IMPACT OF MICROLEARNING-SUPPORTED FLIPPED LABORATORY ON STUDENTS' LEARNING MOTIVATION AND ACHIEVEMENTS IN APPLIED CHEMISTRY

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Abstract

This study investigated the impact of a microlearning-supported flipped laboratory (MSFL) approach on students' learning motivation and achievements in Applied Chemistry. Laboratory experiences are essential in science education, yet traditional setups often present challenges. The flipped laboratory model, enhanced with microlearning, addresses these by enabling pre-class engagement with theoretical concepts and optimising hands-on learning during lab sessions. A mixed-method quasi-experimental design was employed with 60 polytechnic students divided into experimental (n=36) and control (n=24) groups. The experimental group received MSFL instruction for three lab sessions, while the control group received conventional instruction. The intervention utilised Edpuzzle, an interactive video platform that presents essential information in small, manageable chunks with embedded quiz questions to reduce cognitive load and provide immediate feedback. Data were collected through pre- and post-surveys based on the Motivated Strategies for Learning Questionnaire (MSLQ), pre- and post-quizzes, and open-ended questions. Quantitative analysis revealed significantly higher post-quiz scores for the experimental group compared to the control group, indicating improved learning achievement. However, despite consistently higher motivation scores in the experimental group, no significant differences were found in motivation measures between groups. Qualitative analysis of student feedback highlighted benefits such as enhanced preparation, conceptual reinforcement, and self-regulated learning, as well as challenges related to content design and technical issues. Based on these findings, several recommendations emerged for improving MSFL: ensuring alignment between pre-laboratory videos and in-lab procedures, addressing technical issues to enhance engagement, and incorporating additional formative assessments to support motivation and self-regulated learning. This study contributes to science education by providing evidence for the effectiveness of integrating microlearning into flipped laboratory instruction. It highlights both the potential for improved learning outcomes and the complexities of influencing student motivation in laboratory settings, offering valuable insights for educators seeking to enhance student engagement and achievement in science courses.

Keywords: *flipped laboratory, microlearning, motivation, learning achievement, science education*

Introduction

Laboratory experiences play a crucial role in Science education, enhancing student engagement by bridging theoretical knowledge with practical application (Duban et al., 2019; Hofstein & Lunetta, 2003).

Despite their importance, several challenges hinder the effectiveness of laboratory lessons:

1. Varying Student Comprehension: Differences in prior knowledge and cognitive abilities create disparities in understanding, making it challenging for educators to address individual needs effectively. Some students may find the content repetitive and unchallenging, while others may find it novel and overwhelming (Mok, 2012).
2. Cognitive Overload: Extensive laboratory manuals and information-heavy materials can overwhelm students, limiting their ability to focus on core concepts (Johnstone et al., 1994).
3. Limited Personalised Feedback: Large class sizes make it difficult to provide individualised feedback, which is essential for effective learning (Gutiérrez et al., 2011).

To mitigate these challenges, educators have incorporated pre-laboratory activities such as instructional videos, interactive simulations and pre-lab worksheets, which reduce information overload and promote deeper engagement (Johnstone et al., 1994).

The flipped laboratory, an extension of the flipped classroom method, enhances learning by shifting theoretical instruction to pre-lab activities, allowing students to engage in higher-order cognitive processes such as analysis and evaluation (Claesson et al., 2020; Loveys & Riggs, 2018). This method optimises in-lab interactions and promotes a deeper understanding of scientific principles.

Microlearning, which delivers information in small, structured segments, reduces cognitive load and enhances engagement (Kossen & Ooi, 2021; Leong et al., 2020). Edpuzzle, a video application, integrates interactive features and personalised feedback, enabling students to pause, rewind, and track progress, fostering active learning and boosting motivation (Fidan, 2023; Ramasany et al., 2022; Shelby & Fralish, 2021).

As Schnotz et al. (2009) highlight, motivated learners invest more mental effort, leading to improved learning outcomes. Thus, integrating microlearning within flipped laboratory may enhance student motivation, manage cognitive load and improve academic performance. This research, hence, investigates the impact of MSFL on students' learning motivation and achievements in Applied Chemistry.

Literature Review

Pre-lab activities play a crucial role in enhancing students' learning experiences and motivation in laboratory settings. Moozeh et al. (2019) emphasised the benefits of online pre-labs, such as instructional videos, which offer students unlimited access, flexibility, cost-effectiveness, and real-time feedback, leading to improved student preparedness, confidence, sense of autonomy, and experiment efficiency. Similarly, Gregory and Di Trapani (2012) emphasised that well-designed pre-laboratory preparation aids students in understanding and learning. Jolley et al. (2016) introduced visual and critical thinking strategies in pre-lab activities, effectively shifting cognitive learning to the pre-lab phase to reduce cognitive overload at the start of the class. While their study did not show significant improvements in academic performance, the students felt more prepared and motivated for laboratory work. These findings collectively underscore the importance of pre-lab activities in promoting student readiness and motivation for laboratory experiments.

The flipped laboratory approach, an extension of the flipped classroom pedagogy, further enhances pre-lab activities. Claesson et al. (2020) described flipped laboratory as shifting essential knowledge acquisition to pre-lab activities, allowing students to engage in higher-order thinking during lab sessions. This aligns with Bloom's taxonomy, where class time is dedicated to application and analysis rather than passive learning. Mellefont and Fei (2016) found benefits in terms of increased class time for laboratory tasks, flexible preparation opportunities, and access to valuable resources for revision. Moreover, Mshayisa and Basitere (2021) emphasised that well-designed and well-executed flipped laboratory classes can foster independent learning and critical thinking, improving learning outcomes. De La Flor López et al. (2016) further noted that online pre-lab quizzes enhance student readiness for laboratory sessions through real-time formative feedback.

Microlearning principles are increasingly integrated into flipped laboratories to optimise student learning. As defined by Gutierrez et al. (2011), microlearning involves bite-sized instructional units that improve engagement and retention. Nikou and Economides (2018) found that mobile-based microlearning offers just-in-time and flexible learning, catering to individual needs. Fidan (2023) further demonstrated that microlearning-supported flipped classrooms enhance engagement, self-regulation skills, learning performance, and motivation while reducing cognitive overload. Applied to flipped laboratories, microlearning makes content more manageable and appealing, contributing to better student outcomes and satisfaction.

Motivation, explained through Self-Determination Theory (SDT), is a multifaceted concept with distinct categories based on the reasons or goals driving an action. Intrinsic motivation stems from inherent interest while extrinsic motivation is rooted in achieving separable outcomes (Ryan & Deci, 2000). Muir (2021) further delves into the psychological needs integral to SDT, highlighting competence, autonomy, and relatedness as key psychological needs that influence motivation. Abeysekera and Dawson (2014) connect these needs to the flipped classroom, suggesting that fostering active participation and environments satisfying autonomy, competence, and relatedness enhances intrinsic motivation. Supporting this, Sergis et al. (2018) found that students in a Flipped Classroom Model (FCM) reported higher autonomy, competence and relatedness, facilitated by collaborative activities, scaffolding activities as well as peer- and mentor-supported social contexts.

Aims of Study and Research Questions

This study aimed to investigate the effects of MSFL intervention on students' learning motivation and learning achievements. The following research questions were formulated to guide the data analysis:

RQ1: Does using MSFL improve students' learning achievement more than conventional instruction?

RQ2: Does using MSFL improve students' motivation (i.e. intrinsic motivation, extrinsic motivation, self-efficacy and task value) more than conventional instruction?

RQ3: What were the students' learning experiences when adopting MSFL?

Method

This study employed a mixed-method quasi-experimental design implemented across three laboratory lessons.

Convenience sampling was used to recruit participants from the module A391 Materials Processing class in the Polytechnic. A total of 60 students (39 females, 21 males) participated in the study. 18.3% were 17 years old, 45.0% were 18, 26.7% were 19, and 10.0% were 20 years old and above. All participants were informed that participation was voluntary and their responses would be kept confidential. Ethical approval was obtained from the Polytechnic In-House Ethics Review Committee.

The participants were divided into two groups: an experimental group (n=36) and a control group (n=24). The experimental group received the MSFL intervention, while the control group received conventional laboratory instruction for all three laboratory lessons.

The experimental group completed pre-class activities one week before each of the three lab sessions. These activities involved watching Edpuzzle videos of the lab practical with embedded quiz questions. This was followed by short in-class discussions to address the pre-class activity.

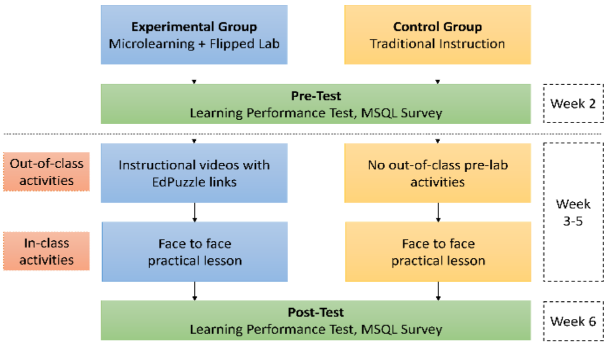

Figure 1. Experimental procedure

Data were collected using online questionnaires (pre-survey and post-survey) and quizzes (pre-quiz and post-quiz). The pre-survey and pre-quiz were administered before the start of the three laboratory sessions to assess students' baseline levels of learning motivation and prior knowledge of the laboratory topics, respectively. The post-survey and post-quiz were administered after the three laboratory sessions to measure any changes in these aspects. Figure 1 shows the experimental procedure. The surveys were based on the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich et al., 1993), which is a validated and reliable instrument for assessing students' motivation. In this study, 17 items with 7-point Likert scale (ranged from 1-"not at all true of me" to 7-"very true of me") from four MSLQ subscales were used:

- intrinsic motivation (3 items, sample item: "In this course, I prefer course material that arouses my curiosity, even if it is difficult to learn"),
- extrinsic motivation (3 items, sample item: "If I can, I want to get better grades in this course than most of the other students"), and
- self-efficacy (5 items, sample item: "I'm confident I can do an excellent job on the assignments and tests in this course").
- task-value (6 items, sample item: "I think I will be able to use what I learn in these practical lessons in other lessons.").

The quizzes consisted of 15 multiple-choice questions designed by the instructor and validated by an expert within Republic Polytechnic (RP) who was not involved in the research team.

The experimental group additionally answered two open-ended questions in the post-survey to provide qualitative feedback on their experiences with the MSFL intervention.

Quantitative data were analysed using IBM SPSS version 24.0. Based on the Shapiro-Wilk normality test, it was found that not all samples from the experimental and control groups followed a Gaussian distribution. Therefore, non-parametric Mann-Whitney U test was used for measuring between-group differences at 0.05 level of significance.

Qualitative responses were analysed thematically by two independent researchers to identify emerging themes and ensure credibility (Braun & Clarke, 2006; Patton, 1999).

Results

Table 1 presents the means and standard deviations for the quiz scores and the four MSLQ subscales (Intrinsic Motivation, Extrinsic Motivation, Self-Efficacy, and Task-Value) for both the control (N=24) and experimental (N=36) groups at pre-test and post-test. In the pre-test, the experimental group showed slightly higher mean scores across all measures compared to the control group. This trend continued in the post-test, with both groups demonstrating improvements in quiz scores and most motivation subscales.

Table 1. Descriptive Statistics

		Pre-Test		Post-Test	
		Control (N=24)	Experimental (N=36)	Control (N=24)	Experimental (N=36)
Learning Achievement	Mean	4.96	5.94	10.79	12.17
	Std. Deviation	1.90	2.01	2.40	2.26
Intrinsic Motivation	Mean	4.49	5.12	4.90	5.13
	Std. Deviation	1.42	1.20	1.36	1.28
Extrinsic Motivation	Mean	5.56	5.78	5.19	5.35
	Std. Deviation	1.45	1.17	1.29	1.35
Self-Efficacy	Mean	4.00	4.51	4.69	4.84
	Std. Deviation	1.21	1.14	1.23	1.26
Task-Value	Mean	4.68	5.13	5.03	5.25
	Std. Deviation	1.25	1.16	1.29	1.22

Table 2 displays the correlations and reliability measures for the post-survey ratings of the four MSLQ subscales. All subscales demonstrated high internal consistency, with Cronbach's alpha values ranging from .86 to .95. Strong positive correlations were observed between all subscales ($r \geq .84$, $p < .01$), indicating a high degree of interrelation among the motivation constructs.

Table 2. Correlations and reliabilities

	M	SD	α	1	2	3	4	5
1. Learning Achievement (LA)	11.62	2.39	-	-				
2. Intrinsic Motivation (IM)	5.04	1.30	.91	.11	-			
3. Extrinsic Motivation (EM)	5.29	1.32	.86	.048	.84**	-		
4. Self-Efficacy (SE)	4.78	1.24	.94	.132	.89**	.85**	-	
5. Task-Value (TV)	5.16	1.24	.95	.158	.93**	.90**	.89**	-

*α denotes Cronbach's alpha; **p<.01*

To ensure the comparability of the experimental and control groups at baseline, Mann-Whitney U tests were conducted on the pre-test scores (see Table 3). The results indicated no significant differences between the groups on any of the measures ($p > .05$ for all comparisons). This suggests that the groups were homogeneous at the start of the intervention, allowing for meaningful comparisons of post-test results.

Table 3. The Mann-Whitney U test results of pre-quiz and pre-survey for the two groups of students

	Mann-Whitney U	Z	p
Learning Achievement	308	-1.892	.058
Intrinsic Motivation	327	-1.591	.112
Extrinsic Motivation	404	-.426	.670
Self-Efficacy	317	-1.739	.082
Task-Value	333	-1.497	.134

Mann-Whitney U tests were also used to compare the post-test scores between the experimental and control groups (see Table 4). The analysis revealed a significant difference in quiz scores ($U = 293$, $Z = -2.116$, $p = .034$), with the experimental group ($M = 12.17$, $SD = 2.26$) outperforming the control group ($M = 10.79$, $SD = 2.40$). This suggests that the MSFL intervention had a positive effect on students' learning achievements. Regarding motivation, the experimental group showed slightly higher mean scores across all MSLQ subscales compared to the control group. However, these differences were not statistically significant.

Table 4. The Mann-Whitney U test results of post-quiz and post-survey for the two groups of students

	Mann-Whitney U	Z	p
Learning Achievement	293	-2.116	.034
Intrinsic Motivation	377	-.834	.404
Extrinsic Motivation	397	-.533	.594
Self-Efficacy	384	-.718	.473
Task-Value	379	-.794	.427

These results indicate that while the intervention appeared to improve learning achievements, it did not significantly affect students' motivation as measured by the MSLQ subscales, despite the consistently higher motivation scores in the experimental group.

The results from the qualitative data, collected through open-ended questions, are organised into two main categories: benefits and challenges of the MSFL.

The following were some benefits of MSFL as suggested from the thematic analysis:

- Pre-Class Preparation: The most frequently mentioned benefit (40.48%) involved the value of pre-class activities in preparing students for the laboratory sessions. Students appreciated the opportunity to familiarise themselves with the upcoming practical work *("I'd like that I get to familiarise myself with pre-reading activities before my practical lesson"*). This pre-exposure allowed them to develop a foundational understanding and anticipate the learning objectives *("It gives me a heads-up of what to expect for the next few lessons and gives me a gist of what I can learn in future sessions"*).
- Conceptual Reinforcement: Students (33.33%) highlighted the effectiveness of the intervention in solidifying their grasp of laboratory concepts. By watching videos and engaging with the material beforehand, students felt better prepared for the hands-on activities *("It gives a good understanding of the process and procedure of the practical lab lessons"*). Observing the visual demonstrations *("I get to see the actual process which helps me better understand the concepts"*) facilitated a deeper connection between theory and practice.
- Facilitation of Self-Regulated Learning: A smaller portion of students (14.29%) emphasised the intervention's role in promoting self-regulated learning. The embedded quizzes within the pre-class activities (*"It also has short quizzes and videos to watch which could help me gauge my understanding of the next topic I am going to learn"*) were seen as valuable tools for self-assessment. Students also appreciated the opportunity to clarify any uncertainties before the laboratory session (*"Immediate answers so that students can do more research to bring up more questions and understanding of the topic"*).
- Engagement and Interaction: While less frequent (11.90%), some students commented on the engaging and interactive nature of the pre-class activities ("*It was fun and very interactive. The questions were easy and doable*"). The immediate feedback provided by the quizzes ("*I like that it can test us on what we learn immediately*") was perceived as a positive aspect.

The following were some challenges of MSFL as suggested from the thematic analysis:

- Content and Delivery Design: Students identified challenges related to the content and delivery design of the pre-class materials (36.00%). Some students expressed a desire for more detailed explanations within the microlearning activity ("*A bit more could be explained…"*). Additionally, a few students reported inconsistencies between the video demonstrations and the actual laboratory procedures ("*It was very different from the practical we carry out in the videos shown and some of the values were changed or reduced to a lower one*").
- Technical Factors: Technical issues with the Edpuzzle platform were another point of concern (36.00%). Students mentioned the inability to skip certain sections ("*For Edpuzzle, I'm not allowed to skip*") and technical glitches within the videos ("*Some of the videos were a bit bugged*") as hindrances to their learning experience.
- Time and Effort Considerations: A smaller group of students (28.00%) expressed concerns regarding the time commitment required for the pre-class activities. The mandatory nature of the pre-work ("*We have to do it*") and the perceived length of the activities ("*It can be quite lengthy*") were aspects that some students found challenging.

Discussion

The results of this study provide insights into the effectiveness of an MSFL approach in enhancing students' learning achievements and motivation in an Applied Chemistry module. The discrepancy between improved learning achievement and unchanged motivation in the MSFL intervention likely stems from technical issues with Edpuzzle, content design challenges, and the mandatory nature of pre-work activities that fostered compliance rather than enthusiasm. While providing cognitive benefits, these factors created friction that counteracted potential motivational gains, suggesting that learning outcomes and student engagement may be influenced by different aspects of educational design. Based on the findings, several recommendations can be made for lesson design and implementation. First, ensuring alignment between pre-laboratory instructional videos and in-lab procedures can improve clarity and student confidence. Second, addressing technical issues, such as allowing students to navigate video content more flexibly, may enhance engagement. Finally, incorporating additional formative assessments, such as open-ended reflections or peer discussions, could further support motivation and self-regulated learning. These considerations provide practical insights for educators seeking to refine flipped laboratory implementations.

Limitations of Study and Future Research

While the intervention demonstrated potential in enhancing achievement scores, several limitations warrant consideration. The study's small sample size and brief intervention period constrain the generalizability of findings and our understanding of long-term effects. Future research should address these limitations by employing larger, more diverse samples across multiple institutions and conducting longitudinal studies to assess sustained impacts. Moreover, incorporating in-depth qualitative methods such as focus groups or semi-structured interviews could yield richer insights into students' experiences and perceptions. To further explore the intervention's efficacy, subsequent studies could investigate its impact on self-regulated learning using validated instruments like the MSLQ self-regulation subscale (Pintrich et al., 1993). Future efforts should also focus on optimising the design and delivery of microlearning components. By addressing these limitations and pursuing these research directions, the field of science education can gain valuable insights to inform the development of more effective, student-centred learning experiences that foster autonomy and deep understanding in laboratory settings.

Conclusion

This study demonstrates the potential of MSFL approaches to significantly enhance student learning achievements in Applied Chemistry, despite no quantitative evidence of improved motivation. Qualitative feedback revealed perceived motivational benefits, including enhanced pre-class preparation, reinforced conceptual understanding, and facilitated self-regulated learning. However, the complex nature of student motivation in laboratory contexts and implementation challenges underscore the need for careful design and ongoing refinement. These findings contribute to the literature on innovative science laboratory education approaches, suggesting that while MSFL can improve learning outcomes, further research is needed to optimise their motivational impact and address implementation issues. Educators and instructional designers should consider incorporating these approaches in laboratory settings while remaining mindful of potential obstacles. Future research should focus on refining these methods, investigating their long-term effects, and developing a more nuanced understanding of their influence on student motivation and learning in science education.

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