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Blended Teaching Reform in Pathogenic Biology Experiment Course based on SPOC, Rain Classroom, and Virtual Simulation Platforms

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ABSTRACT

This study explores a novel blended teaching model that integrates Small Private Online Course (SPOC), Rain Classroom, and a Virtual Simulation Experiment Platform for the Pathogenic Biology Experiment course in medical education. The purpose of this instructional reform is to enhance students' theoretical knowledge, practical competencies, and learning engagement by bridging digital resources with in-person instruction. A quasi-experimental design was implemented, comparing an experimental cohort (n=55) adopting the blended model and a control cohort (n=53) following traditional methods. Data were collected on academic performance, skill assessments, and satisfaction levels. The results demonstrated statistically significant improvements ($P<0.01$) in all measured outcomes for the experimental group. In particular, a Giemsa-staining case study on Plasmodium-infected mouse blood was employed to contextualize virtual interaction and biosafety practices. This research provides an effective instructional blueprint for integrating simulation and digital tools into laboratory-intensive medical curricula.

KEYWORDS

Pathogenic Biology; SPOC; Rain Classroom; Virtual Simulation; Blended Learning; Teaching Reform.

1. INTRODUCTION

Laboratory teaching in medical education is undergoing rapid digital transformation, driven by the demand for safer, more interactive, and accessible learning environments[1]. Pathogenic Biology Experiment courses, which often involve biosafety challenges, represent an ideal context for blended learning innovation[2]. Traditional classroom instruction typically relies on fixed content delivery and manual experimentation, which limits student engagement, flexibility, and reflective feedback[3]. Moreover, logistics and cost constraints in preparing high-risk biological samples necessitate innovative educational solutions. Recent advancements in online education platforms such as SPOC and Rain Classroom, coupled with immersive virtual simulation technologies, provide opportunities to revamp teaching methods and align with competency-based learning outcomes[4-7]. This study investigates the development and impact of a blended instructional framework tailored for teaching Plasmodium diagnosis and staining techniques through a hybrid of online modules, live feedback systems, and simulation environments.

2. PEDAGOGICAL FRAMEWORK AND MODEL DESIGN

The design of the instructional framework draws upon contemporary educational theories, particularly constructivism and experiential learning, to enhance students' engagement and knowledge retention. Three core components were integrated to support this pedagogical foundation. The first is the SPOC (Small Private Online Course) module, which offers structured, asynchronous learning opportunities. Students accessed pre-recorded lectures, clinical case demonstrations, embedded quizzes, and interactive reading materials. This module facilitated personalized pacing and reinforced foundational knowledge prior to hands-on or simulated practice.

Secondly, Rain Classroom was employed as a dynamic, synchronous interaction tool. This platform, embedded in PowerPoint and WeChat, enabled instructors to deliver in-class quizzes, collect student feedback, and visualize real-time comprehension heatmaps. The immediate analytics provided by Rain Classroom empowered educators to adjust teaching content based on student response trends and knowledge gaps.

Lastly, the Virtual Simulation Platform was introduced to replicate high-risk laboratory procedures in a safe and scalable digital environment. This platform provided a realistic, scenario-based interface where students practiced parasite handling, Giemsa staining, and biosafety operations. It supported repeated trials and performance feedback, thereby aligning with skill acquisition and mastery learning objectives.

Together, these components formed a cohesive instructional ecosystem that encouraged iterative learning across digital and physical environments, reinforcing key competencies through multi-modal engagement.

3. INSTRUCTIONAL IMPLEMENTATION STRATEGY

The instructional process was systematically divided into four interlinked phases, each reinforcing the previous one to foster cumulative learning. During the pre-class phase, students engaged with the SPOC platform to review micro-lectures focusing on core topics such as the malaria lifecycle, Plasmodium stages in erythrocytes, and the principles of Giemsa staining. Short multiple-choice assessments and open-ended reflections ensured comprehension and triggered metacognitive engagement.

In the in-class phase, Rain Classroom facilitated active learning. Students participated in problem-solving tasks that required analyzing patient case data, identifying diagnostic approaches, and interpreting blood smear images. Real-time data from Rain Classroom allowed instructors to address misconceptions instantly and tailor their instruction accordingly.

The laboratory phase was highlighted by the dual-track approach to Giemsa staining practice. Students participated in both physical smearing and staining exercises using surrogate samples, and parallel virtual simulation exercises simulating a mouse infected with Plasmodium. The simulation platform provided interactive tools to collect, fix, stain, and view digital blood smears under virtual microscopy, offering learners a comprehensive diagnostic experience.

Post-class activities reinforced and evaluated learning outcomes. Students submitted digital lab reports and responded to adaptive quizzes through Rain Classroom. They also completed reflective surveys assessing the clarity of instruction, difficulty of tasks, and personal progress. This feedback loop supported both student self-assessment and iterative course refinement by faculty.

4. CASE STUDY: PLASMODIUM BLOOD SMEAR AND SIMULATION INTEGRATION

To exemplify the practical integration of the blended teaching model, a detailed case study on malaria diagnosis was embedded into the curriculum. The instructional design recreated the diagnostic process for Plasmodium infection, combining digital simulation with hands-on laboratory tasks. In the virtual component, students conducted simulated inoculations of laboratory mice, monitored infection progression, and observed the erythrocytic cycle of Plasmodium under digital microscopy. The system allowed learners to perform each stage of the Giemsa staining procedure virtually, including sample fixation, staining duration control, and cellular observation under magnification.

High-resolution simulated slides displayed various parasite stages—ring forms, trophozoites, schizonts—requiring students to identify and document findings accurately. Concurrently, the physical lab enabled students to replicate similar tasks with safe surrogate materials, fostering alignment between simulated and manual skills.

Student feedback emphasized that this multimodal experience significantly boosted diagnostic confidence. The ability to visualize parasitic evolution and staining outcomes in a controlled virtual space made abstract concepts more tangible. Moreover, repeated virtual trials promoted procedural fluency, bridging theoretical learning with applied biomedical practice.

5. RESULTS AND DATA ANALYSIS

5.1. Quantitative Outcomes

Quantitative analysis conducted via SPSS 26.0 revealed that the blended instructional model led to significant academic gains compared to the traditional teaching cohort. The mean score for the theoretical knowledge assessment in the experimental group was 86.9 with a standard deviation of 4.5, while the control group recorded a mean of 77.8 and a standard deviation of 6.2. This substantial difference (P<0.01) suggests that pre-class preparation and interactive in-class engagement contributed to a deeper understanding of pathogenic biology concepts.

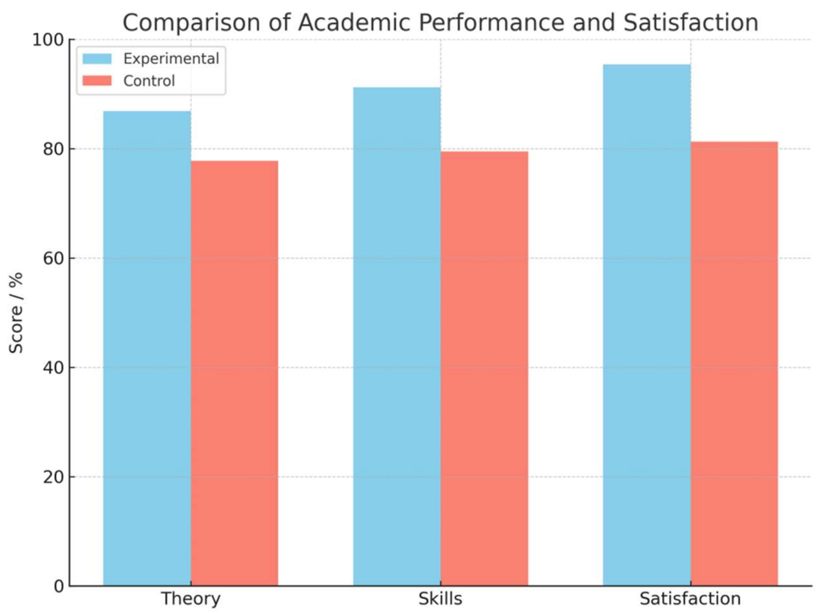

Figure 1. Comparison of academic performance and satisfaction

In terms of practical competencies, students subjected to the blended model demonstrated stronger laboratory skills. The experimental group achieved a mean practical skills score of 91.2 (SD = 3.7), significantly higher than the 79.5 (SD = 5.3) recorded by the control group ($P<0.01$). This enhancement reflects the effectiveness of virtual simulation and its alignment with psychomotor learning domains.

Additionally, student satisfaction surveys showed marked differences. The experimental group reported a satisfaction rate of 95.4%, compared to 81.3% in the control group ($P<0.01$). Respondents attributed their satisfaction to the flexibility of SPOC, the immediacy of feedback in Rain Classroom, and the engaging nature of virtual practice tasks.

These results, illustrated graphically in Figure 1, substantiate the model's positive impact on both cognitive and affective learning outcomes.

5.2. Insights from Learner Experience

Post-experiment qualitative data gathered from student reflections revealed insightful perspectives into the learner experience under the blended instructional model. Many students commented on the realistic nature of the virtual simulation, noting that it substantially enhanced the authenticity and applicability of the learning process. This sense of realism helped bridge the gap between theoretical content and its clinical application, especially in the context of laboratory diagnosis.

Another commonly cited theme was the ease of navigating the simulation platform. Students felt that the intuitive interface alleviated anxiety often associated with performing laboratory tasks, particularly those involving biohazardous materials. The ability to repeat procedures in a risk-free environment allowed for error-based learning and self-paced correction, thereby supporting a mastery approach to skill development.

Furthermore, students expressed that the SPOC component provided them with valuable flexibility. They appreciated the opportunity to revisit core content and manage their study schedules more effectively, which contributed to better preparedness for both physical and simulated laboratory sessions.

These themes collectively highlight that the blended learning model not only improves academic performance but also fosters a more confident and autonomous learning disposition. The frequency of these reflection themes is summarized in Table 2.Additional descriptive statistics are detailed in Table 1.

Table 1. Thematic Frequency from Student Reflections

Theme	Frequency
Realism enhanced comprehension	42
Virtual safety appreciated	39
Time-flexible SPOC benefit	33

6. DISCUSSION

The findings of this study affirm the pedagogical viability and instructional efficacy of integrating SPOC, Rain Classroom, and virtual simulation into medical laboratory education. Students benefited from a layered learning strategy in which content was introduced asynchronously, reinforced through real-time class interaction, and mastered via immersive simulation. The notable improvement in both theory and skills assessments among the experimental cohort illustrates how such a multi-pronged approach addresses diverse learning needs.

The integration of virtual simulation allowed students to repeatedly practice complex procedures, such as Giemsa staining, without the risk of biohazard exposure. This safe and scalable alternative proved particularly valuable in replicating the procedural rigor of clinical diagnosis. Moreover, the data analytics provided by Rain Classroom enabled instructors to adapt explanations dynamically, addressing misconceptions on-the-fly and fostering a more responsive learning environment.

Student reflections further revealed the cognitive and emotional advantages of the blended model. Many students expressed appreciation for the realism of the simulation interface and the autonomy granted by SPOC. These elements collectively reduced learning anxiety and enhanced intrinsic motivation. However, challenges remain, including faculty workload associated with managing multiple platforms and occasional technical disruptions that could impede synchronous teaching sessions.

To enhance sustainability and scale, institutions should invest in faculty training for educational technology and standardize platform interoperability[8]. Additionally, expanding the repository of disease-specific simulations could enrich the curriculum and tailor learning to clinical scenarios beyond malaria diagnosis. However, challenges involved faculty training demand and occasional technical lag during simulations. Continuous interface optimization and expanded simulation scenarios are needed for broader implementation.

7. CONCLUSION

This study provides an evidence-based instructional model for medical educators seeking to modernize experimental teaching. Integrating SPOC, Rain Classroom, and Virtual Simulation leads to measurable improvements in student performance and engagement. Future work may expand this framework to virology, immunology, and pharmacology labs.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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