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Original Article

Building for the Future: Exploring the Role of Sustainably Designed Replacement Schools on Student Engagement

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Abstract

For the past twenty-five years, educators have embraced and implemented the concept of functional and sustainably designed school infrastructure. This study investigates the contribution of sustainably built replacement schools on student engagement in Nepal. Drawing from extensive experience developing educational facilities, including constructing schools using sustainable methods, the authors emphasize the importance of involving diverse educational stakeholders in the design process. Using Schlechty's framework, the study focuses on creating learning environments that support both student-driven and teacher-led activities. Despite the recognized benefits of well-designed spaces, the empirical impact on student engagement remains underexplored. This research uses qualitative case studies in two public schools recently rebuilt using rammed earth technology to examine how the new infrastructure influences student engagement. Findings show that sustainably designed schools positively affect students' overall school experience, engagement in learning, and teachers' motivation. This study contributes to the discourse on educational architecture, suggesting that investment in thoughtful school design can enhance student and teacher satisfaction and performance.

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Introduction

Over the past twenty-five years, educators have embraced and implemented the concept of good, functional, and sustainably designed and built school infrastructure (Dedieu & Plé, 2023). Educators with varied perspectives recognize that a core principle is that design should prioritize the user's needs, primarily students (Miller et al., 2001). Drawing from our extensive experience developing sustainably built educational facilities, including constructing replacement schools using sustainable methods across Nepal and engaging with various other aspects of school education, we emphasize that effective school building should involve diverse educational stakeholders. Replacement schools, new facilities built to replace outdated infrastructure, present a unique opportunity to study how sustainable design shapes student engagement during transitions from old to new learning environments. This group should include local government officials, school management committees, principals, teachers, and students. The design process should focus on the student's needs while remaining open to new ideas. Planning educational environments, especially infrastructure, should be holistic, encouraging everyone involved in education to explore innovative concepts and opportunities (Miller et al., 2001). When experienced individuals who understand the importance of school design collaborate, the emphasis is on creating balanced learning environments that support student-driven and teacher-led activities (Taylor & Parsons, 2011).

Current educational policy in Nepal emphasizes local governance and inclusion in schooling; the new constitution delegates school management to local bodies to better address diverse community needs (Neupane, 2019; Pradhan et al., 2019; Saeed et al., 2024; Thapa, 2013). However, the impact of sustainably designed and built school infrastructure, particularly in the context of newly built replacement schools, on student engagement remains largely unexplored. While recent ‘model school’ initiatives in Nepal reflect globalized, neoliberal ideals, an approach criticized for marginalizing local communities, sustainably designed replacement schools may counterbalance this by integrating community input, fostering engagement through inclusive and context-sensitive design. Sustainably designed schools integrate environmental, economic, and

social sustainability principles into their physical infrastructure to create healthy, energy-efficient, and adaptable learning spaces. Features like natural lighting and ventilation, for example, are theorized to enhance cognitive engagement by improving focus and well-being. Recent model school initiatives in Nepal reflect globalized, neoliberal ideals, an approach that can inadvertently marginalize local languages and less privileged communities (Rajbhandari & Rajbhandari, 2016) . These schools prioritize natural lighting, improved ventilation, resource-efficient materials, and flexible learning environments that promote student well-being and engagement. In this study, sustainably designed infrastructure refers to the physical school environment, including classroom layouts, natural lighting, ventilation, spatial arrangements, and sustainable construction materials. It does not include teaching and learning materials like textbooks or digital tools.

This research defines student engagement as the student's commitment to learning, interest, and proactive desire to participate cognitively in educational activities (Schlechty, 2011). Schlechty (2011) advocated redesigning tasks to enhance student engagement and intrinsic motivation. The authors of this study have adopted Schlechty's framework, using these principles to guide their design of learning spaces for both current and future students in the remote setting of Nepal, considering what is required now and in the future.

The team acknowledges the crucial role of a well-designed physical school environment in facilitating student learning. However, until now, they have lacked empirical evidence to show the direct influence of sustainably designed school spaces on student engagement. This gap is particularly pronounced in replacement schools, where transitions from outdated to modern infrastructure may amplify or disrupt engagement dynamics. Stakeholders aim to create environments that builts a constructive culture where safety and engagement are prioritized and teachers, students, and families collaborate effectively (Boehnert et al., 2022). Nonetheless, the tangible effects of sustainably built replacement schools on student engagement have seldom been examined.

This study explores how sustainably built school infrastructure, particularly in two newly built replacement schools, influences student engagement, aiming to address the research question: What influence does a sustainably built replacement school have on

student engagement in learning? The broader research reported in this article explores the effect of learning environments on student engagement across various new schools, not limited to just replacement schools. However, this article focuses specifically on replacement schools to examine how transitioning students from old to sustainably designed facilities shapes engagement. It seeks to fill a gap in existing literature concerning how sustainably designed and built schools contribute to student engagement, particularly in replacement schools where students transition from an old facility to a newly constructed one. While research exists on the cost-effectiveness of building replacement schools versus remodeling old ones (Boehnert et al., 2022), there is a lack of focused studies examining how the physical aspects of sustainably built replacement schools contribute to student engagement. By bridging this gap, the study offers insights into how sustainable replacement schools can reconcile Nepal's policy goals of local governance with equitable student engagement, providing a model for context-sensitive educational infrastructure.

Sustainable Infrastructure and Educational Spaces

Student engagement, crucial for learning, is significantly influenced by instructional design and the physical learning environment. This environment can enhance learning outcomes beyond what is typically measured by standardized tests; thus, designing these spaces is essential (Brooks, 2011; Gurzynski-Weiss et al., 2015). Sustainably designed school infrastructure involves creating physical spaces that incorporate sustainable practices such as natural lighting, adequate ventilation, spatial flexibility, thermal comfort, and environmentally friendly construction materials (Khanal, 2021). These features are theorized to directly influence engagement—for instance, natural lighting reduces eye strain and improves focus, while spatial flexibility supports collaborative learning activities that drive cognitive participation. These sustainably designed schools integrate ecological principles to ensure healthy and energy-efficient learning environments, which support contemporary educational practices and student well-being (Cole, 2014; Brandisauskiene et al., 2021).

Research indicates that the effectiveness of innovative learning spaces depends significantly on whether educators adopt teaching methods that align with these spaces (Bouslama & Kalota, 2013; Dahal, 2022; Dittoe, 2002). Sustainable infrastructure's benefits, such as energy-efficient layouts or adaptable classrooms, are maximized when

paired with pedagogical strategies that leverage these features to foster active, student-centered engagement. Classrooms should function as practical spaces facilitating teaching and the application of learned knowledge (Earthman & Lemasters, 2009). Well-designed educational spaces support student-driven lessons, promote equal participation, and encourage collaboration with peers, thus creating an environment conducive to student-centered learning (Gurzynski-Weiss et al., 2015).

Student Engagement in Learning

Student engagement encompasses a student's commitment, interest, and proactive desire to participate cognitively in educational activities (Schlechty, 2011). Schlechty (2011) argued that task design shapes student engagement and intrinsic motivation. This framework extends to physical environments: spaces designed to accommodate varied tasks (e.g., collaborative zones, quiet study areas) can amplify engagement by aligning with students' cognitive and social needs. Classrooms supporting student-centered approaches are particularly effective in minimizing setup time, facilitating student-driven lessons, and encouraging equal and collaborative participation, which aligns with contemporary student preferences and lifestyles (Gurzynski-Weiss et al., 2015).

However, the configuration of learning environments critically shapes student engagement and academic outcomes. Different classroom layouts contribute to instructional styles; large, row-oriented classrooms facilitate teacher-led instruction, while smaller, grouped arrangements enhance student interaction and collaborative learning (Dittoe, 2002; Herzog, 2007). Sustainable designs often prioritize flexible, grouped layouts, which may inherently promote the interaction and engagement Herzog identifies. Herzog (2007) also identified several other classroom characteristics impacting learning outcomes, including windows, classroom size, scheduling of classes, and student density.

While these factors emphasize the importance of physical spaces, other crucial factors influencing student engagement, such as school culture, teachers' roles, and administrative support, are equally important but often overlooked. Teachers are pivotal as they mediate students' interactions within educational spaces and facilitate active learning through instructional methods suited to these spaces. Similarly, school culture and administrative support significantly influence how effectively new physical designs

support student engagement and learning outcomes (Boehnert et al., 2022). In the context of sustainably built replacement schools, these factors become critical: community buy-in and teacher training determine whether innovative spaces translate into sustained engagement. However, existing research has not sufficiently explored how these mediating factors enhance or limit the influence of physical learning spaces.

Identifying the Research Gap

Despite recognizing the importance of architectural design, empirical research specifically examining the support of sustainably redesigned school environments on student engagement is scarce. Existing literature has predominantly emphasized the economic and logistical aspects, with limited direct examination of physical environments on learning engagement (Earthman & Lemasters, 2009). The role of sustainably designed replacement schools, particularly regarding students transitioning from outdated to newly constructed facilities, remains understudied. This transition, where students experience a stark contrast between old and new environments, provides a unique lens to study how sustainable design reshapes engagement dynamics.

Furthermore, previous literature often overlooks the interaction between physical environments and other critical factors, such as teaching practices, school culture, and administrative support, which can significantly shape student engagement (Bouslama & Kalota, 2013; Gurzynski-Weiss et al., 2015). In Nepali public schools, students' sustainability awareness is only average, and their actual eco-friendly practices are minimal, revealing a gap between knowing and doing (Rai et al., 2023). This gap underscores the need to study how sustainably built replacement schools, as tangible manifestations of sustainability principles, might bridge awareness and action by embedding eco-friendly practices into daily school life. Given the rapid evolution of educational paradigms and the increasing implementation of sustainable designs, this gap represents an important area for investigation.

This study addresses this gap by exploring how sustainably designed replacement schools, characterized by thoughtfully constructed physical spaces, influence student engagement. By focusing on replacement schools, where transitions from outdated to modern infrastructure create a natural experiment, the study isolates the impact of sustainable design on engagement while accounting for contextual factors like teacher adaptation and community involvement. By investigating the interplay between

sustainable infrastructure, student engagement, and the broader educational environment, including teacher practices, administrative support, and school culture, this research contributes to a more nuanced understanding of the influence of sustainable school infrastructure on educational outcomes.

Methodology

This study employed a qualitative case study methodology to explore the contribution of sustainably designed replacement schools on student engagement in two public schools in Nepal: Golmeshwori Basic School (elementary K-5) and Dwarpaleshwor Secondary School (High School K-10). These schools were recently rebuilt by Kids of Kathmandu, a non-profit organization focusing on education infrastructure. They are the only schools in the Kavrepalanchok District constructed using rammed earth technology, making them unique examples of sustainable school design in the region. The case study approach was chosen to capture the complexity of transitioning students from outdated to sustainably designed infrastructure, providing rich, context-specific insights into how physical environments shape engagement (Starman, 2013).

Before reconstruction, both schools operated a few classes in temporary classrooms built using corrugated galvanized iron (CGI) sheets. Both schools had only one permanent building constructed with conventional government-funded materials, which offered minimal natural light and poor ventilation. Due to a shortage of classrooms, several grade levels were merged, resulting in overcrowded classrooms that negatively impacted the learning environment. Rammed earth technology, a sustainable method using locally sourced soil, minimizing cement and red bricks, aligns with Nepal's emphasis on local governance and ecological sensitivity, offering a tangible contrast to the previous infrastructure's limitations.

The selection of these schools was purposeful, given that their construction uses rammed earth technology, a sustainable building method that leverages locally sourced materials and minimizes cement and red bricks. This method not only reflects the ecological ethos of the region but also positions these schools as unique environments to study the interplay between sustainably designed and built infrastructure and student engagement (Patton, 2002; Starman, 2013). By focusing on replacement schools, the

study leverages a natural experiment where students' pre- and post-transition experiences provide a baseline for evaluating engagement shifts.

Participant Selection

The study focused on fourth and fifth graders, totaling 40 students (both male and female), who were selected to represent the highest common grade level available in both schools. This transitional age group (9–12 years) is particularly sensitive to environmental changes, offering critical insights into how sustainable design influences engagement during a pivotal developmental stage. This selection was intentional, as students in these grades have developed the cognitive and verbal abilities to articulate their experiences, perceptions, and engagement in learning environments. Younger students may struggle to express their thoughts clearly, while older students might have had different transitional experiences that could influence their perspectives on engagement. Additionally, fourth and fifth graders are at a critical stage of academic and social development, where engagement in school activities is highly influenced by environmental factors, making them ideal participants for exploring the contribution of school infrastructure to student engagement. The selection process was not based on academic performance but aimed to gather a broad spectrum of student experiences. Each focus group consisted of 4–6 students, ensuring diverse yet manageable discussions during the data collection process (Bryman, 2012; Palazzolo, 2023). This size allowed students to reflect on both their old and new learning environments, aligning with Schlechty's (2011) emphasis on task and environmental redesign as drivers of engagement.

Data Collection

Data were collected through eight semi-structured focus group interviews (Creswell, 2014), with four groups from each grade across the two schools. Each focus group was conducted separately with questions about understanding the students' perceptions and experiences of their learning environments before and after the redesign. The interview protocol explicitly linked sustainable design features (e.g., natural lighting, spatial flexibility) to Schlechty's (2011) engagement framework, probing how these elements influenced participation, interest, and cognitive commitment. The questions were crafted to elicit detailed accounts of how the new learning spaces influenced their engagement and interaction within the school setting

(Maxwell & Kerja, 2012). Each session lasted approximately 30 minutes and was held in a familiar, comfortable environment within the school to encourage open and honest communication.

Data Analysis

The narrative data from the focus groups were recorded, transcribed, and analyzed using NVivo software to assist in organizing and identifying recurring themes. Thematic analysis followed a hybrid approach: deductive codes drew from Schlechty's engagement framework (e.g., "cognitive participation," "intrinsic motivation"), while inductive codes emerged from students' descriptions of their experiences (e.g., "light effects on focus," "collaboration in flexible spaces"). This qualitative software facilitated a systematic approach to coding and theme identification, ensuring a comprehensive analysis of the textual data. The analysis followed established empirical methods, adhering to the principles outlined by Maxwell and Kerja (2012) and Creswell (2014), which advocate for a meticulous approach to qualitative research. The coding process involved multiple iterations of theme identification and refinement, using inductive and deductive coding techniques to ensure thoroughness.

Ensuring Trustworthiness

Several measures were implemented to enhance the reliability and validity of the study. Triangulation was achieved by having multiple researchers independently analyze the data to avoid bias and ensure a variety of perspectives were considered in interpreting the findings (Koro-Ljungberg, 2010). Member checking was also conducted by sharing preliminary themes with a subset of participants to confirm interpretive accuracy. Additionally, reflexivity was maintained throughout the study, with researchers acknowledging their biases and actively working to minimize their influence on the analysis. Disagreements and alternative viewpoints were explored through collaborative discussions and meetings to reconcile different interpretations, enriching the depth of the discussion and the conclusions drawn (Creswell, 2014; Koro-Ljungberg, 2010). Thick descriptions of the schools' contexts, participant quotes, and sustainable design features were included to bolster transferability and contextual relevance.

Findings

After meticulously analyzing the focus group data from the selected students, three prominent themes emerged: (a) the influence of the new spaces on their overall school experience, (b) how attending a new school affected their engagement in learning, and (c) the changes they observed in their teachers since moving to the replacement school.

Space of Learning and Exploring

Consistent with previous research highlighting the benefits of natural lighting, openness, and thermal comfort (Cole, 2014; Herzog, 2007), Students frequently referred to the new spaces available throughout the focus groups at both school sites, emphasizing the freedom to move and explore. They highlighted the advantages of the new school design, which were not possible in the old building. Many students reported that attending School in the replacement building made them more eager to attend School. One fourth-grade boy shared that the old School was "not fun," which diminished his desire to attend. Conversely, he loved being in the new building and felt excited to attend School. Students appreciated the freedom and comfort the new building provided(Vandaele & Stålhammar, 2022), mentioning the openness, classroom temperature, and natural light that came through the windows(Dedieu & Plé, 2023), creating a feeling of spaciousness, naturalness, and comfort(Bouslama & Kalota, 2013).

Students highly appreciated the construction style employed in the replacement school. They expressed admiration for the unique and beautiful design of the new building, which set it apart from their old School and other schools in the community. The aesthetic appeal of the new construction contributed to a sense of pride and enthusiasm toward attending School (Brooks, 2011). Furthermore, students noted that the new building had a distinct natural feel. They appreciated using natural materials and elements, such as the rammed earth construction, which created a sense of harmony with the surrounding environment. The building's natural walls and overall design gave the students a visually pleasing and calming atmosphere (Gurzynski-Weiss et al., 2015).

Additionally, students observed that the new building was well-suited for different weather conditions. They reported that the interior of the new building felt cooler during the summer months and warmer during the winter compared to their old classrooms (Miller et al., 2001). This enhanced thermal comfort, a direct benefit of

sustainable construction principles, created a more conducive learning environment, allowing students to focus on their studies without the distractions of extreme temperatures (Miller et al., 2001). The students' positive experiences of the new building's climate control reflected thoughtful design considerations to provide a comfortable and sustainable space for learning (Herzog, 2007).

Moreover, students were dissatisfied with the old building's layout, which featured small windows and limited classroom space. At one site, students discussed the inconvenience of walking long distances to reach restrooms. The new designs of both schools addressed these issues effectively. The students consistently referred to the spaciousness of their classrooms and the new spaces outside the classroom, such as the green roof, which also functions as a collaboration space, a new computer lab, a library, and abundant open spaces around the School. A student shared that they could roam more and that "in the old school, it was not fun."

During the focus groups, another student shared their positive experience of the new School, noting that they could hang out in open spaces and relax. When asked about the open spaces every group mentioned, a student explained that they allowed them to meet friends, get fresh air and sunlight, play games, and eat lunch in groups. These areas provided a space to discuss classwork and gain new perspectives.

At one of the schools, students discussed the collaboration spaces outside their classrooms. They shared how they would gather outside classrooms, bring their movable furniture, and conduct classes. Teachers also use these spaces to pull small groups of students aside to work, as it is quieter than the classroom. Despite enthusiasm about the new building, students highlighted a significant disparity, emphasizing that sustainable design must be applied equitably across school communities (Taylor & Parsons, 2011). As some classes still operate in the old building, they felt those classes were missing out on the benefits of the new building. A fifth-grade boy expressed his feelings of sadness, stating,

"*The feeling of sadness arose when I realized that some classes are still held in the old building, which has minimal facilities compared to the new building. It made me feel like those students are missing out on the fun and not receiving the same benefits as we are in the new building, which is not a good feeling.*"

Although students primarily discussed classrooms, they also valued new non-classroom spaces. For instance, the green roof, used for group work and relaxation, was frequently cited as a positive change. One student said, 'We can study outside or just talk with friends there, which we could not do before.' Similarly, the computer lab and library were praised for enabling new learning activities. However, students did not spontaneously mention bathrooms or playgrounds despite these facilities being upgraded in the new design. When asked about bathrooms, responses were brief (e.g., 'They are better now'), suggesting these spaces were less salient to their engagement than academic and social areas.

Engagement and Learning

The study discussed learning engagement, a student's commitment, interest, and self-driven willingness to be actively involved in the learning process (Schlechty, 2011), and the efforts they put into learning since moving to the new School. The students highly regarded their teachers in the old and new buildings. However, they acknowledged the difference between attending a new school, their sense of pride, engagement, and commitment to learning, and their efforts to make their teachers proud (Brandisauskiene et al., 2021).

According to one student, the new building has changed their learning experience, making them work harder and providing more space to lay out their materials. Another student shared that school days seemed shorter in the new building, and they had more fun, making it feel like learning was no longer a chore (Stoltzfus & Libarkin, 2016). They said, "We are still learning, but learning is fun now." One fifth-grade girl shared her positive experience at the New School, saying that they have access to various areas, allowing them to set up a class anywhere and study individually, in small or even larger groups, making the learning experience much more enjoyable compared to the old school building(Cole, 2014).

The students also expressed being more focused and motivated to finish their work and having time to engage in possible activities due to the unique spaces in the new school buildings (Earthman & Lemasters, 2009). A fifth-grade girl supported her classmates' previous comments by explaining,

> *In the old School, we had limited space, which restricted us from working in groups and learning to work better together. However, this year, we can work in groups*

> *even with people they may not necessarily like and learn how to collaborate with new people, thanks to the increased space available to them.*

The students also expressed their satisfaction with the natural walls in the classroom, which provide a sense of homeliness. They found that having a natural wall made them feel good, and it was easier to focus on their teachers as there were fewer distractions in the classroom (Dedieu & Plé, 2023). The students also appreciated that they could put up chart papers or other materials and maintain a simple and natural look in the classroom.

The students also expressed their willingness to learn since moving to the new building, with one student noting,

> *I did not want to engage in educational activities in the old School. However, in the new building, I am motivated and want to do something new.*

Moreover, the students shared their views on how the new building has positively shaped their teachers' willingness and ability to plan project-based learning opportunities for the students. One boy said they now have more projects than the old building because the teachers have more resources to work more efficiently.

Teachers' Motivation

The students' responses yielded an unexpected theme regarding their teachers' motivation, as the primary focus of the study was student engagement. Nonetheless, this insight underscores the broader benefits of sustainably designed spaces. One boy noted that

> *The teachers now looked happier than before at the old School. Now, the rooms were more enclosed, and there were limited resources and no technology, which often caused frustration for the teachers. However, in the new School, the technology is available, and as a result, the teachers are less frustrated and more enthusiastic about being at School.*

Two other students noted that they have observed a difference in how their teachers use the classrooms. They shared their perception that the teachers are happier now that they have more space (Cole, 2014; Earthman & Lemasters, 2009). Another student explained that teachers can move around more freely, resulting in more transparent communication with the students. Additional students shared their views on how the

new building has shaped the teachers' well-being and work convenience. They noted that the teachers seemed happier and more comfortable, and with all the classroom space, they had more room to organize (Earthman & Lemasters, 2009).

The focus group data revealed that the innovative, sustainably designed replacement school significantly improved the students' overall school experience, engagement in learning, and perceptions of their teachers' motivation and happiness. The new spaces provided a conducive environment for learning and exploration, enhanced student engagement, and positively shaped teachers' ability to deliver quality education (Cole, 2014). These findings underscore the importance of thoughtful, sustainably designed, and built replacement schools in promoting a holistic and engaging educational experience for students and teachers (Dittoe, 2002).

Discussion

This study addresses a significant gap in existing literature regarding the specific contribution of sustainably designed replacement schools on student engagement and teacher practices, particularly in transition contexts. The findings revealed several key themes related to the influence of new learning spaces: (a) enhanced school experiences, (b) increased student engagement in learning, and (c) improved teacher motivation since transitioning to the replacement schools.

Positive Influence on School Experience

Students' enhanced sense of openness and comfort aligns with existing research emphasizing that sustainable design features, such as natural lighting and improved ventilation, positively influence student experiences and perceptions of their school environment (Cole, 2014; Herzog, 2007). The first prominent theme that emerged is the positive influence of the new spaces on students' school experience. Students expressed their excitement and willingness to attend School in the replacement building, highlighting the advantages of the new design. The spaciousness, natural light, and comfortable environment provided by the new building created a sense of openness and freedom for students. These findings align with previous research highlighting the importance of well-designed learning spaces in promoting student-centered environments and supporting modern teaching practices (Gurzynski-Weiss et al., 2015; Weinstein, 1981).

The replacement schools directly addressed the old infrastructure's deficiencies: rammed earth walls improved thermal mass, and strategically placed windows optimized natural light. These changes resolved longstanding issues reported by students, such as discomfort and restricted movement, thereby enhancing engagement. Moreover, the students' positive experiences in the new building were contrasted with their dissatisfaction with the layout and limited facilities of the old building. The enhanced facilities contributed to a more enjoyable and conducive student learning environment. This is consistent with previous studies showing the importance of flexible and well-resourced learning environments in fostering better educational outcomes (Brooks, 2011).

Enhanced Engagement and Learning

The second theme from the data focused on the influence of attending a new school on student engagement and learning. Since moving to the replacement school, students expressed a higher level of engagement, commitment, and effort in their learning. They reported feeling more motivated and focused on their studies and perceived learning as a fun and enjoyable experience. The new spaces provided opportunities for collaborative group work, hands-on activities, and individualized learning, positively influencing students' engagement and learning outcomes. The findings support the notion that well-designed learning spaces can enhance student engagement and intrinsic motivation, aligning with the principles of sustainably designed replacement schools in education (Schlechty, 2011).

The students' appreciation for the unique construction style and the natural feel of the sustainably designed replacement school underscored the positive contribution of the new building to their overall school experience. The aesthetic appeal of the construction, which set it apart from other schools in the community, contributed to a sense of pride and enthusiasm among the students. Using natural materials and incorporating elements such as rammed earth construction created a visually pleasing and calming atmosphere. Moreover, the student's observation that the new building provided better thermal comfort, feeling cooler in summer and warmer in winter compared to their old classrooms, highlighted the thoughtful design considerations to enhance the learning environment. These findings emphasize the significance of well-designed and aesthetically pleasing learning spaces in fostering student engagement and

creating a positive school environment. Practical features such as rammed earth construction, natural walls, and effective climate control improved aesthetic appeal and significantly enhanced comfort, thus directly influencing student and teacher experiences.

Contribution to Teachers' Motivation

Teachers' increased motivation and enthusiasm corroborate previous findings that improved physical teaching environments significantly enhance instructional effectiveness and overall teacher well-being (Boehnert et al., 2022; Earthman & Lemasters, 2009). Another noteworthy theme that emerged was the influence of the sustainably designed replacement school on teachers. Students perceived their teachers happier and more enthusiastic about teaching in the new building. The availability of technology, increased space, and improved resources contributed to a more positive working environment for teachers. The findings suggest that the design of learning spaces shapes students' and teachers' well-being and instructional practices. A supportive and conducive physical environment can empower teachers to deliver more engaging and effective instruction (Brooks, 2011). The observed improvement in teacher motivation, although initially unexpected, highlights an important reciprocal benefit: enhanced teacher enthusiasm may further amplify student engagement, creating a reinforcing cycle of positive outcomes.

Deeper Analysis and Implications

The findings underscore the transformative potential of sustainably designed replacement schools, filling critical gaps by demonstrating how physical infrastructure directly affects student engagement and teacher motivation. Students' positive experiences and observations of improved teacher attitudes highlight the multifaceted benefits of well-designed educational spaces. These insights contribute to the broader discourse on educational architecture, suggesting that investment in thoughtful school design can yield significant returns regarding student and teacher satisfaction and performance. While our new school design improved engagement, it is important to heed warnings that such model-school reforms may contribute to school gentrification and erode linguistic diversity if not implemented inclusively.

The students' emphasis on classrooms and collaborative zones, rather than bathrooms or playgrounds, aligns with cultural and pedagogical priorities in Nepali

education, where formal learning spaces are often central to stakeholders' perceptions of school quality (Shrestha, 2022). The lack of detailed commentary on upgraded bathrooms, despite their practical importance, may reflect their perceived role as functional rather than educational. Similarly, playgrounds, while present, might not have been framed as 'learning infrastructure' in students' minds. This underscores the need for explicit design and curricular integration of non-classroom spaces to amplify their perceived value. Future designs could pair infrastructure improvements with pedagogical initiatives (e.g., outdoor learning programs) to foster holistic engagement.

A deeper analysis of why and how specific sustainably designed replacement school elements contributed to increased engagement and motivation could further enhance the discussion. For example, the spaciousness and natural light in classrooms may reduce stress and create a more inviting learning environment, while movable furniture can facilitate dynamic and collaborative learning experiences. Integrating theoretical frameworks, such as environmental psychology or educational design theories, could provide a richer understanding of these impacts.

Our findings gain broader relevance in Nepal's educational landscape and other Global South contexts, where inadequate infrastructure and resource limitations remain pervasive challenges. Following the 2015 Gorkha earthquake, over 50,000 classrooms in Nepal were destroyed, exposing the systemic vulnerability of the country's educational infrastructure (UNICEF, 2015). A decade later, fewer than 15% of school buildings meet earthquake-resistant standards (Government of Nepal, 2022). These conditions mirror widespread patterns in the Global South, where overcrowded classrooms, poor lighting, and poor ventilation undermine student focus and engagement (Lewin, 2007). Conversely, better-designed learning environments have positively influenced attendance, academic performance, and student well-being (Barrett et al., 2015). The sustainably built schools examined in this study offer a contextually grounded response to these barriers by leveraging local materials, such as rammed earth construction, and community participation to reduce costs, enhance thermal comfort, and instill a sense of ownership. Beyond improving physical conditions, these designs represent a paradigm shift toward more inclusive and sustainable schooling models that can inspire similar innovation across under-resourced educational systems in the Global South.

This study positions sustainably designed school infrastructure as a transformative catalyst for achieving Sustainable Development Goal 4 (Quality Education), notably Target 4. (Inclusive, safe learning environments) and Target 4.5 (equity in education). By empirically linking rammed earth technology and student-centered design principles, such as natural lighting, thermal comfort, and flexible spatial arrangements, to enhanced student engagement and teacher motivation, the findings advocate for reimagining infrastructure as a physical asset and a pedagogical service that amplifies learning outcomes. The prioritization of user-centric design, evidenced by students' heightened enthusiasm and teachers' renewed instructional energy, demonstrates that sustainable architecture fosters collaborative, student-driven learning cultures aligned with Schlechty's (2011) principles of intrinsic motivation. However, the transformative potential of such infrastructure hinges on its integration with other SDG 4 pillars, including teacher training and curriculum reform. For instance, while teachers in Nepal's new schools leveraged flexible classrooms and technology to adopt innovative pedagogies, this shift demands ongoing professional development to maximize impact. Similarly, students' valuation of auxiliary spaces (e.g., green roofs, computer labs) underscores the need to embed these environments into curricular planning, such as outdoor science modules, to unlock their holistic potential. However, disparities in access to new facilities within the same school community highlight the ethical imperative for equitable implementation, urging policymakers to adopt phased, inclusive strategies. In resource-constrained contexts like Nepal, a synergistic triad of infrastructure, teacher capacity-building, and curriculum adaptation is critical to breaking cycles of disengagement. Policymakers must frame school design as a pedagogical intervention, allocating funds for sustainable materials like rammed earth and teacher workshops and curricula tailored to leverage these spaces. By bridging ecological resilience, cultural relevance, and pedagogical innovation, sustainably built schools become dynamic ecosystems that scaffold SDG 4's broader vision: equitable, lifelong learning where infrastructure and pedagogy evolve to nurture future-ready communities.

Limitations and Future Research

While the findings of this study provide valuable insights into the influence of sustainably designed replacement schools on student engagement, several limitations should be acknowledged. First, this study focused on only two schools in a specific

region, limiting the generalizability of the results. Future research should explore how similar sustainable design principles might be adapted to various contexts, such as urban versus rural settings, providing a broader understanding of their applicability. Additionally, comparative studies across different geographical or cultural contexts could further enrich our understanding of the conditions under which sustainable design principles best enhance student engagement.

Second, this study employed qualitative methods, relying heavily on students' perceptions and experiences. While qualitative research offers rich, in-depth insights, it inherently limits generalizability. Future studies incorporating mixed-methods approaches, such as quantitative surveys or observational methods alongside qualitative data, could provide a more comprehensive assessment of student engagement outcomes. Employing mixed-method designs could further validate findings and extend their applicability across various educational contexts.

Moreover, future research should consider longitudinal studies to explore sustained impacts. Tracking cohorts of students over multiple years could clarify how prolonged exposure to sustainably designed spaces influences academic trajectories, engagement patterns, and overall well-being. Such longitudinal approaches could also reveal whether initial excitement and motivation in new buildings persist. While this study focused on the relationship between infrastructure and student engagement, it did not deeply explore how other factors, such as pedagogical practices, teacher-student relationships, or school culture, might also contribute to or mediate student engagement, representing an important area for future inquiry.

Lastly, involving multiple stakeholders, including teachers, parents, administrators, and community members, in future research would provide nuanced insights into how sustainably designed learning spaces affect broader educational practices and community involvement. Understanding stakeholder perspectives could inform more inclusive and effective school design processes, holistically supporting student learning and community engagement.

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