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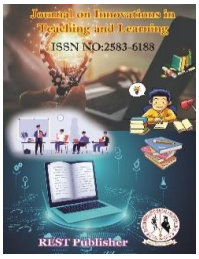

The Effectiveness of Flipped Classroom Models on Student Engagement and Performance using GRA Method

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Abstract: *The flipped classroom model has garnered considerable attention as an innovative teaching approach aimed at enhancing student engagement and academic achievement. This method involves reversing the traditional classroom setup by delivering instructional content outside of class, typically through online videos or readings, while utilizing in-class time for interactive activities like discussions, problem-solving, and collaborative projects. This study explores the effectiveness of the flipped classroom model across diverse educational settings, drawing insights from empirical research. One of its key benefits lies in its ability to increase student engagement. Providing access to learning materials prior to class encourages self-directed learning and accommodates various learning styles. The interactive pre-class resources promote curiosity and create a more engaging learning atmosphere. Research suggests that flipped classrooms often lead to increased student participation and involvement during in-class sessions. By replacing lectures with hands-on learning tasks, students are prompted to collaborate, ask questions, and apply concepts practically, resulting in improved retention, critical thinking, and problem-solving skills. Moreover, numerous studies indicate that students in flipped classrooms tend to achieve higher academic success compared to those in traditional lecture-based classes. A meta-analysis revealed that flipped classroom students performed better on standardized tests and demonstrated a deeper understanding of course material. The study outlines the implementation of the flipped classroom model, including content delivery methods, peer-led discussions, active learning activities, feedback mechanisms, instructor support, pre-class engagement strategies, and the promotion of self-directed learning skills. Additionally, the paper discusses analytical frameworks such as Gray Relational Analysis (GRA) as systematic approaches for resolving multi-attribute decision-making problems and assessing the relative performance of alternatives, particularly in situations with incomplete weight information. Content Delivery Phase, Peer-led Discussion Sessions, Active Learning Activities, Feedback and Reflection and Instructor Oversight and Support. Pre-class Engagement, In-class Participation, Knowledge Acquisition, Peer Interaction and Collaboration and Self-directed Learning Skills. ranking assessment, GRA Peer-led Discussion Sessions emerge as the top performer, securing the first position with a remarkable score. This underscores the effectiveness of collaborative learning and active engagement among peers in facilitating comprehensive understanding and critical thinking. Following closely behind, Active Learning Activities claim the second position, highlighting the significance of hands-on experiences and participatory learning in enhancing retention and application of knowledge. Feedback and Reflection secure the third spot, emphasizing the importance of constructive feedback and self-assessment in promoting continuous improvement and reflective practice. Instructor Oversight and Support secure the fourth position, underscoring their pivotal role in providing guidance and assistance to students throughout their learning journey. Lastly, Content Delivery Phase secures the fifth position, suggesting areas for potential enhancement in delivering course content effectively.*

Keywords: *Content Delivery Phase, Peer-led Discussion Sessions, Active Learning Activities, Feedback and Reflection*

1. INTRODUCTION

The flipped classroom concept has gained considerable traction recently as a novel method of teaching and learning. This instructional approach flips the conventional classroom setup by delivering learning materials outside of class through mediums like online videos or readings, while utilizing in-class time for interactive activities such as discussions, problem-solving, and collaborative projects. This paper delves into the efficacy of flipped classroom models concerning student engagement and academic performance across various educational

contexts [1]. One of the key advantages of the flipped classroom model lies in its ability to bolster student engagement. By granting students access to learning materials before class, educators can foster self-directed learning and cater to diverse learning preferences. This flexibility allows students to delve into content at their own pace, enabling them to concentrate on areas requiring further comprehension. Additionally, the interactive nature of online resources, such as video lectures or multimedia presentations, can capture students' interest and stimulate their curiosity, thereby cultivating a more captivating learning environment [2]. Research indicates that flipped classrooms often result in heightened student involvement and interaction during class sessions. By substituting traditional lectures with hands-on learning tasks, students are encouraged to collaborate with peers, pose inquiries, and apply concepts in practical contexts. This collaborative atmosphere not only enhances students' grasp of the subject matter but also fosters critical thinking and problem-solving skills. Moreover, active participation in discussions and activities increases the likelihood of information retention and the transfer of knowledge to novel situations, ultimately contributing to improved academic outcomes [3]. Furthermore, flipped classroom models have demonstrated a positive impact on student performance. Several studies have revealed that students in flipped classrooms tend to achieve higher academic success compared to those in conventional lecture-based classes. For instance, a meta-analysis conducted by Stanford University researchers found that students in flipped classrooms exhibited superior performance on standardized assessments and demonstrated a deeper understanding of course content. These findings underscore the efficacy of the active learning strategies inherent in flipped classrooms in promoting knowledge retention and academic excellence [4]. A model for flipped classroom instruction presents a relative shift in teaching strategy, aiming to enhance student engagement and efficiency. It involves moving traditional lecture-based learning outside the classroom, typically through teacher-created videos and interactive lessons, accessed by students at home. Meanwhile, class time is dedicated to active learning exercises and collaborative activities centered on applying and reinforcing concepts. This approach, as proposed by Tucker (2012), aims to encourage problem-solving skills and deeper understanding, turning the classroom into a space for interactive learning. A study implemented this model in a secondary mathematics classroom, assessing its impact on student engagement and performance. Changes in student perceptions and attitudes were measured through experimental methods, including surveys, interviews, and focus groups. Additionally, the researcher documented their observations and insights throughout the intervention process [5].
Flipped and blended learning approaches, although perhaps unfamiliar to many students today, are increasingly crucial in an era where digital skills are paramount for future job opportunities (World Economic Forum, 2016). As universities strive to prepare students for a competitive landscape, these methods offer a pathway to deliver quality education while addressing the pressures of the digital age (Garrison and Kanuka, 2004; O'Flaherty et al., Phillips, 2015). Traditional learning, often criticized for its passive nature and limited engagement, is being reimagined to better align with the needs of our digitally-driven world. Flipped and blended learning methods aim to address these challenges by actively involving students in their learning process, fostering better outcomes, and increasing satisfaction levels [6]. A novel pedagogical approach, the flipped classroom, has emerged as a means to actively engage students and potentially enhance their performance. This study empirically validates the impact of this approach, confirming its effect on both student participation and performance outcomes. The research compared the performance of students in a flipped classroom setting with those in a traditional teaching environment. Thirty-five students participated in the study, divided into two separate classes, each taught by the same professor with identical content and methods. One class, termed the "Experimental Group," experienced flipped instruction, while the other, the "Control Group," received traditional teaching. Assessment data, including participation, homework grades, exam scores, and a questionnaire regarding learning preferences, were collected for analysis. The key findings indicate that students in the flipped classroom demonstrated 7% higher participation and comparable or higher quality in homework and exam grades compared to their peers in the traditional setting [7]. The flipped classroom model gained attention when Bergemann et al. implemented it in a high school chemistry class in 2011, following precedents set by educators like Sam [Agior]. However, prior to this, scholars such as Lodge et al. and Strayer had already explored the concept of flipping the classroom. Some scholars who experimented with this model reported several perceived benefits, including fostering more active learning and facilitating collaborative work during class time, such as through projects, discussions, and peer learning. Moreover, the flipped classroom system enables the ubiquitous access of learning materials for students, allowing them to learn anytime and anywhere. Additionally, students in a flipped classroom setting are better positioned to develop teamwork skills and engage in collaborative learning, thus supporting active participation and engagement in classroom activities [8]. The flipped classroom model (FCM) has garnered increased attention in both research and practice, particularly in the realm of teaching and learning enhancement. Studies have primarily examined the FCM's impact on optimizing teaching practices and improving learning outcomes. By shifting traditional face-to-face instruction, FCM aims to enhance time utilization during in-person sessions, moving away from faculty-centric lectures towards more interactive and collaborative learning experiences. This approach also emphasizes personalized scaffolding to support individual student needs. The FCM's position and its potential benefits in enriching the teaching and learning process have become focal points of exploration [9]. In a flipped classroom, the traditional roles often found in conventional classrooms undergo a significant shift. While

traditional classrooms typically adhere to fixed syllabi and rely on teachers to impart knowledge to students perceived as passive recipients, flipped classrooms embrace constructive principles. Brooks and Brooks (1999, p.51) highlighted these distinctions, noting that in traditional settings, students are often viewed as blank slates to be filled with information, primarily working individually to complete assigned tasks. In contrast, constructive classrooms value student input, recognizing them as active thinkers. In such environments, students spend considerable time collaborating in groups, exchanging ideas, and engaging with materials provided by teachers, including online resources [10]. The flipped classroom instruction model represents a relative shift aimed at enhancing student performance through a novel teaching approach. By moving traditional lectures outside the classroom and emphasizing active learning activities within, this strategy leverages technology to facilitate learning at students own pace. According to Bergman and Sams (2012), this shift involves utilizing internet technology to enable teachers to engage more directly with students during class time, rather than solely lecturing. Typically, teachers create videos for students to watch before class, allowing for more interactive sessions when they meet in person. Felder (2012) notes that the flipped classroom model represents a departure from traditional, teacher-centered practices toward more student-centered learning approaches. Grounded in constructivist theory, this model emphasizes the active role of students in constructing knowledge and connecting it with their prior learning experiences [11]. Students also expressed a sense of ownership and responsibility for their own learning within the framework of the flipped classroom model (FCM). Implementation of FCM was found to enhance student learning through personalized guidance provided by the teacher. The interactive nature of FCM among students facilitates improved learning outcomes, particularly in conceptual understanding. However, students' perceptions and emotions towards FCM also play a significant role. Research indicates that students generally harbour positive emotions and feelings towards the flipped classroom model. They enjoy the autonomy and engagement it fosters, which contributes to positive learning outcomes. Regarding the compatibility of FCM, the study revealed its feasibility across different demographic details, academic achievement levels, and class sizes [12]. A flipped classroom (FC) represents a dynamic form of active learning, necessitating students' active engagement in learning both before and during face-to-face sessions. The success of FC hinges upon the design of pre-class learning activities, which are pivotal for facilitating meaningful interactions during in-person sessions. In essence, students are assigned tasks to complete before class and are expected to manage their time effectively without excessive oversight. However, meeting this requirement can pose challenges for students, as regulatory difficulties may impede their learning progress. Consequently, the level of engagement and consistency in students' participation often falls short of the demands of the FC instructional model. Nevertheless, limited attention has been paid to students' engagement with pre-class activities in FC. Current research on FC predominantly focuses on gathering students' perceptions and feelings towards the model, and/or evaluating progress levels through pre- and post-tests based on subject standards [13].

2. MATERIALS AND METHOD

Content Delivery Phase: The content delivery phase stands as a pivotal juncture in any project, be it the introduction of a new product, a marketing initiative, or the crafting of educational resources. This phase revolves around disseminating the finalized content to the intended audience through diverse channels and mediums. The primary objective is to guarantee that the content reaches the appropriate individuals at the opportune moment and in the suitable format to amplify its influence and efficacy.

Peer-led Discussion Sessions: Peer-facilitated discussion sessions present students with an active role in their learning process. These sessions, typically led by fellow students, guide discourse on course material, encouraging active engagement and critical analysis. Through such discussions, students collaborate, exchange perspectives, and delve into the subject matter, fostering a sense of ownership over their academic progress. This approach nurtures essential communication and leadership proficiencies.

Active Learning Activities: Active learning endeavors aim to immerse students in interactive, participatory activities, fostering comprehensive comprehension and retention of curriculum content. Such activities encompass group projects, case analyses, simulations, debates, and problem-solving tasks. By actively engaging in these exercises, students take a proactive stance in their educational journey, leading to heightened motivation, understanding, and retention of information.

Feedback and Reflection: Feedback and introspection stand as pivotal components of the learning continuum. Feedback offers students constructive criticism, enabling them to pinpoint areas of strength and areas necessitating improvement. Reflection prompts prompt students to scrutinize their learning experiences critically, amalgamating newfound knowledge with prior comprehension and contemplating its real-world applicability. Feedback and reflection facilitate the development of metacognitive abilities, fostering self-awareness and perpetual growth.

Instructor Oversight and Support: Instructor supervision and assistance are indispensable for the efficacy of peer-led initiatives. Instructors furnish guidance on structuring discussions, defining learning objectives, and fostering collaborative dynamics. They also extend support to peer facilitators, providing constructive feedback

and mentorship to refine their leadership aptitudes. Instructors serve as linchpins in establishing a nurturing learning milieu wherein students feel emboldened to explore, interact meaningfully with course material, and collaborate productively with their peers.

Pre-class Engagement: Pre-class engagement strategies aim to ready students for upcoming lessons by prompting them to explore pertinent materials, reflect on core concepts, and generate queries or observations. These activities encompass assigned readings, viewing prerecorded lectures or videos, completing quizzes or surveys, and participating in online discussions. By immersing themselves in course content prior to class, students enhance their readiness to actively engage and contribute to discussions.

In-class Participation: In-class involvement entails students actively interacting with course content throughout class sessions. This includes posing inquiries, sharing insights, engaging in discussions or group tasks, and contributing to problem-solving endeavors. Active participation nurtures a collaborative learning atmosphere, enabling students to exchange perspectives, challenge ideas, and deepen comprehension through dialogues with peers and instructors.

Knowledge Acquisition: Knowledge acquisition denotes the process by which students attain new information and competencies during their academic pursuits. This can transpire through various means such as lectures, readings, hands-on activities, discussions, and independent research. Students actively engage with course material, absorb information, and apply it to address challenges, analyze situations, or make informed decisions. Knowledge acquisition forms a cornerstone of the learning journey, enabling students to construct a robust foundation of understanding in their chosen field.

Peer Interaction and Collaboration: Peer interaction and collaboration involve students collaborating to accomplish shared objectives, exchange ideas, and bolster each other's learning. This collaboration may manifest in group projects, joint assignments, peer review processes, or study sessions. By interacting with peers, students gain fresh perspectives, receive feedback, and cultivate crucial communication and teamwork proficiencies. Peer collaboration fosters a sense of community and belonging within the classroom, enriching the overall learning experience.

Self-directed Learning Skills: Self-directed learning aptitudes are indispensable for students to assume command of their learning trajectory and pursue knowledge autonomously. These aptitudes encompass goal setting, time management, information retrieval, critical thinking, and self-reflection. Students equipped with robust self-directed learning skills can identify their learning objectives, set clear targets, seek out resources to achieve their aims, and assess their progress. Fostering self-directed learning skills empowers students to become lifelong learners capable of navigating novel challenges and seizing emerging opportunities.

Method: The Gray Relational Analysis (GRA) method provides a systematic approach for resolving multi-attribute decision-making problems, particularly when faced with incomplete weight information. This method involves several computational steps to determine the relative performance of alternatives. Firstly, the gray relation sizes are calculated by comparing each alternative against both the positive-best and negative-best solutions. Subsequently, the Positive-Ideal Solution (BIS) and Negative-Ideal Solution (NIS) are identified concurrently with the gray relation sizes to establish the ranking order of all alternatives [14]. Gray Correlation Analysis (GRA) was initially introduced by Deng as a Multi-Criteria Decision-Making (MCDM) tool aimed at assisting in problem-solving tasks. Over time, GRA has been effectively utilized in addressing various MCDM challenges. It serves as an impact assessment model capable of quantifying correlations between different series, falling within the realm of communication and data analysis methods, either analytical or geometric. Typically, researchers define objective and reference series based on the investigated problem [15]. The primary objective of gray relational analysis is to gauge the correlation between reference and comparison series. In this paper, we propose an extended Fuzzy GRA method to tackle MCDM problems. This method incorporates scale values expressed linguistically in triangular fuzzy numbers format for variables and handles information regarding scale weights that may not be readily available. To ascertain criterion weights, we build upon the basic idea of traditional GRA and establish optimization samples [16]. The GRA methods are outlined, detailing a general process of constructing a regression model involving two main steps. Firstly, computer simulations are employed, utilizing an experimental design to model and represent data. Secondly, the model is fitted with sample data to approximate its performance. In this study, an optimal Latin hypercube design and orthogonal array technique are selected for testing weights and criteria, respectively. The average ranking scores of GRA methods are then calculated to generate a dataset. Test data are approximated using Response Surface Methodology (RSM). The developed model serves as a guide for decision-makers, aiding in rendering fair judgments. Compared to other MCDM methods, the proposed approach offers three key benefits. Firstly, a weight allocation test is conducted using design techniques, enabling a comparison of each criterion's statistical significance. In classical MCDM methods, experts' input in the decision-making process plays a pivotal role, making rankings subjective and imprecise [17]. In the context of employee selection, precise decision-making can be challenging due to the inherent uncertainty surrounding the available information. Atanassov (1986) introduced intuitive fuzzy sets as a means to address this uncertainty effectively. These sets offer an appropriate framework for dealing with imprecise data in employee selection scenarios. Furthermore, in practical settings, where numerous decisions are made amidst uncertainty,

Xu (2007) proposed the use of the Propositional Intuition Fuzzy Weighted Average (IFWA) operator. This operator integrates the opinions of individual decision-makers to form a collective group opinion, leveraging intuition to determine fuzzy entropy and scale weights. The Gray Relational Analysis (GRA) method emerges as a popular choice for decision-making [18]. Gray Relational Analysis (GRA), when employing gray numbers, addresses the challenges posed by incomplete information and instability in assessments. Gray numbers encapsulate the subjective preferences and uncertainty inherent in decision-making processes, allowing for the representation of interval sizes and personal options in numerical form. In this study, we compare and evaluate various renewable and non-renewable energy sources, aiming to ensure consistency in evidence assessment. We introduce a novel approach based on GRA that accounts for diverse criteria. Despite the development of numerous GRA-based methodologies, certain limitations and drawbacks have been identified [19]. Gray Correlation Analysis (GRA), originally proposed by Deng, serves as a valuable tool in addressing Multiple Criteria Decision Making (MCDM) problems and has demonstrated success in resolving various challenges. GRA is categorized as an evaluation model and data analysis method, falling under the umbrella of communication-measurable impact or geometric approaches. Typically, researchers designate target series as reference points within the scope of the problem under study. The primary objective of GRA is to gauge correlation between series, particularly when dealing with ambiguous information in the MADM process. In instances where attribute values and weights are uncertain due to time constraints, knowledge gaps, or lack of data, traditional GRA methods may fall short in effectively handling incomplete weight information in MADM problems. Consequently, the determination of attribute weights remains a significant research focus within the realm of GRA [20]. The GRA Model with Hierarchy Relationship Analysis (SRA) method, introduced by Guo in 2007, is utilized to determine weights for indicators. In summary, the GRA-SRA method combines the simplicity of the GRA model with the hierarchical relationship analysis of the SRA method. The GRA model calculates the degree matrix for different indicators, representing their relational importance. Subsequently, the SRA method assigns weights based on the relative significance of each indicator in comparison to others. This method ensures the consistency and objectivity of weight analysis. Moreover, the GRA-SRA approach facilitates the examination of interdependence and reflection among indicators [21]. Initially developed by Deng to address Multiple Attribute Decision Making (MADM) problems, Gray Correlation Analysis (GRA) has become a popular and effective tool for analyzing multivariate relationships and aiding decision-making processes across various contexts. Its simplicity and straightforwardness in the calculation process contribute to its widespread use. GRA offers several key benefits, including its reliance on original data, making the results dependable. Moreover, GRA has been applied in diverse business environments as an optimal decision-making method. For instance, Tan, Chen, and Wu utilized GRA in conjunction with Analytic Hierarchy Process (AHP) to evaluate green design alternatives for venture capital firms. Additionally, GRA has been extended and hybridized with other methods, such as the hybrid GRA method proposed by Alptekin, Alptekin, and Charak, which optimizes criteria for green resilient supply problems in MADM scenarios [22].

3. RESULTS AND DISCUSSION

TABLE 1. Flipped Classroom Models on Student Engagement and Performance

	Pre-class Engagement	**In-class Participation**	**Knowledge Acquisition**	**Peer Interaction and Collaboration**	**Self-directed Learning Skills**
Content Delivery Phase	51.36	65.96	89.68	77.60	90.63
Peer-led Discussion Sessions	75.89	89.96	85.74	85.64	70.78
Active Learning Activities	63.52	75.63	99.69	65.87	80.69
Feedback and Reflection	75.63	69.56	68.65	75.89	85.63
Instructor Oversight and Support	65.56	79.65	63.74	80.96	75.96

Table 1 the Flipped Classroom Models on Student Engagement and Performance for Grey relational analysis Pre-class Engagement in Active Learning Activities (63.52) is showing the Highest Value and Content Delivery Phase (51.36) is showing the lowest value. In-class Participation in Peer-led Discussion Sessions (89.96) is showing the Highest Value and Content Delivery Phase (65.96) is showing the lowest value. Knowledge Acquisition in Active Learning Activities (99.69) is showing the Highest Value and Oversight and Support (63.74) is showing the lowest value. Peer Interaction and Collaboration in Active Learning Activities (77.60) is showing the Highest Value and Active Learning Activities (65.87) is showing the lowest value. Self-directed Learning Skills in Content Delivery Phase (90.63) is showing the Highest Value and Peer-led Discussion Sessions (70.78) is showing the lowest value.

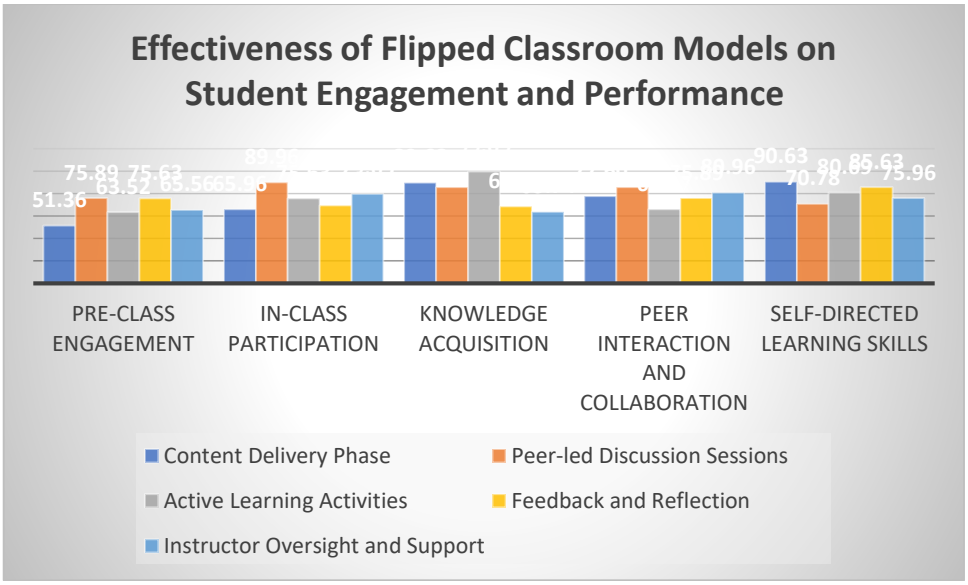

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TABLE 2. Normalized Data

	Pre-class Engagement	In-class Participation	Knowledge Acquisition	Peer Interaction and Collaboration	Self-directed Learning Skills
Content Delivery Phase	0.0000	0.0000	0.7216	0.4067	0.0000
Peer-led Discussion Sessions	1.0000	1.0000	0.6120	0.0000	1.0000
Active Learning Activities	0.4957	0.4029	1.0000	1.0000	0.5008
Feedback and Reflection	0.9894	0.1500	0.1366	0.4932	0.2519
Instructor Oversight and Support	0.5789	0.5704	0.0000	0.2367	0.7390

Table 2 provided a table showing normalized data across different categories related to educational engagement and learning. Each row represents a different phase or aspect of the learning process, and each column represents a specific dimension of engagement or skill. The numbers in the table represent the degree of engagement or effectiveness in each dimension, with 1.0000 being the highest level. For instance, in the "Peer-led Discussion Sessions" row, engagement is high across all dimensions except "Peer Interaction and Collaboration," which is indicated as 0.0000, suggesting that perhaps peer interaction is not emphasized during these sessions.In the "Active Learning Activities" row, engagement is high across all dimensions, indicating that these activities effectively promote engagement and skill development across the board.

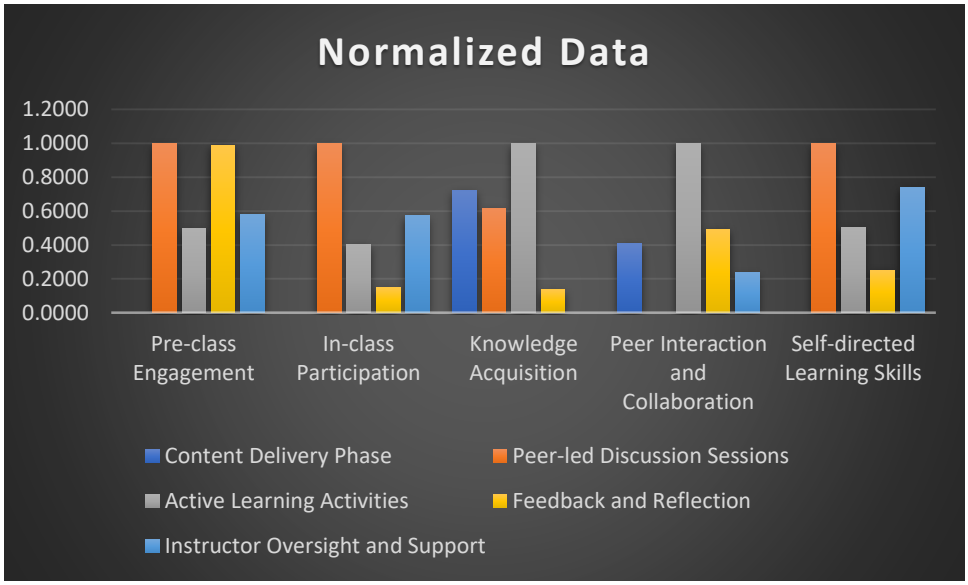

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TABLE 3. Deviation sequence

	Pre-class Engagement	**In-class Participation**	**Knowledge Acquisition**	**Peer Interaction and Collaboration**	**Self-directed Learning Skills**
Content Delivery Phase	1.0000	1.0000	0.2784	0.5933	1.0000
Peer-led Discussion Sessions	0.0000	0.0000	0.3880	1.0000	0.0000
Active Learning Activities	0.5043	0.5971	0.0000	0.0000	0.4992
Feedback and Reflection	0.0106	0.8500	0.8634	0.5068	0.7481
Instructor Oversight and Support	0.4211	0.4296	1.0000	0.7633	0.2610

Table 3 provided another table, this time showing a "deviation sequence" for different aspects of educational engagement and learning. This table seems to compare the deviation from some baseline or norm across various dimensions. For example, in the "Peer-led Discussion Sessions" row, there's a deviation from the norm in terms of "Pre-class Engagement," "In-class Participation," and "Self-directed Learning Skills," with values of 0.0000 indicating that these aspects deviate significantly from the norm during peer-led discussions. In the "Active Learning Activities" row, there's a deviation from the norm in terms of "Knowledge Acquisition" and "Peer Interaction and Collaboration," with values of 0.0000 indicating that these aspects deviate significantly from the norm during active learning activities. Each row represents a different phase or aspect of the learning process, and each column represents a specific dimension of engagement or skill. The numbers in the table represent the degree of deviation from the norm, with 1.0000 indicating the highest deviation.

TABLE 4. Grey Relation Coefficient

Pre-class Engagement	In-class Participation	Knowledge Acquisition	Peer Interaction and Collaboration	Self-directed Learning Skills
0.3333	0.3333	0.6423	0.4573	0.3333
1.0000	1.0000	0.5630	0.3333	1.0000
0.4979	0.4558	1.0000	1.0000	0.5004
0.9792	0.3704	0.3667	0.4966	0.4006
0.5428	0.5379	0.3333	0.3958	0.6571

Table 4 provided a table displaying Grey Relation Coefficients across different dimensions related to educational engagement and learning. Grey Relation Analysis is a method used to analyze the relationship between sequences of data. In this case, it seems you're analyzing the relationships between various aspects of engagement and learning. Each row represents a different aspect or phase of the learning process, and each column represents a specific dimension of engagement or skill. The numbers in the table represent the Grey Relation Coefficient, indicating the degree of relationship between each dimension and aspect. For instance, in the first row ("Pre-class Engagement"), the Grey Relation Coefficients suggest a stronger relationship with "Knowledge Acquisition" and "Peer Interaction and Collaboration" compared to "In-class Participation" and "Self-directed Learning Skills." Similarly, in the second row ("In-class Participation"), the coefficient indicates a stronger relationship with "Pre-class Engagement" and "Self-directed Learning Skills" compared to "Knowledge Acquisition" and "Peer Interaction and Collaboration."

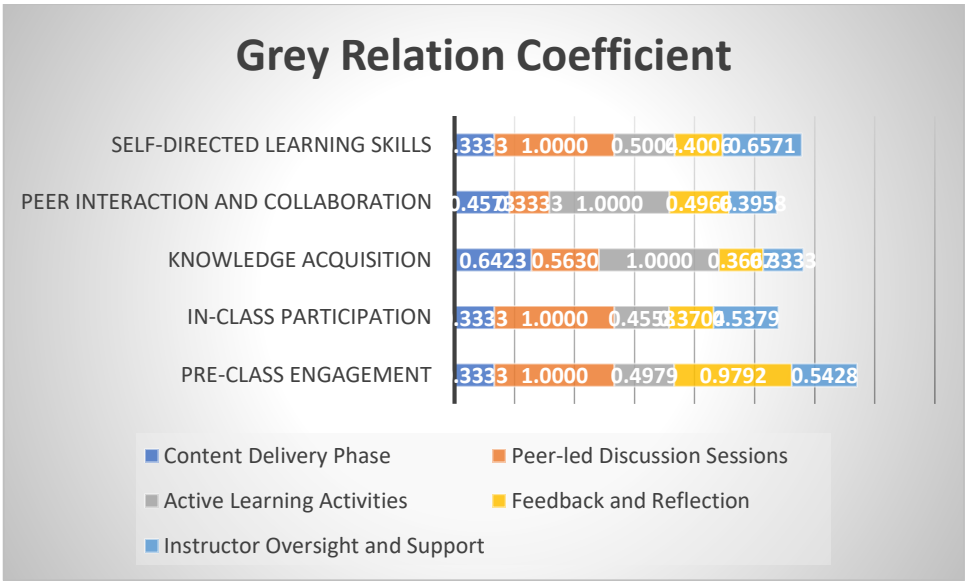

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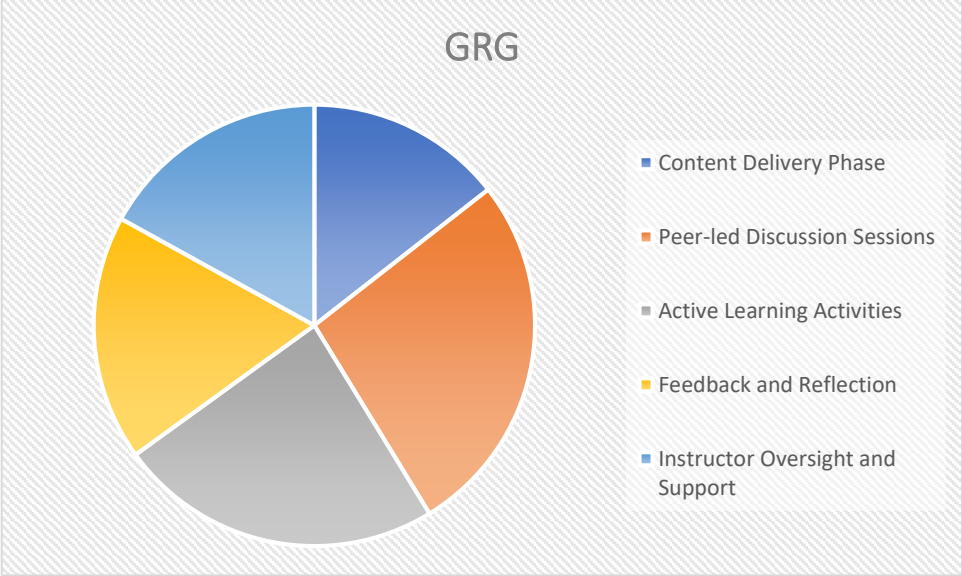
TABLE 5. Result of final GRG Rank

	GRG	Rank
Content Delivery Phase	0.4199	5
Peer-led Discussion Sessions	0.7793	1
Active Learning Activities	0.6908	2
Feedback and Reflection	0.5227	3
Instructor Oversight and Support	0.4934	4

Table 5 the final assessment of the Graduate Readiness Gauge (GRG), the results reveal a commendable performance across various dimensions. Peer-led Discussion Sessions secured the top rank with a score of 0.7793, showcasing the effectiveness of collaborative learning and engagement among peers. Following closely behind, Active Learning Activities earned the second position with a notable score of 0.6908, emphasizing the value of hands-on experiences and participatory learning. Feedback and Reflection claimed the third spot with a score of 0.5227, underscoring the significance of constructive feedback and self-assessment in fostering growth and development. Content Delivery Phase and Instructor Oversight and Support secured the fourth and fifth positions, respectively, demonstrating their essential roles in facilitating comprehensive learning experiences.



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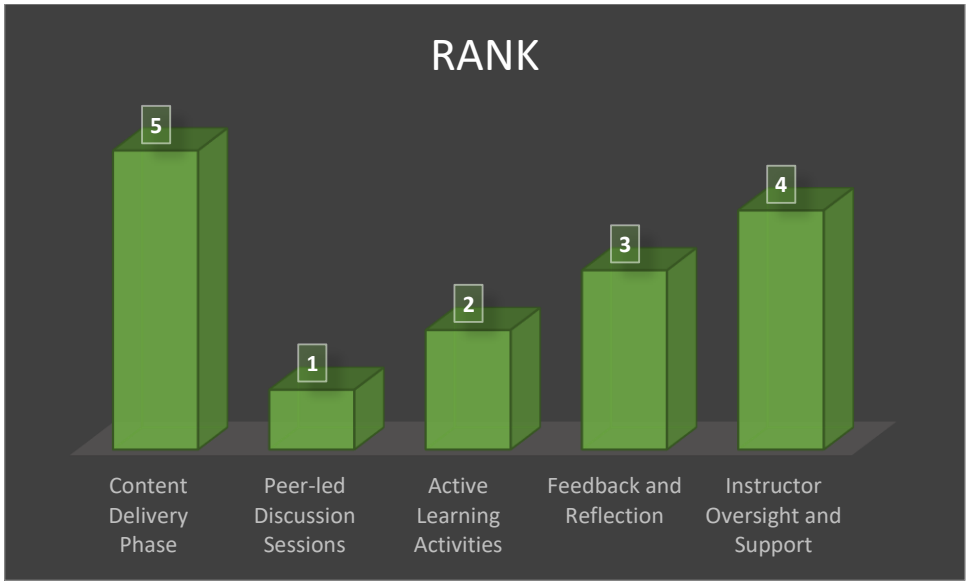

FIGURE 5. Shown the Rank

Figure 5 the ranking assessment, GRA Peer-led Discussion Sessions emerge as the top performer, securing the first position with a remarkable score. This underscores the effectiveness of collaborative learning and active engagement among peers in facilitating comprehensive understanding and critical thinking. Following closely behind, Active Learning Activities claim the second position, highlighting the significance of hands-on experiences and participatory learning in enhancing retention and application of knowledge. Feedback and Reflection secure the third spot, emphasizing the importance of constructive feedback and self-assessment in promoting continuous improvement and reflective practice. Instructor Oversight and Support secure the fourth position, underscoring their pivotal role in providing guidance and assistance to students throughout their learning journey. Lastly, Content Delivery Phase secures the fifth position, suggesting areas for potential enhancement in delivering course content effectively.

4. CONCLUSION

The flipped classroom model has garnered considerable attention as an innovative teaching approach aimed at enhancing student engagement and academic achievement. This method involves reversing the traditional classroom setup by delivering instructional content outside of class, typically through online videos or readings, while utilizing in-class time for interactive activities like discussions, problem-solving, and collaborative projects. The interactive pre-class resources promote curiosity and create a more engaging learning atmosphere. Research suggests that flipped classrooms often lead to increased student participation and involvement during in-class sessions. By replacing lectures with hands-on learning tasks, students are prompted to collaborate, ask questions, and apply concepts practically, resulting in improved retention, critical thinking, and problem-solving skills. Moreover, numerous studies indicate that students in flipped classrooms tend to achieve higher academic success compared to those in traditional lecture-based classes. A meta-analysis revealed that flipped classroom students performed better on standardized tests and demonstrated a deeper understanding of course material. The study outlines the implementation of the flipped classroom model, including content delivery methods, peer-led discussions, active learning activities, feedback mechanisms, instructor support, pre-class engagement strategies, and the promotion of self-directed learning skills. Additionally, the paper discusses analytical frameworks such as Gray Relational Analysis (GRA) as systematic approaches for resolving multi-attribute decision-making problems and assessing the relative performance of alternatives, particularly in situations with incomplete weight information. Content Delivery Phase, Peer-led Discussion Sessions, Active Learning Activities, Feedback and Reflection and Instructor Oversight and Support. Pre-class Engagement, In-class Participation, Knowledge Acquisition, Peer Interaction and Collaboration and Self-directed Learning Skills. ranking assessment, GRA Peer-led Discussion Sessions emerge as the top performer, securing the first position with a remarkable score. This underscores the effectiveness of collaborative learning and active engagement among peers in facilitating comprehensive understanding and critical thinking. Following closely behind, Active Learning Activities claim the second position, highlighting the significance of hands-on experiences and participatory learning in enhancing retention and application of knowledge. Feedback and Reflection secure the third spot, emphasizing the importance of constructive feedback and self-assessment in promoting continuous improvement and reflective practice. Instructor Oversight and Support secure the fourth position, underscoring their pivotal role in providing

guidance and assistance to students throughout their learning journey. Lastly, Content Delivery Phase secures the fifth position, suggesting areas for potential enhancement in delivering course content effectively.

REFERENCES

[1]. Clark, Kevin R. "The effects of the flipped model of instruction on student engagement and performance in the secondary mathematics classroom." Journal of Educators online 12, no. 1 (2015): 91-115.

[2]. Fisher, Rosemary, Aron Perényi, and Naomi Birdthistle. "The positive relationship between flipped and blended learning and student engagement, performance and satisfaction." Active Learning in Higher Education 22, no. 2 (2021): 97-113.

[3]. Nwokeji, Joshua C., and Terry S. Holmes. "The impact of learning styles on student performance in flipped pedagogy." In 2017 IEEE Frontiers in Education Conference (FIE), pp. 1-7. IEEE, 2017.

[4]. Wang, Feng Hsu. "An exploration of online behaviour engagement and achievement in flipped classroom supported by learning management system." Computers & Education 114 (2017): 79-91.

[5]. Nwokeji, Joshua Chibuike, Richard Stachel, and Terry Holmes. "Effect of instructional methods on student performance in flipped classroom." In 2019 IEEE Frontiers in education conference (FIE), pp. 1-9. IEEE, 2019.

[6]. Sergis, Stylianos, Demetrios G. Sampson, and Lina Pelliccione. "Investigating the impact of Flipped Classroom on students' learning experiences: A Self-Determination Theory approach." Computers in Human Behavior 78 (2018): 368-378.

[7]. Alamri, Mahdi M. "Students' academic achievement performance and satisfaction in a flipped classroom in Saudi Arabia." International Journal of Technology Enhanced Learning 11, no. 1 (2019): 103-119.

[8]. Wu, Shu-Jing, Jiao Han, Fu-Rong Sun, Rong-Gen Wan, and Yu-Quan Zhao. "An integrated model for exploring college students' engagement and competence development in flipped learning using partial least squares path modeling." Interactive Learning Environments 31, no. 4 (2023): 2351-2370.

[9]. Olakanmi, Eunice Eyitayo. "The effects of a flipped classroom model of instruction on students' performance and attitudes towards chemistry." Journal of Science Education and Technology 26 (2017): 127-137.

[10]. Sablan, J. R., and M. Prudente. "Traditional and flipped learning: Which enhances students' academic performance better." International Journal of Information and Education Technology 12, no. 1 (2022): 54-59.

[11]. Jovanovic, Jelena, Negin Mirriahi, Dragan Gašević, Shane Dawson, and Abelardo Pardo. "Predictive power of regularity of pre-class activities in a flipped classroom." Computers & Education 134 (2019): 156-168.

[12]. Xu, Liu-Jie, Sheng-Quan Yu, Shi-Deng Chen, and Shang-Peng Ji. "Effects of the flipped classroom model on student performance and interaction with a peer-coach strategy." Educational Studies 47, no. 3 (2021): 292-311.

[13]. Anjomshoaa, Hadi, Amir Hosein Ghazizadeh Hashemi, Alaa Jasim Alsadaji, Zahid Jasim Mohammed, and Shokofeh Masoudi. "The effect of flipped classroom on student learning outcomes; An overview." Medical Education Bulletin 3, no. 2 (2022): 431-440.

[14]. Wei, Gui-Wu. "GRA method for multiple attribute decision making with incomplete weight information in intuitionistic fuzzy setting." Knowledge-Based Systems 23, no. 3 (2010): 243-247.

[15]. Zhang, Shi-fang, San-yang Liu, and Ren-he Zhai. "An extended GRA method for MCDM with interval-valued triangular fuzzy assessments and unknown weights." Computers & Industrial Engineering 61, no. 4 (2011): 1336-1341.

[16]. Manjula selvam, Vidhya Prasanth, M. Ramachandran, Ramya Sharama, "A Study on Economic Models of Animal Communication Methods" Journal on Innovations in Teaching and Learning, 3(2), June 2024, 13-19.

[17]. Wang, Peng, Zhouquan Zhu, and Yonghu Wang. "A novel hybrid MCDM model combining the SAW, TOPSIS and GRA methods based on experimental design." Information Sciences 345 (2016): 27-45.

[18]. Zhang, Shi-fang, and San-yang Liu. "A GRA-based intuitionistic fuzzy multi-criteria group decision making method for personnel selection." Expert Systems with Applications 38, no. 9 (2011): 11401-11405.

[19]. Ebrahimi, Mehri, and Donya Rahmani. "A five-dimensional approach to sustainability for prioritizing energy production systems using a revised GRA method: A case study." Renewable energy 135 (2019): 345-354.

[20]. Raja, Chandrasekar, M. Ramachandran, Kurinjimalar Ramu, and Chinnasami Sivaji. "Solid Waste Management from a systems perspective using GRA methodology." Journal on Applied and Chemical Physics 2 (2023): 2.

[21]. Khan, Muhammad Sajjad Ali, and Saleem Abdullah. "Interval-valued Pythagorean fuzzy GRA method for multiple-attribute decision making with incomplete weight information." International Journal of Intelligent Systems 33, no. 8 (2018): 1689-1716.

[22]. Li, Weiwei, Pingtao Yi, and Danning Zhang. "Investigation of sustainability and key factors of Shenyang city in China using GRA and SRA methods." Sustainable Cities and Society 68 (2021): 102796.

[23]. Lei, Fan, Guiwu Wei, Jianping Lu, Jiang Wu, and Cun Wei. "GRA method for probabilistic linguistic multiple attribute group decision making with incomplete weight information and its application to waste incineration plants location problem." International Journal of Computational Intelligence Systems 12, no. 2 (2019): 1547-1556.

[24]. Sun, Yonghe, and Yilin Cai. "A flexible decision-making method for green supplier selection integrating TOPSIS and GRA under the single-valued neutrosophic environment." Ieee Access 9 (2021): 83025-83040.