classroom to develop competent students. This is also the goal of Vietnam's 2018 high school general education curriculum. Research has highlighted FC as a potential model to support student learning. Therefore, it is logical to ask how an FC model helps Vietnamese students develop statistical literacy.

3. MATERIALS AND METHODS

To answer the research question, we use a quasi-experimental method. Information about the research participants, the research tools and design is presented as follows.

3.1. Research participants

The participants in this study include 89 10^{th}-graders in two classes, 10A4 and 10A10, at Chau Thanh High School, Ba Ria City, Ba Ria Vung Tau Province. This is a convenience sample, meaning that these classes were chosen because of their closeness and willingness to participate in research (with the teacher as a researcher in this study). In addition, students of these two classes are equivalent in academic performance.

The study was conducted in the second semester of the 2022-2023 school year and lasted seven weeks. This is the first school year for 10^{th}-grade students to study the new curriculum. Conducting research in this context is appropriate as the statistical content in the program is more up to date, focusing on understanding the meaning of statistical concepts and applying statistical knowledge to solve real-life problems. Two classes were randomly assigned into an experimental group and a control group. The experimental group (Class 10A4) was studied according to the FC model, and the control group (Class 10A10) followed the traditional model. The same teacher taught these two classes to ensure that the change in outcomes (if any) is due to the different experiences of the two classes.

3.2. Research design

To begin the research, 89 students took a pretest on statistical literacy in Week 6 of the semester. Next, the teacher taught two lessons of Grade 10 statistics in seven hours (three weeks); the experimental class was conducted in a flipped classroom model with content focusing on statistical literacy, while the control group was taught with the traditional model and textbook content. At the end of the study, students in both classes took the posttest with the same content as the pretest.

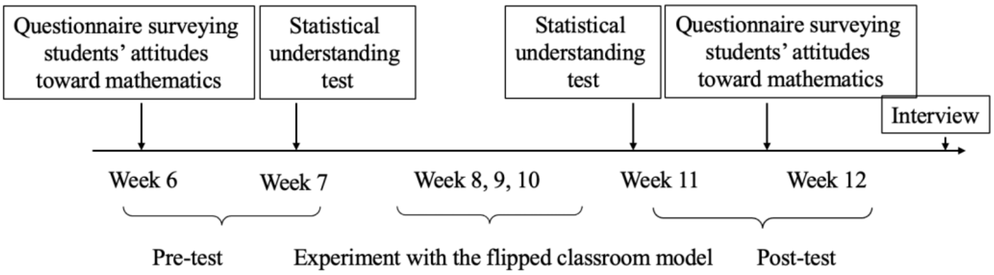

Figure 2. Experimental plan

The flipped classroom model in this study was designed so that before class, the students reviewed relevant knowledge and accessed new knowledge through short videos. Class time was spent on activities to understand concepts, connect concepts, and solve problems, thereby developing the students' statistical literacy. Figure 3 summarises one lesson in the FC.

	Before studying in class	While studying in class	After studying in class
Target	• Students understand basic types of charts. • Students understand how to calculate and the meaning of average, median and mode.	• Students deeply understand the concepts of mean, median and mode. • Students know how to apply knowledge to solve related problems in practice.	Consolidate learned knowledge about average, median and mode.
Content	• ***Content 1:*** Students watch a review video about types of charts. • ***Content 2:*** Students watch a video to review average and median numbers (calculation, meaning) and introduce the concept of fashion. • ***Content 3:*** Students complete individual study sheets and submit them to the website.	• The teacher summarizes the main contents of the lesson: basic types of graphs, calculation and meaning of average, median and mode. • The teacher corrects individual study sheets and corrects students' mistakes. • Activity 1 helps students deeply understand the concepts of mean, median and mode. *Get height data of students in class.* *a. Calculate the average height of students in the class.* *b. How many students are of equal height in the class?* *c. If our class adds Ren Keyu whose height is 221cm, what is the average height of everyone in the class right now? Can this value represent the height of the layer? Explain how.* *In your opinion, when should we use mean, median, mode to represent a data sample?* • **Learning activity 1** helps students apply understanding of the concept of concentration to problem solving in real situations.	Exercises in the textbook
Product	Personal study sheet	Students' work on learning activities 1 and 2	Student's work
How to perform	Students watch contents 1, 2 and complete content 3 at home ((individually).	Participate in group interactive learning activities.	Students do their homework in their notebooks (individually).

Figure 3. Summary of a lesson plan in the FC

The statistical literacy test consists of nine questions that require students to select answers and provide explanations. Questions were adapted from previous research on statistical literacy (Watson & Callingham, 2003; Tran et al., 2022) and translated into Vietnamese with updated contexts familiar to Vietnamese students. The questions are divided into four groups to measure statistical literacy.

- Group 1 includes Question 5: Assessing ability to read and understand charts;
- Group 2 includes Questions 1 and 4: Assessing understanding of measures of central tendency;
- Group 3 includes Questions 2 and 9: Assessing understanding of measures of variability;
- Group 4 includes Questions 3, 6, 7, and 8: Assessing statistical problem-solving ability using the above concepts.

3.3. Data collection and analysis

Research data included 89x2 pre- and post-tests of statistical literacy in a paper-and-pencil format. To analyze the data, we used quantitative and qualitative analysis methods. Quantitative data are the results of evaluating student responses to questions. All answers were coded into four levels (0, 1, 2, and 3), except for the answers to Question 5, which were coded into two levels (0 and 1). The coding scheme was based on previous research (Watson & Callingham, 2003; Tran et al., 2022). Next, we calculated the average score for each group of questions and the entire test. We then compared the pretest scores between the experimental and control classes to check the equivalence of the two groups. We also compared the pre and posttests of each class using a t-test of two samples on SPSS software. Qualitative analysis was applied to students' explanations of the questions, focusing on how statistical literacy was evident and the different levels they used their understanding to solve statistical problems.

4. RESULTS AND DISCUSSION

Equivalence of the two classes at the beginning of the study

The results of the t-test analysis with the nine questions using SPSS-26 software are shown in Table 1. The results with the total pretest scores of the experimental and control classes show no statistical difference (row 4 - Table 1); the difference between the two classes is 0.2 with a coefficient sig. p=0.76. So, the experimental and control classes' statistical literacy could be considered equivalent prior to the treatment.

Table 1. Comparison of the pretests and posttests of two classes (t-tests)

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-
				Lower	Upper			
Post- Pre control class	.94	3.52	.52	-.11	2.00	1.80	44	.079
Post- Pre experimental class	9.7	4.76	.72	8.26	11.15	13.53	43	.000
Post experimental class - control class	8.60	4.15	.63	7.34	9.86	13.74	43	.000
Pre experimental class - control class	-.20	4.34	.65	-1.52	1.11	-.31	43	.756

Changes from the pretest to the posttest

When comparing the post-test results with the pre-test results, it was shown that both classes improved, but the increase in the control class was not statistically significant (p=0.08, see row 4 of Table 1). The experimental class' increase was statistically significant (average score increased by 9.7 and p=0.00, see row 2 of Table 1). In addition, the posttest results of the experimental class were also significantly higher than those of the control class. The experimental class scored 23.57, 8.6 points higher than the control class (p = 0.00, see row 3 of Table 1). Thus, from the above results, it can be said that the FC has helped develop students' statistical literacy.

Next, we compared the post-test and pre-test results of four groups of statistical literacy questions (Table 2) in the experimental class: understanding graphs, measures of central tendency, measures of variability, and solving statistical problems. The results show that in all four groups of questions, the students in the experimental class made statistically significant progress (p = 0.00) (Table 2). Particularly, the score of the questions on solving statistical problems increased the most, with an increase of 5.02 points. The chart reading comprehension group's score increased slightly (0.75 and p = 0.00).

Table 2. Statistics of pre-test and post-test scores by group of questions

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Reading and understanding the chart	.75	1.06	.16	.43	1.07	4.70	43	.00
Understanding measures of central tendency	1.00	1.51	.23	.54	1.46	4.40	43	.00
Understand dispersion measures of variability	2.93	1.98	.30	2.33	3.53	9.81	43	.00
Solving statistical problems	5.02	3.14	.47	4.07	5.98	10.62	43	.00

Qualitative analysis

To look more clearly at the changes in the students' statistical literacy in the experimental class, we qualitatively analyzed each group. The proportions of the coded levels of each question are shown in Table 3:

Table 3. Average score for each question of the post and pretest

Level	Measures of central tendency		Measures of variability		Statistical Problem-solving ability			
	Q1	Q4	Q2	Q9	Q3	Q6	Q7	Q8
	Posttest (Pre)	Posttest (Pre)	Posttest (Pre)	Posttest (Pre)	Posttest (Pre)	Posttest (Pre)	Posttest (Pre)	Posttest (Pre)
0	1 (2)	0 (8)	1 (14)	3 (23)	5 (16)	0 (10)	1 (14)	1 (8)
1	0 (3)	4 (2)	4 (11)	7 (7)	6 (21)	9 (31)	3 (9)	4 (25)
2	21 (17)	8 (27)	5 (15)	4 (10)	6 (7)	14 (0)	15 (15)	26 (9)
3	22 (22)	32 (7)	34 (4)	30 (4)	27 (0)	21 (3)	25 (6)	13 (2)
Mean	2.46 (2.34)	2.64 (1.75)	2.64 (1.21)	2.39 (0.89)	2.25 (0.8)	2.27 (0.91)	2.46 (1.3)	2.16 (1.11)

Changes in understanding of graphical displays

For the group of questions testing chart reading comprehension (Question 5 including 5a, 5b, 5c, 5d, 5e), the results of the experimental class increased statistically significantly (average score increased by 0.75 and p=0.00, see row 1 of Table 2).

For example, in the pre-test, a student's work on questions 5d and 5e received 0 points. Figure 4a illustrates such an answer. Here, the student gave a subjective answer based on his living conditions and family economy. However, that explanation was not reasonable because it was completely not based on data analysis on the given chart.

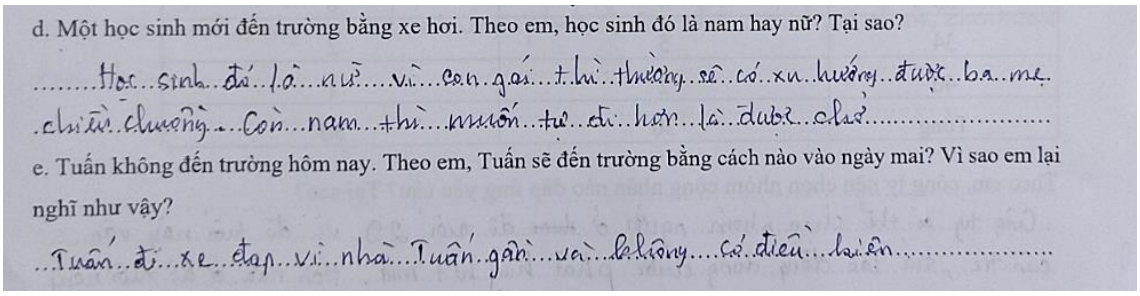

Figure 4a. Samples of answers to Question 5d and 5e (Pre) of students achieving Level 0

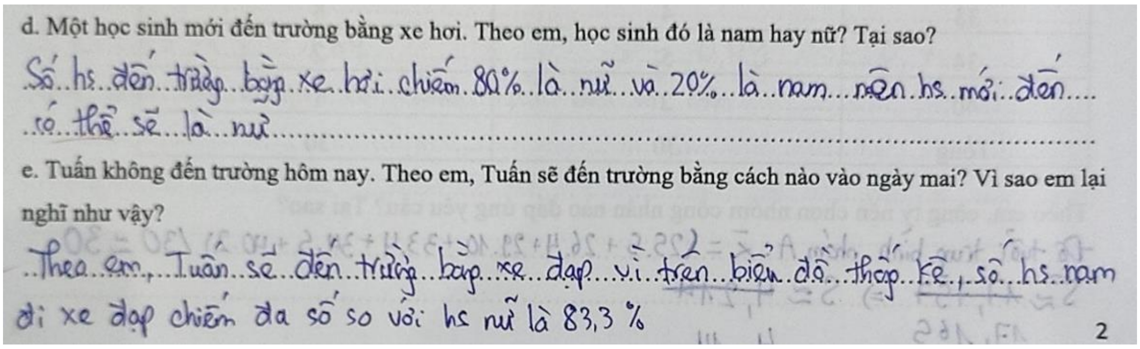

Figure 4b. Samples of answers to Question 5d and 5e (Pre) of students achieving Level 3

Figure 4. Sample student responses to Question 5

However, in the posttest (Figure 4b), the same student showed progress and reached the maximum score (1 points - Level 3). This student understood statistics better based on data analysis on the chart about the ratio of male and female students going to school by car. From that result, the students provided a reasonable answer that a student coming to school may be female.

Changes in understanding of measures of central tendency

For the group of questions testing understanding of measures of central tendency (Questions 1 and 4), the results of the experimental class increased statistically significantly (average score increased by 1.00 and p=0.00, see row 2 of Table 2).

Figure 5 detailed Q4, evaluating students' understanding of measures of central tendency.

Câu 4. Một vật nhỏ lần lượt được cân bởi 9 học sinh ở một lớp Khoa học. Khối lượng của vật (đơn vị gam) được ghi lại bởi 9 học sinh như sau:

6,3 6,0 6,0 15,3 6,1 6,3 6,2 6,15 6,3

Tìm giá trị đại diện cho mẫu số liệu cân nặng của vật. Giải thích cách làm của em.

Figure 5. Question 4 evaluating students' understanding of measures of central tendency

This question tests students' knowledge of how they use measures of central tendency to select a representative value for the data sample (addressed in the first lesson). Most pretest responses (61.4%) were coded at Level 2 when students chose the average of nine data to represent the sample (without eliminating the data value 15.3). However, some students were confused when they did not know which data to choose to represent the sample, and the number of students who left their responses blank (did not answer) (coded as Level 0) was 18.2%. In the posttest, the percentage of students reaching Level 3 accounts for 72.7%. The following student work explains that because of the outlier 15.3 in the sample, he chose the median as the appropriate representative of the sample (coded as Level 3).

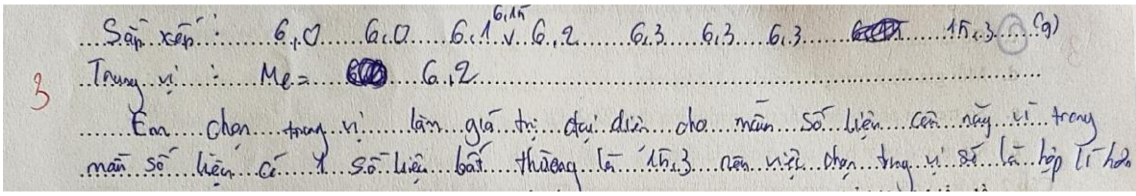

Figure 6. A student response achieving Level 3 in Question 4

In this question, the students recognized the concept of median as an appropriate value to represent the sample. The students ordered the data sample into a non-decreasing series. The response also explained in detail why the median was chosen to represent the data sample. The following example illustrates the response coded at Level 2.

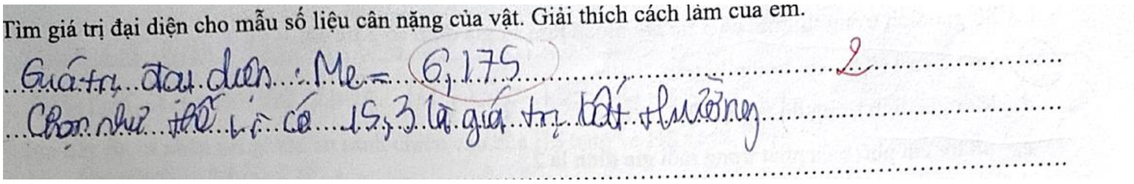

Figure 7. Sample of student response to Question 4 achieving code level 2

In the above response, the student recognized the outlier 15.3 and chose the mean of the data sample after eliminating the outlier. This is a reasonable and creative choice when they clearly understand and effectively apply the concept of mean. However, the response was coded at Level 2 because the student did not explain why 6.175 was chosen as the mean of the data sample consisting of eight data points (after removing 15.3), and he made a mistake in the symbol for the average. It can be seen that they understood the selection of appropriate values to represent a sample.

Changes in understanding of measures of variability

For the group of questions testing understanding of measures of variability (Questions 2 and 9), the results of the experimental class increased statistically significantly (average score increased by 2.93 and p=0.00, see row 3 of Table 2).

The following illustrates one question in this group.

Câu 2. Một cổ động viên của câu lạc bộ Everton, Anh đã thống kê điểm số mà hai câu lạc bộ Leicester City và Everton đạt được trong năm mùa giải của giải Ngoại hạng Anh gần đây, từ mùa giải 2014 – 2015 đến mùa giải 2018 – 2019 như sau:

Leicester City:	41	81	44	47	52.
Everton:	47	47	61	49	54.

Cổ động viên đó cho rằng, Everton thi đấu ổn định hơn Leicester City. Em có đồng ý với nhận định này không? Vì sao?

Figure 8. Question 2 in the test

For example, a student's response was coded at Level 0 in the pre-test and Level 3 in the post-test (Figure 8a, 8b). In the pre-test, this student compared the average scores achieved by the two clubs in five seasons. However, that value did not take into account the clubs' stability. In the posttest, this student knew how to use the interquartile range to measure the variability of scores achieved by the two clubs, thereby concluding that the Everton team played more stably than Leicester City.

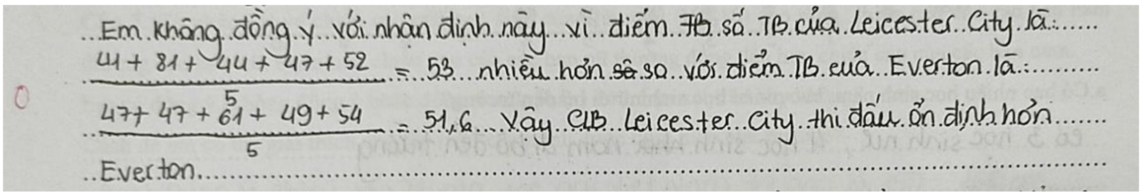

Figure 9a. Sample student response to Question 2 (Pre) achieving code level 0

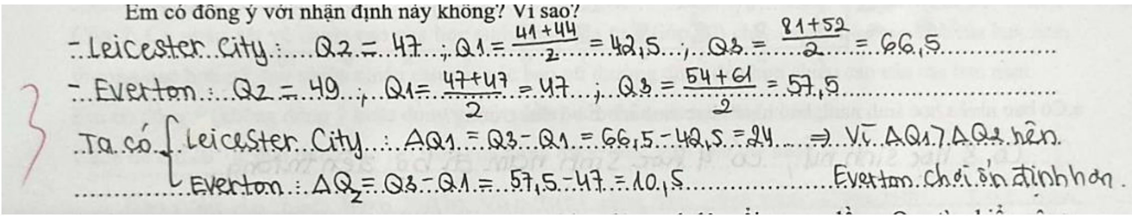

Figure 9b. Sample student response to Question 2 (Post) achieving Level 3

Figure 9. Sample student responses to Question 2

Changes in solving statistical problems

The results of students' scores on four questions concerning the statistical problem-solving group all increased with statistical significance. In particular, Question 6 received a score of 3, increasing by 41% and a score of 0, decreasing by 22.7%.

Câu 6. Có nhận xét về chiều cao của học sinh cùng lứa tuổi (lớp 10) cho rằng, chiều cao của các bạn nam thường cao hơn nữ, tuy nhiên chiều cao của các bạn nữ thường đồng đều hơn chiều cao của các bạn nam.

Em có đồng ý (không đồng ý hoặc đồng ý một phần) với nhận xét trên hay không?

Cách để em có thể giải thích cho lập luận của mình được thực hiện như thế nào?

Figure 10. Question 6 in the test measuring statistical problem-solving

In the pre-test, 93.2% of the students achieved scores of 0 and 1, and only 6.8% achieved scores of 2 and 3. About 22.7% did not recognize the problem that needed to be solved, while 70.5% identified the problem that needed to be solved. Still, they only answered by agreeing, disagreeing, or partially agreeing with the statement in the question, and the explanation was mainly subjective without being based on data. Figure 11a illustrates such an answer. Here, the student thought that female students start puberty earlier than male students, so girls' height develops from 10-15 years old and male students are taller than female students.

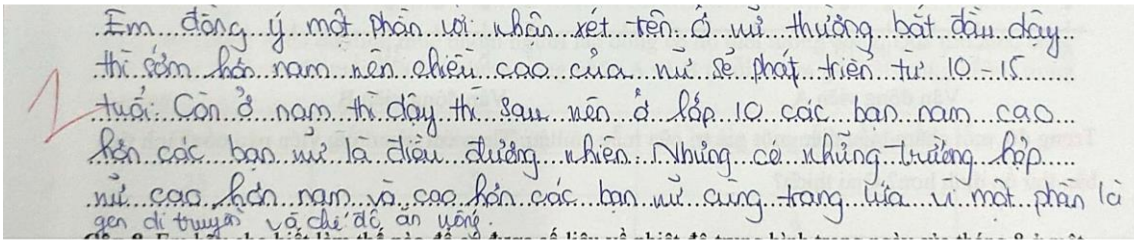

Figure 11a. Sample response to Question 6 (Pre) achieving Level 1

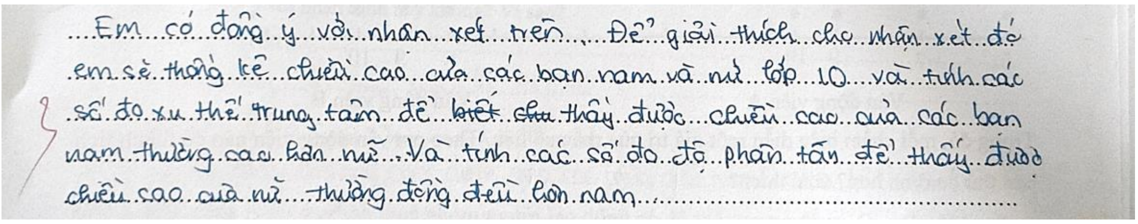

Figure 11b. Sample response to Question 6 (Post) achieving code level 3

However, in the post-test (Figure 11b), the above student showed progress in his work and reached 3 points. The student realized that the problem requires them to compare the heights of male and female students; he needed to rely on collecting and processing reasonable data samples to explain the results and answer the question. In the response, this student connected the concepts of measures of central tendency and variability to compare the heights of male and female students.

5. CONCLUSION

This study investigates the impact of FC on students' statistical literacy. The results of the pretest show the students' limited statistical literacy. Over 70% of the students demonstrated little understanding of data on graphs and how to apply their knowledge related to measures of central tendency and variability. The results can be explained by the fact that the students did not have the opportunity to engage in learning activities to understand and interpret the meaning of statistical data on the chart and use them to make statistically meaningful conclusions. The results show a statistically significant difference from the pretest to the posttest regarding overall statistical literacy scores and their four components in the experimental class. In contrast, there was no statistically significant change in the traditional class.

The learning experience in the FC might explain the results. Learning activities outside the classroom in the FC environment create opportunities for students to demonstrate the knowledge they have mastered and reveal the shortcomings that they bring before class. This reason has also been confirmed by research on how people learn with understanding (Bransford & colleagues, 2000). Based on students' learning products outside of class (e.g., study sheets assigned before class), students' misconceptions can be revealed and identified. In the FC environment, the students had time and were given opportunities to understand concepts and develop statistical problem-solving abilities. The students had time to interact with learning activities that helped them connect with the conceptual objects. The experimental class had time to explore and expand their knowledge in real life derived from the games in teaching. This finding contrasts with Clark et al.'s (2003) results that all 17 students in their study calculated the average quite easily. Still, only two of them could develop the conception of average as an object compatible with that of mathematicians and statisticians.

The results show that teaching statistics using the FC model creates an environment for students to apply their understanding to solve problems better. In particular, the results of the experimental class regarding Group 4 were much higher in the posttest compared with the pretest. With the teacher's guidance, the students interacted in groups and completed learning tasks that connect the meaning of average in real life. They provided their own opinions about a statement/prediction/drew conclusions related to statistics, or devised a strategy to confirm statistical information. This learning activity deepened the students' awareness and formed their opinions using data to draw reliable real-life conclusions. For the first time, the students realized that to be able to test a conclusion or make judgments or predictions in real life, it was necessary to rely on an appropriate statistical data sample.

The results highlight the efficacy of FC on student learning. However, many challenges must be considered when implementing it on a large scale. When implementing the FC model, the teacher encountered many challenges. Although having more than 20 years of teaching experience, the teacher found it difficult to use technology and learning systems to prepare students before class. In addition, preparing learning resources for students outside the classroom was time-consuming. According to our estimate, the time to complete a video before class is 3 to 4 times as much as that to prepare a lecture in class. Wanner and Palmer (2015) note that the time required to prepare re-rolled course materials can be nearly six times as much as traditional course preparation. This is considered the top challenge for sustainably applying the FC model to teaching mathematics. Therefore, we propose that a learning system that allows teachers to access and develop common learning resources be built. This can reduce the workload for teachers. In addition, learning resources enable teachers to learn from colleagues, constantly improve their professional capacity and pedagogical skills, and create more formal learning channels for students that are convenient for exploration and reference to the documentation. Despite facing many difficulties, the teacher had the opportunity to improve her professional knowledge when implementing FC. Considering the content selection for students before class and directly teaching them in the classroom has helped the teacher develop their practice, including implementation methods and knowledge levels (see Tran & O'Connor, 2023).

The current study provides empirical data for the effectiveness of FC. Students make the most of their interactive time in class with activities to understand concepts. Time outside of class tasks can be used for students to engage with conceptual approach activities, along with open-ended questions to demonstrate their statistical knowledge and reveal their shortcomings. Through flexibly connecting the learning process outside and in the classroom, we could help students develop statistical problem-solving.

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