

Developing a Framework for the Influence of Experiential Learning on Motivation and Effectiveness in STEM Education in Guizhou, China

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Abstract

STEM education is widely recognized as a key driver of innovation and economic development; however, in under-resourced regions such as Guizhou, China, student motivation, engagement, and learning effectiveness remain persistently low. Traditional lecture-based instruction continues to dominate STEM classrooms, limiting opportunities for active participation and real-world application of knowledge. This study develops a theoretical framework to examine how experiential learning influences student motivation and learning effectiveness in STEM education within the Guizhou context. Grounded in Kolb's Experiential Learning Theory, Self-Determination Theory, and the Theory of Planned Behaviour, the framework positions experiential learning as the central pedagogical approach, with student engagement serving as a critical mediating factor and motivation acting as a key driver of learning effectiveness. Through an extensive review of international and regional literature, the study synthesizes evidence demonstrating that hands-on, project-based, and community-linked STEM activities enhance students' autonomy, competence, and relatedness, leading to higher engagement and sustained motivation. The proposed framework provides a theoretically integrated and contextually relevant model for understanding the mechanisms through which experiential learning improves STEM learning outcomes. It offers practical implications for curriculum design, instructional strategies, policy development, and

assessment in Guizhou and similar underdeveloped regions, contributing to more effective, engaging, and meaningful STEM education.

Keywords: STEM experiential learning, student engagement, learning effectiveness, theoretical framework

1. Introduction

STEM education has become a global priority because of its pivotal role in driving creativity, innovation, and economic growth. International frameworks emphasize STEM as essential for equipping students with the knowledge and skills needed to meet the demands of rapidly evolving technological industries (Bybee, 2013; English, 2016; OECD, 2019). However, despite this global emphasis, STEM education in Guizhou, China, continues to face persistent challenges that undermine student motivation and learning effectiveness (Gao, 2014; Dong et al., 2020; Lyu et al., 2022). Low enrolment rates, limited interest in STEM disciplines, and suboptimal academic performance highlight systemic weaknesses in pedagogy and infrastructure (Zeng et al., 2019).

Traditional lecture-based approaches dominate many STEM classrooms in Guizhou, often failing to develop practical skills, creativity, and problem-solving competencies required for success in STEM fields (Freeman et al., 2014; Schweingruber et al., 2014). Consequently, students frequently become disengaged and demotivated, struggling to connect theoretical concepts with authentic, real-world applications (Jonathan & Laik, 2019; Keshtkar et al., 2023). This challenge underscores the need for a structured framework to understand how experiential learning influences motivation and learning effectiveness in STEM education in the region.

Within this context, student engagement emerges as a critical mediating factor. Engagement, encompassing behavioural participation, emotional investment, and cognitive involvement, strengthens the impact of experiential learning on motivation and learning outcomes (Hsieh & Yu, 2023; Haq et al., 2025). Research shows that when students actively engage in hands-on, project-based, or problem-based STEM activities, their motivation increases, leading to improved comprehension, creativity, and critical thinking skills (Julia & Antolí, 2019; Khairati et al., 2021). Conversely, a lack of engagement diminishes the effectiveness of experiential learning, leaving students passive and disconnected from learning tasks (Almeda & Baker, 2020).

Another challenge is the insufficiency of resources, including well-equipped laboratories, technological tools, and qualified educators (Lyu et al., 2022; Zeng et al., 2019). Limited access to these resources restricts students' ability to participate in experiential learning fully and hinders the development of autonomy, competence, and relatedness, which are core drivers of intrinsic motivation (Moore et al., 2020; Chiu, 2024). This situation contributes to low enthusiasm for STEM careers, as many students perceive STEM subjects as overly difficult and disconnected from personal or professional aspirations (Bayanova et al., 2023; Jaafar & Maat, 2020).

Although prior studies have investigated STEM education challenges, experiential learning, and student motivation independently, few studies have empirically examined the interconnected influence of experiential learning on motivation, engagement, and learning effectiveness specifically in the context of Guizhou, China. Existing research in China often focuses on general STEM instructional practices (Dong et al., 2020; Lyu et al., 2022) or on global active learning approaches (Freeman et al., 2014; Remington et al., 2023), leaving a

gap in understanding how experiential learning can be systematically applied to enhance student engagement and motivation in under-resourced regional settings. Furthermore, there is a lack of comprehensive frameworks that integrate theoretical perspectives such as Kolb's Experiential Learning Theory, Self-Determination Theory, and the Theory of Planned Behaviour to explain the mechanisms through which experiential learning translates into improved learning outcomes in STEM.

Applying the theoretical framework developed in this study addresses this gap by providing a structured lens to examine how experiential learning influences motivation and learning effectiveness in STEM education in Guizhou, China. Experiential learning strategies, including laboratory experiments, project-based tasks, and community-linked STEM activities, have been shown to increase engagement, strengthen motivation, and improve learning outcomes (Remington et al., 2023; Lestari, 2021; Baahmad, 2025; Keshtkar et al., 2023). By linking engagement and motivation to learning effectiveness, this framework aims to guide educators and policymakers in implementing effective STEM pedagogical practices that are contextually relevant to Guizhou's educational setting.

2. Global Perspectives on STEM Education

STEM education has emerged as a global priority due to its critical role in fostering innovation, creativity, and economic competitiveness in knowledge-based economies. International organizations and governments worldwide emphasize STEM education as a strategic response to rapid technological advancement and workforce transformation (OECD, 2019). Countries across Asia, Europe, and North America have implemented STEM-focused policies to equip students with scientific literacy, digital skills, and problem-solving competencies required for future industries (Bybee, 2013).

Despite this strong global emphasis, persistent challenges remain in sustaining student motivation and engagement in STEM learning. Research indicates that traditional lecture-based instructional approaches often fail to connect abstract STEM concepts with authentic, real-world applications, resulting in student disengagement and superficial understanding (Freeman et al., 2014). Such passive learning environments limit opportunities for inquiry, experimentation, and critical thinking, which are essential for meaningful STEM learning (Schweingruber et al., 2014).

The literature consistently highlights that effective STEM education requires pedagogical strategies that actively involve learners in contextualized and problem-based learning experiences. Approaches such as inquiry-based learning, project-based learning, and experiential learning have been shown to enhance creativity, collaboration, and higher-order thinking skills by situating learning within real-world contexts (English, 2016). Active participation in STEM learning not only improves theoretical understanding but also strengthens students' motivation and engagement, which are key predictors of long-term success in STEM education (Freeman et al., 2014).

2.1 Challenges in STEM Education in Guizhou, China

Despite global advancements in science and technology education, STEM education in

Guizhou, China continues to face considerable challenges. Studies indicate that low student enrolment, inadequate educational resources, and limited exposure to hands-on and practical applications significantly hinder student motivation and learning effectiveness (Gao, 2014; Zeng et al., 2019). Traditional lecture-oriented teaching methods remain dominant in many classrooms, contributing to student disengagement and insufficient preparation for future STEM-related careers (Dong et al., 2020).

Existing literature further highlights structural and systemic deficiencies, including poorly equipped laboratories and a shortage of qualified and professionally trained STEM educators, which restrict opportunities for experiential and inquiry-based learning (Lyu et al., 2022; Gao, 2014). These constraints exacerbate motivational challenges, as many students perceive STEM subjects as overly complex, abstract, and disconnected from real-life contexts (Dong et al., 2020; Zeng et al., 2019). Addressing these interconnected pedagogical, infrastructural, and motivational barriers is therefore essential to improving the quality and outcomes of STEM education in Guizhou and similar underdeveloped regions in China.

2.2 Experiential Learning Theory (ELT) and STEM Education

Kolb's Experiential Learning Theory (ELT) provides a foundational framework for understanding learning as a cyclical process involving concrete experience, reflective observation, abstract conceptualization, and active experimentation. This theory has been widely applied in higher education to explain how learners construct knowledge through direct engagement and reflection (Jonathan & Laik, 2019). Within STEM education, experiential learning is commonly operationalized through laboratory experiments, project-based learning, and community- or industry-linked applications that situate learning in authentic contexts.

Empirical studies demonstrate that experiential learning approaches significantly enhance students' ability to transfer theoretical knowledge into practical problem-solving situations, thereby improving theoretical understanding and long-term knowledge retention (Keshtkar et al., 2023). Such learning environments also promote higher-order cognitive processes, including creativity, critical thinking, and systematic problem-solving, which are essential competencies for success in STEM-related careers (Baahmad, 2025). Moreover, experiential learning has been shown to support the development of soft skills such as collaboration, communication, and adaptability, which are increasingly valued in engineering and scientific professions (Baahmad, 2025).

The literature further emphasizes that in the absence of structured experiential learning opportunities, students often struggle to bridge the gap between abstract theory and real-world application, leading to reduced engagement and limited instructional effectiveness in STEM education (Jonathan & Laik, 2019; Keshtkar et al., 2023). Consequently, integrating ELT-informed pedagogical strategies is critical for enhancing the relevance, effectiveness, and sustainability of STEM instruction.

2.3 Self-Determination Theory (SDT) and Student Motivation

Self-Determination Theory (SDT) explains student motivation as being driven by the

fulfilment of three basic psychological needs: autonomy, competence, and relatedness (Ryan & Deci, 2020). From an educational perspective, SDT provides a robust framework for understanding how learning environments can either support or hinder intrinsic motivation and sustained engagement (Reeve, 2012). When these needs are satisfied, learners are more likely to demonstrate higher levels of motivation, persistence, academic satisfaction, and overall well-being (Howard et al., 2021).

In the context of STEM education, experiential learning activities create meaningful opportunities for students to exercise autonomy through choice and decision-making, develop competence via hands-on experimentation and problem-solving, and foster relatedness through collaborative and community-based learning experiences (Moore et al., 2020; Chiu et al., 2023). Empirical research indicates that STEM learning environments aligned with SDT principles enhance students' interest, engagement, and identity development in STEM disciplines (Chiu, 2024). Such environments are particularly effective in encouraging students to persist in challenging STEM tasks and develop a sense of belonging within scientific and technical fields.

On the contrary, instructional contexts that limit student autonomy, provide insufficient feedback, or fail to support competence development often result in disengagement, reduced interest, and demotivation (Reeve, 2012; Ryan & Deci, 2020). The literature consistently underscores that experiential learning approaches align closely with SDT by naturally supporting autonomy, competence, and relatedness, thereby making them powerful pedagogical tools for fostering intrinsic motivation and sustained engagement in STEM education (Howard et al., 2021; Chiu et al., 2023).

2.4 Theory of Planned Behaviour (TPB) and Student Engagement

The Theory of Planned Behaviour (TPB) provides a valuable explanatory lens for understanding how students' attitudes, subjective norms, and perceived behavioural control shape their intentions and subsequent learning behaviours. In educational research, TPB has been widely applied to explain students' engagement, persistence, and decision-making in STEM-related learning and career pathways (Foltz et al., 2015). By focusing on intention as a precursor to action, TPB helps clarify how motivational factors are translated into observable engagement in learning activities.

Within STEM education, students' attitudes toward experiential learning play a central role in determining their willingness to engage in hands-on and inquiry-based activities. Positive attitudes toward STEM learning have been shown to strengthen students' intentions to participate actively and persist in STEM-related tasks (Moore & Burrus, 2019). Similarly, subjective norms, such as encouragement from teachers and expectations from peers, significantly influence students' engagement by shaping their perceptions of the social value of participating in experiential learning activities (Foltz et al., 2015).

Perceived behavioural control further influences student engagement by affecting students' confidence in their ability to manage learning tasks and overcome challenges. Research indicates that when students believe they possess the skills and resources necessary to

succeed, they are more likely to engage consistently in STEM learning activities (Moses et al., 2020). Conversely, low perceived control can lead to avoidance behaviours and reduced participation, even when students hold positive attitudes toward STEM learning (Moore & Burrus, 2019).

Through integrating TPB into the theoretical framework, this study clarifies how experiential learning can lead to sustained behavioural engagement rather than short-term motivational responses. TPB highlights the mechanisms through which experiential learning environments influence students' intentions, ensuring that motivation is not merely theoretical but enacted through consistent and purposeful engagement in STEM learning behaviours (Foltz et al., 2015).

2.5 Student Engagement as a Mediating Factor

Student engagement is widely recognized as a key mediating mechanism that strengthens the relationship between experiential learning, student motivation, and learning effectiveness in STEM education. Engagement is commonly conceptualized as a multidimensional construct encompassing behavioural participation, emotional investment, and cognitive involvement in learning activities. Empirical research has shown that higher levels of engagement are associated with stronger achievement motivation and improved learning outcomes among STEM students (Hsieh & Yu, 2023).

In experiential learning environments, engaged students are more likely to perceive learning tasks as meaningful and relevant, which enhances their intrinsic motivation. Studies focusing on project-based and problem-based STEM learning have demonstrated that active participation and emotional involvement significantly increase students' motivation and sustained interest in STEM subjects (Haq et al., 2025). Cognitive engagement, in particular, enables students to reflect on their learning experiences and apply knowledge effectively, thereby supporting deeper understanding and skill development (Hsieh & Yu, 2023).

Student engagement also plays a critical role in translating experiential learning into long-term educational and career-related outcomes. Research indicates that affective and cognitive engagement during STEM learning experiences positively influences students' aspirations and persistence in STEM pathways (Almeda & Baker, 2020). When students are emotionally connected and cognitively invested in experiential tasks, they are more likely to develop positive attitudes toward STEM learning and future participation in STEM fields.

On the other hand, the absence of student engagement can significantly weaken the effectiveness of experiential learning initiatives. Without active behavioural involvement or emotional connection, students may remain passive or disconnected from learning activities, limiting the motivational and educational benefits of experiential approaches (Haq et al., 2025). These findings underscore that student engagement functions as a crucial bridge linking experiential learning to motivation and learning effectiveness in STEM education.

2.6 Motivation and Learning Effectiveness in STEM Education

Motivation is widely recognized as a critical determinant of learning effectiveness in STEM

education, as it influences how students engage with content, persist in challenging tasks, and achieve academic success. Empirical studies have shown that motivated students demonstrate stronger academic performance and higher levels of persistence in STEM learning environments (Jaafar & Maat, 2020). Motivation also plays a key role in shaping students' long-term interest in STEM disciplines and their willingness to pursue STEM-related careers (Bayanova et al., 2023).

High levels of motivation enhance students' comprehension of complex STEM concepts by encouraging deeper cognitive processing and active engagement with learning tasks. Research indicates that motivated learners are more capable of applying theoretical knowledge to practical and real-world problems, particularly in active and inquiry-based STEM settings (Wahono et al., 2020). Moreover, sustained motivation fosters resilience, enabling students to cope with cognitive challenges and persist in solving complex and unfamiliar problems (Bayanova et al., 2023).

The literature further highlights that experiential and active learning approaches significantly strengthen student motivation when they are combined with meaningful engagement. Longitudinal evidence from STEM-based active learning courses shows that hands-on, student-centred instructional designs lead to sustained improvements in student motivation and learning effectiveness over time (Julia & Antolí, 2019). Such approaches allow students to see the relevance of STEM knowledge, thereby reinforcing motivation and supporting effective knowledge transfer (Wahono et al., 2020).

Conversely, students who experience low motivation often exhibit weaker academic performance, limited creativity, and reduced ability to apply STEM knowledge in practical contexts. Studies have found that low self-efficacy and diminished motivation are associated with disengagement and poor learning outcomes in STEM education (Jaafar & Maat, 2020). These findings underscore the importance of fostering motivation as a central mechanism for enhancing learning effectiveness in STEM education.

3. Development of the Framework

The theoretical framework for this study is developed to illustrate the relationships among experiential learning, student engagement, motivation, and learning effectiveness in STEM education. Experiential learning has been widely recognized as an effective pedagogical approach in STEM contexts, as it enables learners to apply theoretical knowledge through authentic and hands-on activities (Remington et al., 2023). Empirical evidence suggests that STEM-based experiential learning enhances students' problem-solving abilities and critical thinking skills, leading to improved learning outcomes (Khairati et al., 2021; Lestari, 2021).

This framework is grounded in Kolb's Experiential Learning Theory (ELT), which conceptualizes learning as a cyclical process involving concrete experience, reflective observation, abstract conceptualization, and active experimentation. In STEM education, this learning cycle is operationalized through laboratory work, project-based learning, and inquiry-driven tasks that support knowledge construction through experience (Lestari, 2021). Such approaches have been shown to improve students' theoretical understanding and

engagement with complex STEM content (Remington et al., 2023).

To address the motivational dimension of learning, the framework integrates Self-Determination Theory (SDT), which posits that student motivation is driven by the fulfilment of autonomy, competence, and relatedness (Moore et al., 2020). In STEM learning environments, experiential activities allow students to exercise autonomy through decision-making, develop competence through repeated practice and feedback, and strengthen relatedness through collaborative learning (Ortiz et al., 2018). Research further indicates that when these psychological needs are satisfied, students demonstrate stronger engagement, persistence, and identity development in STEM disciplines (Chiu, 2024).

The framework also incorporates the Theory of Planned Behaviour (TPB) to explain how students' attitudes toward experiential learning influence their engagement and motivation. According to TPB, behavioural intentions are shaped by attitudes, perceived social norms, and perceived behavioural control, all of which play a critical role in educational contexts (Wu et al., 2022). In STEM education, supportive teacher expectations and peer influence can strengthen students' willingness to participate in experiential activities, while perceived control over learning tasks enhances sustained engagement (Wu et al., 2022).

Within the proposed framework, student engagement functions as a mediating mechanism that strengthens the relationship between experiential learning and student motivation. Experiential learning environments that actively involve students cognitively, emotionally, and behaviourally are more likely to foster intrinsic motivation (Moore et al., 2020). Motivated students, in turn, demonstrate higher levels of learning effectiveness, as reflected in improved academic performance, deeper understanding, and enhanced problem-solving skills (Khairati et al., 2021).

The theoretical framework is illustrated in Figure 1, which depicts the directional pathways linking experiential learning, student engagement, motivation, and learning effectiveness among STEM students in Guizhou, China. By integrating ELT, SDT, and TPB, the framework provides a theoretically robust and contextually relevant model for examining how experiential learning shapes motivational processes and learning outcomes in STEM education.

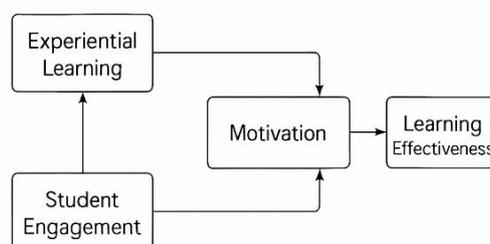


Figure 1. Theoretical framework for the influence of experiential learning on student motivation and learning effectiveness in STEM education

Figure 1 illustrates the central and foundational role of student engagement within the proposed theoretical framework. Consistent with prior research, student engagement is a critical mechanism through which experiential learning and motivation are activated in STEM education (Reeve, 2012; Almeda & Baker, 2020; Hsieh & Yu, 2023). The framework indicates that when students are actively engaged, they are more likely to participate meaningfully in experiential learning activities, such as hands-on experimentation, project-based learning, and community-linked STEM tasks (Freeman et al., 2014; Jonathan & Laik, 2019; Haq et al., 2025).

These experiential learning opportunities support students' autonomy, competence, and relatedness, thereby stimulating intrinsic motivation, as explained by Self-Determination Theory (Ryan & Deci, 2020; Howard et al., 2021; Chiu, 2024). Heightened motivation subsequently functions as a key driver of learning effectiveness, contributing to deeper theoretical understanding, improved problem-solving abilities, and sustained learning behaviours in STEM contexts (Bayanova et al., 2023; Julia & Antolí, 2019; Wahono et al., 2020).

This sequential relationship reinforces the value of engagement-driven experiential strategies, particularly in under-resourced STEM settings such as Guizhou, China, where traditional instructional approaches and contextual constraints continue to limit student motivation and learning outcomes (Gao, 2014; Dong et al., 2020; Lyu et al., 2022).

4. Potential Application of the Framework

The developed theoretical framework has significant potential for application in both research and practice within STEM education. By positioning experiential learning as the central instructional approach, mediated by student engagement and supported by motivation, the framework provides a structured pathway for improving learning effectiveness (Jonathan & Laik, 2019; Keshtkar et al., 2023; Baahmad, 2025). In practical terms, the framework can be applied to:

- 1) For curriculum design, STEM educators can integrate experiential learning activities such as project-based tasks, laboratory experiments, and community-based STEM projects to foster engagement and motivation (Khairati et al., 2021; Lestari, 2021; Remington et al., 2023).
- 2) For instructional strategies, teachers can use the framework to design lessons that emphasize autonomy, collaboration, and reflection, thereby aligning with both Self-Determination Theory (Reeve, 2012; Chiu, 2024; Moore et al., 2020) and the Theory of Planned Behaviour (Foltz et al., 2015; Moore & Burrus, 2019; Moses et al., 2020).
- 3) For policy development, education policymakers in Guizhou and similar contexts can adopt the framework to guide reforms that prioritize experiential learning as a driver of student-centred STEM education (Wu et al., 2022; Gao, 2014).
- 4) For assessment models, the framework can inform the development of evaluation tools that measure not only academic achievement but also engagement and motivational outcomes,

ensuring a holistic view of learning effectiveness (Hsieh & Yu, 2023; Almeda & Baker, 2020; Haq et al., 2025).

5) For cross-cultural adaptation, contextualized in Guizhou, China, the framework can be adapted to other regions, providing comparative insights into how cultural and institutional factors influence the effectiveness of experiential learning in STEM (Freeman et al., 2014; English, 2016; Schweingruber et al., 2014).

Finally, the framework serves as both a diagnostic tool for understanding current challenges in STEM education and a prescriptive model for designing interventions that enhance student motivation and learning effectiveness through experiential approaches (Jaafar & Maat, 2020; Bayanova et al., 2023; Julia & Antolí, 2019; Wahono et al., 2020)..

5. Conclusion

This study developed a theoretically grounded theoretical framework to explain how experiential learning influences student motivation and learning effectiveness in STEM education within the context of Guizhou, China. Drawing on Kolb's Experiential Learning Theory, Self-Determination Theory, and the Theory of Planned Behaviour, the framework positions experiential learning as the central pedagogical approach, with student engagement functioning as a key mediating mechanism and motivation serving as a critical driver of learning effectiveness. Through an extensive synthesis of the literature, this theoretical analysis highlights how persistent challenges in Guizhou such as limited resources, reliance on traditional lecture-based instruction, and low levels of student engagement that undermine students' motivation and their ability to apply STEM knowledge in meaningful and practical contexts.

Through integrating experiential learning strategies, including project-based learning, laboratory experimentation, and community-linked STEM activities, the proposed framework provides a structured pathway for enhancing student engagement, supporting autonomy, and strengthening perceptions of competence and relatedness. In doing so, it clarifies the mechanisms through which experiential learning can foster intrinsic motivation and improve learning effectiveness in STEM education. The framework also demonstrates how engagement translates motivational processes into sustained learning behaviours, offering a coherent explanation of how experiential approaches can address both motivational and instructional challenges in under-resourced educational settings.

In practical terms, the framework offers valuable implications for curriculum design, instructional practice, policy development, assessment models, and cross-cultural adaptation. It can serve both as a diagnostic tool for identifying existing weaknesses in STEM education and as a prescriptive guide for designing student-centred interventions that prioritise engagement and motivation. For policymakers and educators in Guizhou and similar regions, the framework provides a contextually relevant reference for implementing experiential and engagement-driven STEM reforms.

As a theoretical study, this research is subject to certain limitations. The proposed framework has not yet been empirically tested, and its relationships are derived from theoretical

integration and prior literature rather than primary data. Future research should empirically validate the framework using quantitative, qualitative, or mixed-methods approaches, such as longitudinal studies or structural equation modelling, to examine the causal pathways among experiential learning, engagement, motivation, and learning effectiveness. Comparative studies across regions and educational levels would further strengthen its generalisability.

Overall, this framework offers a theoretically integrated and contextually grounded approach to understanding and improving STEM education outcomes. By systematically linking experiential learning, student engagement, and motivation, it supports the development of more effective, meaningful, and sustainable STEM learning experiences, better preparing students to meet the demands of modern STEM industries.

6. Limitations and Future Research

Although this study has developed a theoretically integrated framework to explain how experiential learning influences student motivation and learning effectiveness in STEM education within the Guizhou context, certain limitations must be acknowledged. The framework is conceptual in nature and has not yet been subjected to empirical testing. While it provides valuable theoretical insights and a structured lens for understanding the mechanisms of experiential learning, its practical applicability and predictive validity remain provisional until supported by systematic research.

Future studies should therefore focus on empirically validating the framework through diverse methodological approaches. Quantitative research could operationalize the constructs of experiential learning, student engagement, motivation, and learning effectiveness, employing techniques such as survey instruments and structural equation modelling to test the hypothesized relationships. Complementary qualitative studies, including classroom observations, interviews, and focus groups, would provide deeper insights into the lived experiences of STEM students and educators in Guizhou, capturing the contextual nuances that shape engagement and motivation. Mixed-method designs are particularly recommended, as they would allow for triangulation of findings and strengthen the robustness of the framework.

In addition, longitudinal studies could examine how experiential learning influences motivation and effectiveness over time, especially as students progress through different stages of STEM education and transition into professional pathways. Comparative studies across other under-resourced regions in China or internationally would also be valuable, as they could highlight cultural and institutional variations in the effectiveness of experiential learning strategies.

By pursuing these empirical directions, future research can validate, refine, and extend the proposed framework, ensuring that it not only advances theoretical understanding but also provides actionable guidance for educators, policymakers, and curriculum designers seeking to improve STEM education in underdeveloped contexts.

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