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Factors influencing the effectiveness of the micro-credential platform in learning complex integration

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ABSTRACT

Micro-credentials (MCs) are becoming a new and innovative tool in higher education under the Higher Education 4.0 framework. The factors influencing the MCs effectiveness, particularly in learning the complex integration topic, have not, however, been thoroughly investigated. Thus, the purpose of this study is to investigate the factors that influence the effectiveness of the MC platform in learning the topic of complex integration among students of Bachelor of Science (Hons.) Mathematics from Universiti Teknologi MARA. A mixed-methods approach was employed, using a 37-item questionnaire developed via Google Forms. The questionnaire included three parts: part A on demographics, part B on students' perceptions of the MC platform, and part C on students' reflections, combining closed-ended Likert-scale and open-ended questions. Instrument quality was ensured through validity and reliability checks. Data were analyzed in three phases: preliminary checks, correlation and regression analysis, and thematic analysis. Quantitative findings indicate that learning opportunity and student satisfaction are key predictors of platform effectiveness. Qualitative insights reinforce these results, highlighting the platform's structured, flexible, and convenient learning environment as central to students' motivation, understanding, and engagement. The study provides evidence-based guidance for designing effective MC platforms that enhance learning outcomes in complex mathematics topics.

Keywords: correlation, factor analysis, micro-credentials, regression, reliability, thematic analysis, validity

INTRODUCTION

Micro-credentials (MCs) are a form of learning provided by higher education institutions or businesses that reward learners with digital badges (DBs) for achieving certain benchmarks (Alamri et al., 2021). The higher education system issues MCs in the form of DBs, which represent digital evidence of learning, skills, and competencies (Kukkonen, 2021). DBs can be awarded for participation in activities that contribute to completing a MCs or when one completes an MCs or upon completion of an MCs course (Abramovich, 2016; Eager & Cook, 2020; Fanfarelli & MCsDaniel, 2017). MCs can also be awarded for hard skills associated with technical coursework or for day-to-day relational skills and successful completion of specific components or competencies of a course or program (Eraut, 2012). Integrating MCs into higher education systems has the power to transform how higher education institutions structure their degree programs and how students obtain these qualifications (Greene, 2019; Lockley et al., 2016). MCs are a relatively new technology in the learning domain and are quickly becoming recognized in the higher education landscape as one of the disruptive forces of change under Higher Education 4.0 (Brown et al., 2021) and are also considered innovative pedagogical tools (Newby & Cheng, 2020).

In order to ensure the practical relevance and applicability of the skills learned, MCs are usually developed by subject matter experts in accordance with industry requirements (Varadarajan et al., 2023). Numerous studies have emphasized the benefits of MCs, such as their adaptable, modular learning structure that allows people to gradually earn several credentials that can be combined to obtain a more complete qualification, like a degree or diploma (Oliver, 2019). By emphasizing the mastery of particular skills and knowledge, MCs support competency-based education, allowing for a customized, learner-centered approach in which students advance at their own speed and in accordance with their learning goals (Hunt et al., 2020). Furthermore, MCs cultivate a culture of lifelong learning through their modular framework, enabling professionals to continuously enhance their competencies by obtaining new credentials, thereby ensuring alignment with the dynamic demands of their respective industries (Boland & Hazelkorn, 2022). The structure of MCs also facilitates the development of specific competencies, thereby enhancing

Table 1. Structure of the questionnaire

Part	Measurement	Total items	Type of questions
A	Demographic	3	Quantitative
B	Students' perceptions of the MC	27	Quantitative
C	Students' reflections	4	Qualitative

student engagement through the provision of targeted and immediately applicable knowledge. This approach has the potential to attract a broader range of learners and foster greater motivation to complete their studies (Conceição & Howles, 2023).

In educational settings, MCs have drawn more attention as adaptable, competency-based certifications that certify specific skills and knowledge. In mathematics education, MCs offer several special advantages that address both practical and pedagogical problems. Cook (2021) claimed that when mathematical ideas were directly linked to project outcomes, students showed greater levels of engagement with MCs, which lessened the impression of mathematics as a stand-alone subject. Additionally, Li and Ironsi (2024) examined the efficacy of using MCs in the instruction of 21st century skills like communication, problem-solving, and critical thinking. According to the results, MCs were superior to traditional classroom methods in terms of fostering these skills, which are critical for success in mathematics and related fields. Overall, MCs are shaping up to be an exciting breakthrough in mathematics education. They give students the chance to engage in modular and focused learning experiences that really boost their understanding of concepts. When designed thoughtfully, aligned with curriculum goals, and backed by the right teaching strategies, the MCs can strengthen students' mathematical skills and create meaningful, personalized learning journeys.

MC platforms are typically short in duration and designed to help students acquire knowledge, skills, and competencies in a particular field. Although the use of MC platforms in higher education is increasing, there are limited studies that exist to study the factors that influence their effectiveness, particularly in learning the topic of complex integration. This topic is a part of the Complex Analysis with Computational Applications course taken by students of the Bachelor of Science (Hons.) Mathematics at Universiti Teknologi MARA (UiTM). A critical gap in the literature is addressed by this study, which examines whether short, MC courses can effectively teach complex, high-level mathematical concepts. This research provides new insights by exploring how students bridge the gap between theoretical proofs and digital applications within a flexible, self-paced framework, an area often overlooked in existing MC research. In UiTM, students are given access to the MC platform for learning a complex integration topic. Using the offered MC platform, this initiative gives students a more flexible, self-paced, and accessible way to learn this topic while promoting independent study and mastery of key concepts throughout the course of the semester. A study was carried out during this MC course to examine several key aspects of the learning experience among the students, including factors like collaboration, usefulness, motivation, learning opportunities, ease of use, satisfaction, and platform effectiveness.

Hence, this study aims to investigate the factors that influence the effectiveness of the MC platform in learning the topic of complex integration among the students of the Bachelor of Science (Hons.) Mathematics from UiTM Malaysia. A mixed-methods approach is employed, combining qualitative and quantitative methods to analyze the responses collected from Google Forms.

METHODOLOGY

Quantitative and Qualitative Analyses

This study employs a questionnaire as an instrument for data collection. The questionnaire consists of three parts with a total of 37 items. Part A consists of three questions related to the students' demographic information, part B focuses on the students' perceptions of the MC platform, and part C addresses students' reflections, as shown in **Table 1**. The questionnaire was developed using a Google Form and distributed to Bachelor of Science (Hons.) Mathematics students at UiTM to investigate the factors influencing the effectiveness of the MC platform in learning complex integration. All students enrolled in the MC course were required to complete the form as part of the course requirements. Additionally, the MC platform allows the instructor to track form completion, ensuring that every student provides a response. The design of this questionnaire uses both open-ended and closed-ended questions. Open-ended questions allow students to elaborate on their thoughts and give suggestions for the MC platform. Meanwhile, the closed-ended questions followed a structured approach using a 5-point Likert scale: 1 is strongly disagree, 2 is disagree, 3 is neither agree nor disagree, 4 is agree, and 5 is strongly agree. This scale offers the option to measure students' perceptions and agreement with the questions.

The analysis of data in this study was conducted in three phases, consisting of

(1) preliminary data analysis,

(2) correlation and regression analysis, and

(3) thematic analysis.

It covers both quantitative and qualitative analysis. Preliminary data analysis refers to a series of analyses conducted before the main data analysis is performed. In this study, correlation and regression analyses serve as the primary data analysis. Therefore, conducting preliminary data analysis is crucial before running both correlation and regression analysis to ensure the quality and validity of the data (Roni & Djajadikerta, 2021). This phase includes data cleaning, identification of outliers, validity using factor analysis, reliability assessments, normality testing, and descriptive analysis. These analyses help refine the dataset and confirm its suitability for subsequent phases. All analyses were conducted using IBM SPSS statistics version 29.0.

Table 2. Hypothesis of the study

Hypothesis	Description
H1	There is a significant relationship between collaboration and platform effectiveness.
H2	There is a significant relationship between ease of use and platform effectiveness.
H3	There is a significant relationship between usefulness and platform effectiveness.
H4	There is a significant relationship between motivation and platform effectiveness.
H5	There is a significant relationship between learning opportunity and platform effectiveness.
H6	There is a significant relationship between satisfaction and platform effectiveness.

Following the completion of phase 1, correlation and regression analysis are considered to examine the relationship between variables. Correlation analysis is used to describe the strength and direction of the linear relationship between two variables, especially between independent and dependent variables. This analysis determined whether the relationship is linear, the magnitude of the relationship (how strong or weak it is), and whether the direction is positive or negative. A positive relationship means that as one variable increases, the other also increases. Conversely, a negative relationship means that as one variable increases, the other decreases. In addition, multiple regression analysis can be used to assess how well a set of independent variables predicts a particular outcome (dependent variable) and to identify which variable is the best predictor (Pallant, 2016). Before proceeding with regression analysis, multicollinearity should be checked to ensure that no two or more independent variables are highly correlated with each other. High multicollinearity can make it difficult to determine the individual effect of each independent variable on the dependent variable due to overlapping information.

Thematic analysis is a type of qualitative analysis used for identifying, analysing, and reporting patterns (themes) derived from the respondents' answers. Referring to Andreini and Bettinelli (2017), this study employed an inductive thematic analysis devoid of a pre-existing theoretical or coding framework. This method involved iteratively examining the documents to identify themes. Due to the diversity of themes initially identified, an interactive process of theme accordance and categorization was applied. This involved developing overarching classifications with subclasses of themes and ensuring consistency and coherence within and across theme categories, while also checking for duplication and redundancy at each level. Thematic analysis is conducted by classifying the answers into first-order theme and second-order theme (Andreini & Bettinelli, 2017; Liñán & Fayolle, 2015; Rashid et al., 2019).

Hypothesis

Table 2 presents six research hypotheses designed to investigate various attributes that contribute to platform effectiveness. Each hypothesis analyses the significance of the relationship between platform effectiveness (the dependent variable) and one of six independent variables: collaboration (**H1**), ease of use (**H2**), usefulness (**H3**), motivation (**H4**), learning opportunity (**H5**), and satisfaction (**H6**). These hypotheses attempt to discover the factors that have an essential impact on the platform's perceived effectiveness.

RESULTS

The results begin with data cleaning and the identification of extreme outliers, followed by a validity test to assess the suitability of the data. After obtaining significant values indicating that the dataset was suitable for further analysis, factor analysis was conducted to reduce a large number of related variables into a more manageable set. Subsequently, we present the reliability of the questionnaire items in terms of their consistency in measuring the intended variables, while we provide insights into whether the data are normally distributed, which is a necessary condition for subsequent analyses. The results then extend to descriptive analysis, beginning with respondents' demographic backgrounds, followed by the mean (M) and standard deviation (SD) for each questionnaire item. Further analysis includes correlation analysis to examine the relationships between the independent and dependent variables. Proceed with the regression analysis, we indicate whether multicollinearity may affect the relationships among variables. Finally, the ANOVA results demonstrate the overall statistical significance of the model.

Preliminary Data Analysis

Preliminary data analysis is essential to evaluate the relevance of the dataset before proceeding with advanced statistical analysis which include cleaning the data, identification of extreme outliers, validity and reliability analysis, test for normality and descriptive analysis. The first step, which is the data cleaning process, will check for any missing values and extreme outliers. In this dataset, few missing values have been sorted out and there were no extreme outliers found. However, three mild outliers were discovered but this does not significantly influence the normal distribution of the data. Next, reliability analysis was performed by using Cronbach's alpha values to investigate the internal consistency of the measurement scales. Then, in order to examine whether the data follows normal distribution or not, skewness and kurtosis for each questionnaire item will be measured. Finally, descriptive analysis involving frequency, percentage, M, and SD will be conducted to summarize the demographic characteristics of the respondents such as gender, age group, and university branch.

Validity analysis using factor analysis

The validity test was started by conducting the Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity on a set of 27 items of the MC instrument. The KMO and Bartlett's test are used to assess the suitability of the data before conducting the factor

Table 3. KMO and Bartlett's test

Variable		Value
KMO measure of sampling adequacy		.694
Bartlett's test of sphericity	Approximate Chi-square	3,120.881
	df	351
	Significance	< .001

Table 4. Results of MCs factor analysis

Variable	Item	Component	
		1	2
Collaboration	1. MC motivates me to interact with others.	.383	**.631**
	2. MC encourages me to complete tasks together.	**.540**	.420
	3. MC helps me collaborate with others.	.346	**.614**
Usefulness	4. MC helps me be more effective in learning the topic.	**.681**	.245
	5. MC is useful in understanding further about the topic.	**.693**	.097
	6. MC meets my expectations.	**.703**	.219
Motivation	7. MC motivates me to complete tasks assigned by my instructor.	**.731**	.235
	8. MC motivates me to interact with others outside of class.	**.576**	.428
	9. MC motivates me to study and understand the topic.	**.669**	.310
Learning opportunity	10. MC allows and motivates me to learn from my classmates by reading their posts or comments.	**.590**	.396
	11. MC helps me prepare for independent learning on the topic.	**.743**	.206
	12. MC helps me learn and understand further about the topic.	**.855**	.080
Ease of use	13. MC is easy to use.	**.688**	.300
	14. MC is simple to use.	**.688**	.296
	15. MC is user-friendly.	**.699**	.308
	16. MC requires the fewest steps possible to accomplish what I want to do with it.	**.555**	.449
	17. MC can be used without reading instructions.	-.025	**.747**
Satisfaction	18. I am satisfied with MC.	**.889**	-.020
	19. I would recommend MC to my friends.	**.878**	-.015
	20. MC is fun to use.	**.801**	.076
Platform effectiveness	21. The MC has inspired me and helped me improve analytical skills.	**.987**	-.103
	22. The MC has increased my knowledge of the topic.	**.993**	-.234
	23. The MC should be continued and implemented in the future for other topics.	**1.032**	-.163
	24. The MC has helped me understand the topic in better ways.	**.974**	-.118
	25. I am happy to learn using the content provided on the MC.	**.942**	-.042
	26. The use of MC as an educational tool promotes creativity and collaborative learning among students.	**.975**	-.173
	27. The MC serves as a valuable learning resource and a great tool for learning.	**1.026**	-.175
Eigenvalues		19.27	1.484
Variance explained		71.370%	5.497%
Total variance explained		76.867%	

Note. **Bold** items indicate major loadings for each item

Table 5. Reliability analysis for each variable

Variable	Cronbach's alpha	Standardized alpha	Mean inter-item correlation	Number of items
Collaboration	0.903	0.904	0.759	3
Usefulness	0.912	0.913	0.778	3
Motivation	0.912	0.913	0.777	3
Learning opportunity	0.914	0.914	0.780	3
Ease of use	0.902	0.928	0.720	5
Satisfaction	0.954	0.954	0.873	3
Platform effectiveness	0.979	0.979	0.870	7

analysis. The value of KMO should be ≥ 0.6, and the value of Bartlett's test is significant, $p \leq 0.05$. Then, the exploratory factor analysis (EFA) was conducted to determine the construct validity and factor structure of MCs (Pallant, 2016).

Table 3 shows the results for KMO and the Bartlett's test of sphericity. The value of KMO is 0.694, above the recommended value of 0.6, and Bartlett's test with a significant value $p < .001$ indicates that the data set is suitable to proceed with factor analysis. The result of MCs factor analysis using EFA is given in **Table 4**. It shows component 1 explained 71.37% and component 2 explained 5.497%, giving the total variance explained of 76.867%. Also, the major loadings for each item are consistently high, with some exceeding 1.0, indicating that items contribute significantly to the factors.

Reliability analysis

As can be seen in **Table 5**, all seven variables have very high internal consistency according to their Cronbach's Alpha values (between 0.902 to 0.979). Meanwhile, since all variables had fewer than ten questionnaire items, the mean inter-item correlation was also determined which is between 0.720 to 0.873, thus showing very strong inter-item relations. This confirms that the

Table 6. Normality test for each variable

Variable	Skewness	Kurtosis
Collaboration	-0.262	-0.937
Usefulness	-0.618	-0.319
Motivation	-0.404	-0.660
Learning opportunity	-0.321	-0.938
Ease of use	-0.450	-0.884
Satisfaction	-0.647	-0.495
Platform effectiveness	-0.537	-0.752

Table 7. Respondents' profiles

Category	Subcategory	Frequency (n)	Percentage (%)
UiTM branches in Malaysia	UiTM Arau	1	1.6
	UiTM Machang	4	6.5
	UiTM Puncak Alam	7	11.3
	UiTM Seremban	6	9.7
	UiTM Shah Alam	44	71.0
Gender	Female	51	82.3
	Male	11	17.7
Age	21-23 years old	51	82.3
	24-26 years old	11	17.7

questionnaire items demonstrate high reliability, consistently measure the intended variables across all variables, and are suitable for further analysis.

Test for normality

A symmetrical, bell-shaped distribution with the highest frequency of scores in the middle and increasingly lower frequencies towards the extremes is said to be a normal distribution, according to Pallant (2016). Skewness and kurtosis readings can be used to evaluate normality to a certain extent. Kurtosis indicates the "peakedness" of the distribution, whereas skewness indicates the distribution's symmetry (Pallant, 2016).

According to Hair et al. (2010) and Byrne (2010), data is considered normally distributed if the skewness values fall between -2 and +2. Similarly, George and Mallery (2010) suggest that skewness and kurtosis values between -2 and +2 are acceptable indicators of normality. Therefore, based on **Table 6**, all variables fall within the acceptable range, indicating that the data is normally distributed. These variables are thus appropriate for further analysis using parametric statistical techniques.

Descriptive analysis

The respondents' demographic backgrounds in **Table 7** indicates that the majority of participants were from UiTM Shah Alam (71.0%), followed by UiTM Puncak Alam (11.3%), UiTM Seremban (9.7%), UiTM Machang (6.5%), and UiTM Arau (1.6%). In terms of gender, the sample was predominantly female (82.3%), with male respondents making up only 17.7% of the total. Most participants were aged between 21 and 23 years old (82.3%), while the remaining 17.7% were between 24 and 26 years old. This suggests that the study primarily involved young adult female students from UiTM Shah Alam.

The descriptive statistics in **Table 8** show that participants generally had highly favorable perceptions of the MC platform across all measured variables. The overall M scores for each variable ranged from 4.414 to 4.535, with SDs between 0.510 and 0.559, indicating strong agreement and relatively low variability in responses. Platform effectiveness had the highest M (M = 4.535, SD = 0.511), suggesting it was the most positively perceived aspect. This was followed by ease of use (M = 4.497, SD = 0.522) and satisfaction (M = 4.500, SD = 0.559), reflecting those users who found the platform intuitive, enjoyable, and satisfactory. Usefulness (M = 4.468, SD = 0.538), motivation (M = 4.462, SD = 0.510), and learning opportunity (M = 4.430, SD = 0.534) also received high ratings, indicating that the platform supports learning and student engagement effectively. Collaboration had the lowest M (M = 4.414, SD = 0.535), though still high, showing that while peer interaction was valued, it may have been slightly less emphasized compared to other aspects.

Correlation Analysis

According to **Table 2**, the dependent variable is platform effectiveness, while the independent variables are collaboration, usefulness, motivation, learning opportunity, ease of use, and satisfaction. Therefore, the correlation analysis aims to examine how these independent variables relate to the dependent variable.

Based on **Table 9**, there are statistically strong and positive relationships between platform effectiveness and each of the following variables: collaboration ($r = 0.707$, $p < 0.001$), usefulness ($r = 0.756$, $p < 0.001$), motivation ($r = 0.830$, $p < 0.001$), learning opportunity ($r = 0.873$, $p < 0.001$), ease of use ($r = 0.750$, $p < 0.001$), and satisfaction ($r = 0.806$, $p < 0.001$).

Regression Analysis

Pallant (2016) defines tolerance as the amount of variability in a given independent variable that cannot be explained by the other independent variables in the model. A low tolerance value (less than 0.10) shows a strong multiple correlation with other

Table 8. Descriptive analysis for each variable

Variable	Item	M	SD
Collaboration	MC encourages me to complete tasks together.	4.370	0.579
	MC helps me collaborate with others.	4.480	0.535
	MC motivates me to interact with others.	4.390	0.636
	Level of collaboration among the users (total)	4.414	0.535
Usefulness	MC helps me be more effective in learning the topic.	4.450	0.592
	MC is useful in understanding further about the topic.	4.480	0.593
	MC meets my expectations.	4.470	0.564
	Level of usefulness among the users (total)	4.468	0.538
Motivation	MC motivates me to complete tasks assigned by my instructor.	4.500	0.565
	MC motivates me to interact with others outside of class.	4.400	0.557
	MC motivates me to study and understand the topic.	4.480	0.535
	Level of motivation among the users (total)	4.462	0.510
Learning opportunity	MC allows and motivates me to learn from my classmates by reading their posts or comments.	4.370	0.579
	MC helps me prepare for independent learning on the topic.	4.450	0.563
	MC helps me learn and understand further about the topic.	4.470	0.593
	Level of learning opportunity among the users (total)	4.430	0.534
Ease of use	MC is easy to use.	4.550	0.563
	MC is simple to use.	4.550	0.563
	MC is user-friendly.	4.580	0.529
	MC requires the fewest steps possible to accomplish what I want to do with it.	4.530	0.535
	MC can be used without reading instructions.	4.270	0.833
	Level of ease of use among the users (total)	4.497	0.522
Satisfaction	I am satisfied with MC.	4.480	0.565
	I would recommend MC to my friends.	4.500	0.594
	MC is fun to use.	4.520	0.593
	Level of satisfaction among the users (total)	4.500	0.559
Platform effectiveness	The MC has inspired and helped me improve in an analytical skill.	4.500	0.536
	The MC has increased my knowledge of the topic.	4.530	0.564
	The MC should be continued and implemented in the future for other topics.	4.530	0.535
	The MC has helped me understand the topic in better ways.	4.530	0.535
	I am happy to learn using the content provided on the MC.	4.550	0.533
	The use of MC as an educational tool promotes creativity and collaborative learning among students.	4.560	0.532
	The MC serves as a valuable learning resource and a great tool for learning.	4.530	0.564
	Level of platform effectiveness among the users (total)	4.535	0.511

Table 9. Correlation analysis for each variable

Variable		Collaboration	Usefulness	Motivation	Learning opportunity	Ease of use	Satisfaction	Platform effectiveness
Collaboration	r	1	.727**	.869**	.813**	.789**	.715**	.707**
	p		<.001	<.001	<.001	<.001	<.001	<.001
Usefulness	r	.727**	1	.812**	.828**	.735**	.803**	.756**
	p	<.001		<.001	<.001	<.001	<.001	<.001
Motivation	r	.869**	.812**	1	.883**	.835**	.793**	.830**
	p	<.001	<.001		<.001	<.001	<.001	<.001
Learning opportunity	r	.813**	.828**	.883**	1	.824**	.805**	.873**
	p	<.001	<.001	<.001		<.001	<.001	<.001
Ease of use	r	.789**	.735**	.835**	.824**	1	.742**	.750**
	p	<.001	<.001	<.001	<.001		<.001	<.001
Satisfaction	r	.715**	.803**	.793**	.805**	.742**	1	.806**
	p	<.001	<.001	<.001	<.001	<.001		<.001
Platform effectiveness	r	.707**	.756**	.830**	.873**	.750**	.806**	1
	p	<.001	<.001	<.001	<.001	<.001	<.001	

Note. **Correlation is significant at the 0.01 level (2-tailed); r: Pearson correlation; & p: Significance value (2-tailed)

variables, implying the presence of multicollinearity. The variance inflation factor (VIF), which is the inverse of the tolerance value (1 divided by tolerance), also indicates multicollinearity when values surpass 10.

According to **Table 10**, all tolerance values are more than 0.10, indicating no significant multiple correlation among the variables. Similarly, all VIF values are below 10, suggesting that multicollinearity is not a concern. Therefore, all predictors (independent variables) are retained for the multiple regression analysis.

Meanwhile, the modified R^2 value reveals how much of the variation in platform effectiveness can be explained by all factors (collaboration, usefulness, motivation, learning opportunity, ease of use, and satisfaction). In this study, the modified R square is 0.787. When expressed as a percentage, this implies that the model, comprising all predictors, explains 78.7% of the variation in platform effectiveness. The remaining 21.3% of the variance is likely caused by other factors that are not addressed in this model. **Table 11** can be referred to determine the statistical significance of the overall model. To conclude, the model in this analysis is statistically significant ($p < 0.001$).

Table 10. Collinearity statistics for each independent variable

Variable	Standardized coefficients	Significance	Collinearity Statistics	
	Beta		Tolerance	VIF
Collaboration	-0.191	0.128	0.228	4.385
Usefulness	-0.065	0.586	0.249	4.011
Motivation	0.319	0.055	0.132	7.568
Learning opportunity	0.576	< 0.001	0.160	6.242
Ease of use	0.004	0.970	0.255	3.918
Satisfaction	0.275	0.017	0.278	3.597

Table 11. ANOVA

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	12.890	6	2.148	38.536	< 0.001
	Residual	3.066	55	0.056		
	Total	15.957	61			

Next, the contribution of each independent variable was assessed using the standardized beta coefficients. Based on **Table 10**, the largest beta value is for learning opportunity (β = 0.576), indicating that it makes the strongest contribution to explaining the dependent variable, platform effectiveness. This is followed by motivation (β = 0.319), satisfaction (β = 0.275), collaboration (β = -0.191), usefulness (β = -0.065), and ease of use (β = 0.004). However, only learning opportunity ($p < 0.001$) and satisfaction ($p = 0.017$) make statistically significant contributions to predicting platform effectiveness.

Thematic Analysis

Thematic analysis is conducted by classifying the answers into first-order themes and second-order themes. The analysis yielded several first-order themes, which were then classified into 7 variable themes (second-order themes). The thematic analysis process followed a systematic, iterative process to identify recurring patterns as mentioned below:

1. First-order themes: Keywords such as "convenience learning", "helpful learning", "fun learning", and "user friendly" were extracted from the answers.
2. Second-order themes: These categories were further refined into 7 thematic areas that aligned with the research focus which are platform effectiveness, collaboration, usefulness, motivation, learning opportunity, ease of use, and satisfaction.

When students were asked, "Do you agree that MC motivates you to participate in learning activities? Give your reasons," most responses revolved around the theme of learning opportunity. Many students stated that MC platform provides convenient, easy, structured, and flexible learning. This was followed by comments reflecting the usefulness of MC, particularly in supporting their learning process. Some respondents expressed satisfaction, describing MC as "fun to use." Others highlighted the ease of use, noting the platform's user-friendly interface and how it enhanced their motivation and eagerness to complete tasks or exercises. A few also mentioned the platform's contribution to improving their thinking and problem-solving skills, thus contributing to platform effectiveness. However, there were no respondents that mentioned collaboration as their main reasons to participate in the MC learning activities. Meanwhile, three students did not agree that MC motivates them due to reasons of being slow learners, preferred physical learning environment and two-way communication.

Examining the responses for the question, "Do you agree that using MC in class will enhance your understanding of the topic? Give your reasons," most students pointed out the theme of learning opportunity by expressing that MC offered a structured, understandable, comprehensive and flexible learning environment. Other than that, students also mentioned the useful themes where MC has guided them to gain deeper understanding and has saved most of their time. Satisfaction theme is also raised by a few students that describe their learning experience as fun and engaging. Furthermore, they also highlighted the platform's effectiveness in enhancing thinking skills and helping to identify knowledge gaps. One respondent mentioned collaboration, appreciating the opportunity to learn from others through online tasks, while another mentioned ease of use in terms of interactive learning. Interestingly, none of the respondents mentioned motivation as a factor influencing their understanding of the topic. Three students disagreed that MC enhanced their learning, citing reasons such as the need for more detailed explanations, a preference for physical learning, and a desire for direct lecturer guidance.

When asked, "Do you agree that MC helps you collaborate with others? Give your reasons," all responses clearly aligned with the theme of collaboration. Students emphasized that MC provides a platform to discuss questions and answers with peers, especially when tackling difficult questions. They appreciated the ability to compare answers and view feedback, which promoted online communication via the comment section. Several students stated that MC encouraged group discussions and teamwork, particularly with students from other UiTM branches, thus enhancing social interaction and rapport building. However, three students disagreed, expressing that their peers also struggled with the material, that most questions could be completed individually, and that they preferred face-to-face interaction for collaboration.

Finally, when asked for suggestions or feedback regarding the MC regarding the complex integration topic, responses echoed earlier themes, primarily learning opportunity, followed by usefulness, satisfaction, motivation, and ease of use. Notably, no comments related to collaboration or platform effectiveness (in terms of skill enhancement) were raised. Among the suggestions, many students expressed a desire for more examples and exercises, particularly with step-by-step solutions, including past year questions and more challenging problems. Two students preferred face-to-face learning, either through in-class MC sessions or

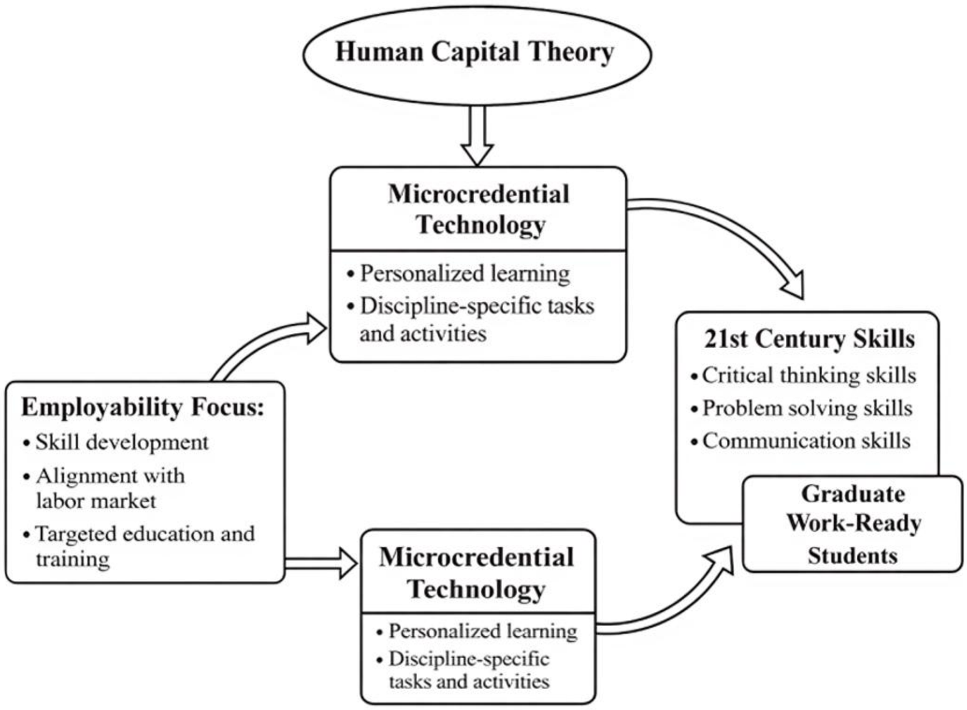

Figure 1. Conceptual framework incorporating human capital theory (Adapted from Li & Ironsi, 2024)

entirely physical lessons, citing the course's difficulty. One notable suggestion proposed the development of more platforms like MC in the future, to help students prepare and self-study before class. Lastly, five respondents expressed satisfaction with the platform in its current form, commenting that it was "already perfect," "good enough," and encouraged to "keep this MC-style learning."

DISCUSSION

Theoretical Framework

Considering how technology-infused education, such as MC platforms, can support students in acquiring new skills, enhancing their learning experiences, and producing effective learning outcomes, its integration into higher education institutions is essential (Li & Ironsi, 2024). In addition, technology-infused education plays a significant role in preparing graduates for workforce participation. The demands of 21st century education necessitate a redesign of teaching and learning practices to ensure the delivery of quality education that addresses the evolving needs of society.

Equipping students with essential 21st century skills such as critical thinking, problem-solving, and communication skills is crucial for bridging existing skill gaps in the modern workplace and enhancing graduate work readiness. In this context, the use of MC learning spaces as online learning tools can support the development of these competencies. MC learning has been identified as an important mechanism for improving students' perceived employability and has a significant impact on their human capital, including cultural, social, and scholastic capital (Zou et al., 2024).

Human capital theory rests on the assumption that formal education is highly instrumental, and even necessary, for improving the productive capacity of a population. In essence, human capital theorists argue that an educated population is a productive population. The theory emphasizes that education enhances workers' productivity and efficiency by increasing the cognitive stock of economically productive human capability, which results from both innate abilities and sustained investment in human development. Consequently, the provision of formal education is viewed as a productive investment in human capital, regarded by proponents of the theory as equally, or even more, valuable than investment in physical capital (Olaniyan & Okemakinde, 2008).

Figure 1 illustrates how human capital theory underpins the use of MC technology as a strategic educational investment to enhance students' skills and employability. Through personalized learning and discipline-specific tasks, MCs facilitate the development of essential 21st century skills, including critical thinking, problem-solving, and communication. These competencies collectively contribute to the production of graduate work-ready students aligned with labor market demands.

Discussion of Findings in Relation to the Theoretical Framework

The findings of this study provide valuable insights into the effectiveness of MC platforms in higher education, particularly within undergraduate mathematics courses for students learning the complex integration topic. Interpreted through the lens of human capital theory, the results suggest that MC platforms function as targeted educational investments that enhance students' cognitive and skill-based capacities, thereby supporting the development of work-ready graduates equipped with essential 21st century skills.

The quantitative analysis revealed that learning opportunity ($\beta = 0.576$, $p < 0.001$) and satisfaction ($\beta = 0.275$, $p = 0.017$) were the only statistically significant predictors of MC platform effectiveness. From a human capital theory perspective, the strong influence of learning opportunity reflects students' recognition of the platform as a meaningful investment in their skill development. The structured, flexible, and accessible learning environment emphasized by students in the qualitative findings indicates that the MC platform effectively increases the "cognitive stock" of economically productive capability by enabling sustained engagement with complex mathematical concepts. This reinforces the theoretical assumption that education enhances productivity by strengthening learners' knowledge and skills through deliberate investment.

Satisfaction also emerged as a significant predictor, highlighting the role of affective experiences in maximizing the returns of human capital investment. Students' enjoyment and positive learning experiences suggest that satisfaction enhances persistence, engagement, and willingness to invest effort in learning activities. This aligns with prior studies showing that MC platforms support flexibility and lifelong learning (Gamage & Dehideniya, 2025) and foster both intrinsic and extrinsic motivation, which in turn enhances satisfaction and learning outcomes (Ahsan et al., 2023; Cheng et al., 2018). In this sense, satisfaction acts as a reinforcing mechanism that strengthens the effectiveness of learning opportunities within MC environments.

Although motivation, collaboration, usefulness, and ease of use did not emerge as statistically significant predictors in the regression analysis, their prominence in the thematic findings underscores their supporting role within the MC learning ecosystem. Consistent with the theoretical framework presented earlier, these factors appear to function as enabling conditions rather than primary drivers of human capital development. Usefulness and ease of use facilitate access and sustained engagement with learning tasks, while motivation and collaboration contribute to students' learning experiences and emotional resilience. This interpretation aligns with previous findings indicating that while learning opportunities and satisfaction drive perceived effectiveness, usability and collaboration primarily enhance the learning process rather than directly determining outcomes (Gilete & García, 2024; Ha et al., 2023).

The integration of quantitative and qualitative findings further demonstrates that MC platform effectiveness cannot be fully captured through statistical analysis alone. While the quantitative results identify key predictors linked to human capital accumulation, the qualitative insights reveal experiential dimensions that shape students' engagement and perception of value. This supports the theoretical proposition that MCs extend human capital theory by embedding employability-oriented and 21st century skills directly into curriculum design. By fostering critical thinking, problem-solving, and communication skills, MC platforms contribute to the production of graduate work-ready students, as conceptualized in the theoretical framework.

Overall, the findings affirm that the MC platform serves as strategic educational investments that align higher education with labor market demands. By prioritizing meaningful learning opportunities and learner satisfaction while supporting motivation, collaboration, and usability, the MC platform can effectively enhance students' human capital and readiness for the 21st century workforce.

CONCLUSION

With their structured, adaptable, and scalable opportunities for students to acquire and demonstrate fundamental mathematical skills, MCs have emerged as a useful teaching strategy in mathematics education. In this study, the factors that influence the effectiveness of MCs in learning mathematics, including the topic of complex integration, were successfully identified. The results show that learning opportunity and student satisfaction play a dominant role in predicting the usefulness of the MC platform. Although learning opportunities and student satisfaction emerged as the strongest predictors of staying engaged with the MC platform, better understanding of the topic and enjoyment of the learning process, the variables such as motivation, collaboration, usefulness and ease of use, were still referenced in the comments made by students. It makes sense to imply that these variables continue to be a part of the learning experience. Therefore, a good MC platform not only offers a flexible format of learning but also ensures the learning opportunity is well designed and structured, as well as easy to use, beneficial, motivating, and enjoyable.

Crucially, the role of MCs in mathematics extends beyond the classroom into industry, particularly through the development of 21st century skills that support graduate work readiness. By helping students develop and demonstrate specific mathematical skills, especially critical and problem solving skills, MCs bridge the gap between academic learning and real-world application. As industries like engineering, data analytics, finance, and technology increasingly require verified and specialized skills, the MC courses give people a flexible way to keep learning and developing their skills, which helps to create a skilled workforce. For further research, one can examine how these variables (motivation, collaboration, learning opportunity, satisfaction, usefulness and ease of use) interact with each other and what impact they have on achieving long-term learning goals on the MC platform, as well as could explore if these variables would be more or less influential across different topics or courses offered on the MC platform.

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