J Med Edu. January-December 2024; 23(1): e145773 https://doi.org/10.5812/jme-145773

Published Online: 2024 November 2 **Research Article**

Evaluation of Knowledge, Skill and Satisfaction Level of Laboratory Sciences Students in Pre-laboratory Immunohematology Course Using Virtual Flipped Classroom

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Received: 7 February, 2024; **Revised:** 16 September, 2024; **Accepted:** 17 September, 2024

Abstract

Background: Medical education emphasizes the importance of facilitating deep learning, promoting professional behavior, and fostering skillful problem-solving in practical courses.

Objectives: To determine student satisfaction, knowledge, and skill levels using the virtual flipped classroom method for the pre-laboratory immunohematology course in laboratory sciences.

Methods: This semi-experimental (before-after) study included 42 laboratory science students who completed the practical immunohematology course. The intervention involved three steps of the virtual flipped classroom method. Knowledge was assessed with multiple-choice questions (MCQs), satisfaction was measured using a rating scale, and students' skills were evaluated using a rating scale. Data were analyzed using descriptive and analytical statistical tests in STATA 14.

Results: The results showed that the post-test knowledge score had an average of 7.42, significantly higher than the pre-test score of 4.04 ($P < 0.05$). Additionally, 92.85% of students reported being satisfied with the course. Regarding skill evaluation, 95.23% of students stated, "I think I have now really achieved it or a part of it."

Conclusions: The virtual flipped classroom method in the immunohematology pre-laboratory course had a positive impact on students' learning and satisfaction. This teaching approach has the potential to improve teaching effectiveness, create an interactive learning atmosphere, and could be implemented in similar courses.

Keywords: Virtual Learning, Flipped Classroom, Education, Teaching, Immunohematology

1. Background

The COVID-19 pandemic and the shift to virtual learning have presented new challenges in implementing practical courses, with traditional teaching methods often failing to meet learners' educational needs (1, 2). Practical course instructors have prioritized ensuring high levels of learning. Typically, practical laboratory science courses are delivered through lectures, followed by protocol presentations, conducting experiments, and sometimes demonstrations (3, 4). In today's context, learners are immersed in new technologies and have greater access to these tools than in the past. Teaching approaches can be improved by leveraging the educational potential of these technologies and blending them with traditional methods, leading to more effective outcomes for practical lessons. While traditional teaching methods are often easier to implement, their effectiveness in enhancing educational quality and learning outcomes is limited. Therefore, using innovative teaching methods is crucial for achieving better learning outcomes (5-7). The flipped classroom approach, which can be delivered virtually, has been shown to produce superior learning results compared to conventional methods (5). Virtual education also leads to greater performance and satisfaction among students and faculty members (8, 9). The flipped classroom model emphasizes student responsibility and autonomy, allowing for independent, asynchronous study of

course material and active learning during scheduled class times. Evidence suggests that flipped classrooms can effectively enhance students' behavioral and cognitive engagement (6, 10). It engages students in self-directed learning and enhances their critical thinking skills (8, 9). Flipped classrooms boost learning motivation, deepen understanding of course materials, and improve communication and clinical thinking skills (9, 11). By addressing learners' comprehensive needs and enhancing interactions and feedback, this method proves to be more effective than traditional teaching methods and increases students' overall course satisfaction (7, 12). Implementing the flipped classroom approach shifts instruction from a teacher-centered to a student-centered model, creating a more dynamic, effective, and engaging teaching-learning environment (10, 13). This method includes multiple steps and fosters a more interactive classroom atmosphere (9-12). Students collaborate to deepen their understanding and think critically to solve problems. However, this approach may not be suitable for all students or majors, as it requires more preparation and out-of-class activities (10, 14, 15).

Currently, offering practical classes in laboratory science that adopt student-centered approaches seems increasingly necessary. Most existing studies focus on theoretical courses with different contexts, approaches, settings, and sample sizes. Many practical courses in the medical laboratory science curriculum require special attention to achieve higher levels of learning and skill development. Therefore, this study aimed to assess the effectiveness of the virtual flipped classroom learning method in the immunohematology pre-laboratory course. Specifically, it aims to determine student satisfaction, knowledge, and skills acquired during the course at Hamadan University of Medical Sciences in 2023.

2. Objectives

To assess student satisfaction, knowledge, and skill levels using the virtual flipped classroom method for the pre-laboratory immunohematology course in the field of laboratory sciences.

3. Methods

3.1. Study Design and Participants

This semi-experimental (before-after) study was conducted after the researchers thoroughly explained the project's aims and implementation methods to the students. After obtaining informed written consent, the students participated in the study. The sampling method was purposeful and included all participants, with a total of 42 undergraduate laboratory science students who had selected the immunohematology practical course in the first semester of the 2022 - 2023 academic year. The inclusion criteria for participation in the immunohematology laboratory course were based on students meeting the educational requirements and completing the necessary prerequisites.

The plan for the immunohematology laboratory course, including its educational objectives, content, teaching/learning methods, and student assessment methods, was approved by the Department Of Laboratory Sciences and the lesson plan committee of the Education Development Center (EDC). The teacher created audiovisual educational materials using Camtasia software, and relevant podcasts and textbooks were introduced or sent to the students. Administrative procedures were carried out to secure the necessary permissions for using the university's facilities and equipment, including access to the Navid/Sama system and the LMS system. Forums for student discussions, assignments, instructional videos, and required resources were uploaded to the system. Before the start of the course, study guides covering the course plan, guidelines for internet access, instructions on how to use the Navid/Sama and LMS systems, submission procedures for assignments, and class regulations were sent to students via common social media platforms (such as Eitaa and Rubika). The classroom and laboratory schedules and locations were also provided.

3.2. Implementation of Teaching Method

The virtual flipped classroom method was implemented considering three steps as follows.

3.2.1. Before Class

The educational objectives for each lesson were sent via the designated social media platforms or the LMS system. The format and type of content were shared with the students, and the schedule for the online or face-to-face practical classes was established. The teacher provided educational materials in the form of recorded lectures, videos, podcasts, and texts for students to review before class. Students were also assigned questions and tasks to complete at home.

3.2.2. During the Class

Online classes were conducted on Adobe Connect. Each session began with a 10-minute overview of the topic, presented by a group of students using slides and

PowerPoint. Following this, the teacher led a 10-minute Q&A session to clarify any content-related questions. Various cases, scenarios, and/or problems were then introduced by the facilitator, all designed according to the educational objectives of the session. For example, during the session on ABO system discrepancies, samples showing a mismatch between forward and reverse typing results were presented and discussed. Students were tasked with resolving the problem. In the case of Rh system mismatches between mother and fetus, a relevant scenario was outlined to guide students in determining the best approach for addressing the situation. Afterward, students were required to submit a written summary of their work and activities. The final 15 minutes of the class were dedicated to the teacher summarizing and addressing scientific knowledge gaps. To further enhance their learning, students communicated with the teacher as a group through social media platforms.

After delivering the educational content through several sessions of the virtual flipped classroom, a practical class was conducted in the laboratory. At the beginning of each session, a multiple-choice test was administered to assess students' understanding of challenging topics, with the assurance that the results would not impact their final grade. The correct answers were then reviewed to ensure that all students were aware of the correct information. Following this, the practical steps of the experiments were thoroughly explained to the students. Assignments, which had been made available to the students beforehand, were discussed in small groups. The groups worked collaboratively, discussing concepts, persuading one another, and refining completed tasks either within or across groups. Group work was carried out under the direct supervision and guidance of the teacher, who acted as a facilitator. The teacher also provided feedback, reinforcing the importance of following class rules and maintaining the schedule.

3.2.3. After the Class

The teacher reviewed the assignments and projects. The grading method followed the same criteria as the final exam, forming an integral part of the overall assessment. Additionally, scores were allocated for in-class activities such as delivering online mini lectures, participating actively in discussion forums, attending class sessions, completing assignments, conducting laboratory practices, and contributing to group projects.

3.3. Evaluation

The students' learning outcomes were evaluated based on knowledge and skill levels using specifically designed tools. The knowledge assessment (pre-test and post-test) involved a researcher-designed test containing 15 multiple-choice questions (MCQs) derived from the immunohematology course content. The test's structure was reviewed by two medical education experts using the Millman checklist, and necessary revisions were made. Each correct answer received a score of 1, and incorrect answers were given a score of 0. The minimum score was 0, and the maximum score was 15.

To assess students' satisfaction with the course, Talimkhani's satisfaction rating scale, with a Cronbach's alpha of 0.89, was used (16). This scale consisted of 17 items rated on a 6-point Likert Scale, ranging from "completely satisfied" to "completely dissatisfied" (scored 0 to 5).

The students' skill levels were evaluated using a researcher-made rating scale consisting of 11 items, rated on a 4-point Likert Scale, with possible scores ranging from 1 to 4. The total scores on this scale ranged from 11 to 44 and were collected two weeks after the teaching was implemented. The face and content validity of the skill scale were confirmed by expert colleagues, and its reliability was verified with a Cronbach's alpha of 0.75. At the end of the academic semester, a summative assessment of students' practical skills in the immunohematology course was conducted through an objective structured practical examination (OSPE).

3.4. Data Analysis

Data were analyzed using STATA version 14 software after data collection. Descriptive statistical indices, including frequency, percentage, mean, and standard deviation, were used to describe the variables. Due to the non-normal distribution of knowledge scores before and after the intervention, the non-parametric equivalent of the paired *t*-test, the Wilcoxon signed-rank test, was employed to compare the pre- and post-test scores. A statistical significance level of less than 5% ($P < 0.05$) was considered for all analyses.

4. Results

The participants' ages ranged from 19 to 21 years, with a mean age of 20 ± 10. The group consisted of 15 females (35.7%) and 27 males (64.3%), totaling 42 students. The Kolmogorov-Smirnov test on the knowledge scores before and after teaching was statistically significant ($P < 0.05$). Therefore, non-parametric analysis was

performed to evaluate the knowledge scores before and after the teaching.

The implementation of the virtual flipped classroom method led to a significant increase in knowledge levels (Table 1). As shown in Table 1, the mean and standard deviation of the knowledge scores in the pre-test and post-test were 4.04 ± 0.1 and 7.42 ± 0.27, respectively. The Wilcoxon signed-rank test was used to compare the knowledge scores before and after the teaching. The results indicated a significant difference between the two scores ($z = -5.438$, $P < 0.001$).

According to student feedback, the overall satisfaction level with the teaching method was 92.85%. Participant satisfaction rates across different areas are presented in Table 2. The differences in satisfaction across various aspects were compared to the average score, as shown in Table 3.

When assessing skill levels, the majority of students reported that they believed they had either fully achieved the desired skill (67.74%) or partially achieved it (27.49%). Conversely, 4.76% of students acknowledged that they did not believe they had achieved the proper skill level (Figure 1).

5. Discussion

The study aimed to assess student satisfaction, knowledge, and skill levels in the immunohematology pre-laboratory course at Hamadan University of Medical Sciences, utilizing an e-learning-based flipped classroom. The results showed a 92.85% overall satisfaction rate among students with the flipped classroom-based course and a knowledge rate of 90.47%.

Taghipour and Ghassemtabar's study similarly found that the flipped classroom method led to a positive student attitude towards practical course teaching, along with increased involvement and performance (17). In Sajid et al.'s study, approximately 35% of students believed that 20% of hematology course lectures should be delivered online. Their study only incorporated five online sessions, and the students expressed satisfaction with this emerging pedagogical model, acknowledging that it improved their exam preparation and conceptual understanding (18).

Christopher conducted a study in which the flipped classroom method was used for teaching a paramedical pre-laboratory course. When compared to traditional teaching methods, several challenges were identified with the flipped approach, including the need for significant time and preparation, as well as limitations in receiving help exactly when needed (19). In contrast to most research, this study concluded that the majority of students preferred the traditional course format over the flipped classroom and found it less effective. Moreover, 80% of students indicated they were not willing to take the course again using the flipped classroom method or recommend it to others (19).

Afrashtehfar et al. reviewed the existing literature on the flipped classroom method and reported that it is generally more effective than traditional teaching methods, particularly for the current generation of students, who tend to be more collaborative and technology-friendly (14). Similarly, in our study, Tang et al. used the flipped classroom method to teach ophthalmology and found that it enhanced learners' motivation and communication skills. The post-test knowledge scores improved after implementing the flipped classroom, though students still expressed a preference for lecture-based teaching (11).

Bhavsar et al. compared flipped classrooms with traditional didactic teaching for first-year MBBS students. Like the current study, Bhavsar found significant improvements in post-test scores with both methods, though overall satisfaction was higher with the flipped classroom approach (13). Street et al. designed an instructional plan that included traditional methods, blended techniques, and a virtual flipped classroom for teaching pre-clinical physiology courses. Their findings indicated that students performed better in the blended and virtual flipped classroom groups, and they ranked the flipped classroom higher than traditional lectures (20).

In a recent study, combining theoretical and pre-laboratory training for practical immunohematology courses led to a 93% increase in both knowledge and satisfaction. Chen et al found that 63.01% of students believed that blended learning in laboratory courses was more effective in achieving educational objectives than traditional learning methods. Most educators agreed that blended learning enhanced experimental skills, practical proficiency, and self-confidence compared to conventional face-to-face teaching, and test results using the blended approach were significantly higher than those achieved through traditional teaching (21).

Gregory and Di Trapani conducted a study titled "Blended Learning Approach to Lab Class Preparation," which incorporated virtual activities, web-based audio presentations, pre-lab questions, and lab quizzes. The findings showed that prior class preparation reduces the potential risk of cognitive dissonance and enhances students' skills, leading to improved experimental learning and a better laboratory experience (22). In line with the results of other studies, the flipped classroom

Table 1. Knowledge Score Before and After of Teaching by Virtual Flipped Classroom [a]

Variable	Pre-test	Post-test	P-Value
Knowledge score	4.04 ± 0.10	7.42 ± 0.27	< 0.001

[a] Values are expressed as mean ± SD.

Table 2. The Level of Students' Satisfaction with the Teaching Method of the Virtual Flipped Class (n = 42) [a]

General Items	Completely Satisfied	Relatively Satisfied	Intermediate	Relatively Unsatisfied	Completely Dissatisfied	I Have No Opinion
Content quality (2 items)	21 (50)	16 (38.09)	5 (11.9)	0 (0)	0 (0)	0 (0)
Assignments (3 items)	23 (54.76)	17 (40.47)	2 (4.76)	0 (0)	0 (0)	0 (0)
Classroom/laboratory activities (4 items)	20 (47.61)	18 (42.85)	4 (9.52)	0 (0)	0 (0)	0 (0)
Teaching skills (7 items)	25 (59.52)	16 (38.09)	1 (2.38)	0 (0)	0 (0)	0 (0)

[a] Values are expressed as No. (%).

Table 3. Comparison of the Students' Satisfaction Score with the Mean Score of Each Filed

General Items	Mean ± Standard Deviation	Difference from Mean	*t*	P-Value	Confidence Interval	
					Less	More
Content quality	4.30 ± 0.07	-0.160	-2.010	0.051	-0.321	0.00008
Assignments	4.50 ± 0.06	0.030	0.459	0.649	-0.102	0.162
Classroom/laboratory activities	4.62 ± 0.04	0.158	3.240	0.002	0.059	0.257
Teaching skills	4.63 ± 0.03	0.169	5.420	< 0.001	0.106	0.232

approach is noted for its resource efficiency, time-saving nature, and convenience for learners (23).

The overarching goal of the educational system in medical sciences is to foster deep learning among students, which is crucial as their future professional behavior will reflect their educational experience. Based on the findings of this study, the virtual flipped classroom method has successfully facilitated deeper learning for students, particularly in practical courses. This is significant because students must be able to perform competently in real-life working conditions after graduation.

5.1. Conclusions

The implementation of the virtual flipped classroom method in the pre-laboratory immunohematology course had a positive impact on students' learning and satisfaction. This teaching approach has the potential to enhance teaching effectiveness, foster an interactive learning environment, and could be applied to similar courses. The study's results indicate substantial improvements in students' knowledge and skills, along with high satisfaction levels regarding the learning process. Therefore, it is recommended that educators across various scientific disciplines consider adopting this innovative teaching method to improve student learning outcomes. However, further research with larger sample sizes is necessary to provide stronger evidence of the intervention's effectiveness and to enhance its methodological rigor.

5.2. Highlights

Active learning: By implementing the flipped class method, the instruction could be switched from a teacher-centered to a student-centered approach. It leads to a more dynamic, effective, and interesting teaching-learning context.

Skill improvement: Creating more time for the practical part of this lesson and the opportunity for students to report

5.3. Lay Summary

The study's objective was to evaluate the level of satisfaction, knowledge and skill of students in the immunohematology pre-laboratory course at Hamadan

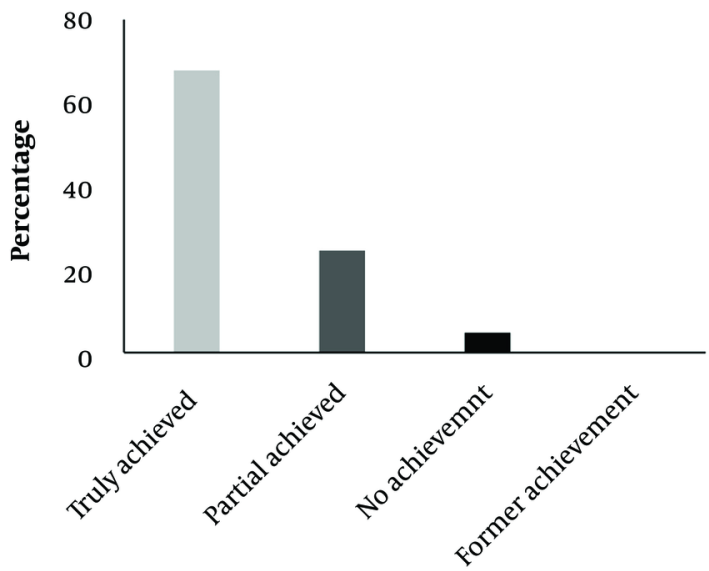

Figure 1. The rate of skill achievement after teaching

University of Medical Sciences, using an e-learning-based flipped class. The sampling method was purposeful and census. All undergraduate students of laboratory sciences (n = 42) who had selected the immunohematology practical course. The implementation of this method in the pre-laboratory immunohematology course positively impacted students' learning and satisfaction.

Acknowledgements

The authors are thankful to all students who participated in this study and answered the questionnaire. Appreciate Hamadan University of Medical Sciences for their financial support.

Footnotes

Authors' Contribution: M. S. and F. A contributed to the study's conception and design, development of the questionnaire, data collection, the analysis and interpretation of the results, to manuscript preparation and writing and all authors approve of the final manuscript.

Conflict of Interests Statement: No potential conflicts of interest were stated by the authors. The authors declare that AI-based tools have not been used in the research and preparation of this manuscript.

Data Availability: The dataset presented in the study is available on request from the corresponding author during submission or after publication.

Ethical Approval: Ethical approval for the present study was obtained from the Hamadan University of Medical Sciences ethics committee by the reference number of IR.UMSHA.REC.1401.405 .

Funding/Support: This study was financially supported by Hamadan University of Medical Sciences (ID: 140107196099).

Informed Consent: After obtaining informed and written consent, the students took part in the study.

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