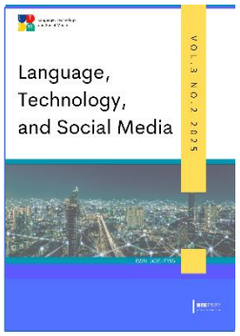

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Research Article

From Isolation to Interaction: The Role of Language and Digital Communication Tools in Empowering Adolescent Virtual Collaboration

Shazia Hamid* and Anthonia Awhinawhi

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Abstract

This qualitative study explores the impact of collaborative learning on adolescent learners' motivation and feelings of isolation in virtual learning environments, with a focus on the role of language-mediated interactions and digital tools. Using exploratory questionnaires and interviews, the study examines how virtual collaborative tasks influence students' engagement. The findings indicate that collaborative learning significantly enhances motivation, particularly when tasks are meaningful and peer interactions are supportive. Survey data revealed that 42.4% of students often found collaborative tasks productive, with positive peer influence acting as a key motivator. Additionally, 70% of participants reported a reduction in isolation due to peer interaction. Autonomy in collaborative tasks was also strongly linked to higher intrinsic motivation, supporting Self-Determination Theory. Synchronous tools such as video conferencing and shared documents were crucial in alleviating isolation. The study highlights how digital tools mediate language use, fostering social connection and engagement in virtual settings. It contributes new insights into the integration of digital tools for language learning, collaboration, and social engagement, offering practical recommendations for virtual education practices, curriculum design, and teacher training, with implications for policymakers to enhance online learning strategies.

Keywords: Collaborative Learning; Motivation; Adolescent Learners; Peer Interaction; Virtual Learning Environments; Sociocultural Theory

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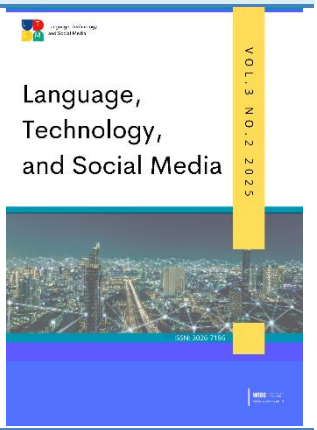

INTRODUCTION

Collaborative learning has long been recognized as an effective pedagogical approach that fosters higher-level thinking, deepens information retention, and enhances communication and social skills among students [1], [2], [3]. This educational model encourages students to engage in discussions, clarify ideas, and critically evaluate the contributions of their peers, all of which contribute to a deeper understanding of the material. Particularly for low-achieving students, collaborative learning has proven beneficial, as students often show significant improvement when working in diverse groups [1], [4], [5]. Recently, the rise of Computer-Assisted Collaborative Learning (CACL) has introduced an essential paradigm in education, where technology supports and enhances collaborative experiences. Digital tools, such as Zoom, Google Docs, and discussion boards, have allowed students to share ideas, co-create content, and provide feedback within virtual learning environments. These tools mediate the language used in communication, shaping how students interact, negotiate meaning, and learn together in online spaces.

The shift toward virtual learning environments, especially accelerated by the COVID-19 pandemic, has profoundly impacted education worldwide. In response to the disruption, educators rapidly adopted online teaching methods, making collaborative technologies crucial for maintaining communication among students, peers, and instructors. However, this transition illuminated significant challenges, particularly in relation to student motivation and feelings of isolation. Studies emphasize growing concerns about adolescent engagement in virtual learning, as many teenagers experience disconnection due to the lack of face-to-face interactions, coupled with the emotional and psychological challenges of online settings [6], [7], [8]. Adolescence is a critical stage in social and emotional development, where the need for social connections and peer recognition is central to identity formation [9], [10], [11]. As such, adolescents are particularly vulnerable to feelings of isolation, which can hinder both their social engagement and academic success.

Language-mediated interactions, facilitated by digital tools, play a key role in mitigating these challenges by offering adolescents opportunities to communicate, collaborate, and build meaningful social connections despite physical distance [12], [13], [14]. Digital tools in virtual learning environments not only enhance academic collaboration but also provide students with the means to construct and express their identities. Whether through written communication or spoken language, students position themselves within social networks, form relationships, and negotiate their roles as learners. As students engage through video calls, group chats, and shared documents, they develop a sense of belonging, which in turn influences their motivation to participate in learning activities [15], [16], [17]. This digital mediation of language use is crucial for addressing emotional and psychological barriers in virtual settings, creating a more interactive and supportive learning environment. By promoting a sense of belonging, these tools play a significant role in fostering motivation, which is further enhanced when teachers create learning spaces that empower students [18].

Despite the growing recognition of the benefits of collaborative learning, there remains a significant gap in the literature, particularly concerning the experiences of adolescent learners in virtual environments. Much of the existing research focuses on adult learners or those in higher education [19], [20], [21], leaving a gap in understanding how these dynamics unfold in secondary education. Also, previous studies on motivation and isolation have largely overlooked the unique

cultural and social contexts that influence adolescents' virtual learning experiences. This study aims to address this gap by examining how collaborative learning in virtual environments impacts adolescents' motivation and feelings of isolation. Specifically, it explores how digital communication tools mediate language use during collaborative tasks and how these tools can foster engagement and social connection across diverse cultural contexts. By focusing on secondary school students from various regions, this research seeks to offer insights into how adolescents in different cultural settings experience collaborative learning and its effects on their social and academic development. This study is grounded in Vygotsky's sociocultural theory, which emphasizes the role of social interaction in learning, and Self-Determination Theory, which identifies autonomy, relatedness, and competence as key factors in motivation [22]. It investigates the psychological and social dimensions of virtual collaborative learning. Specifically, the study seeks to answer the following research questions: How does collaborative learning in virtual environments affect students' motivation? How does it influence students' feelings of isolation in virtual settings? What are the challenges and benefits of collaborative learning in virtual environments for students? The study aims to explore the relationship between the concept of collaborative learning within sociocultural theory and its effects on motivation and isolation in virtual environments. It is hypothesized that the implementation of collaborative learning activities, such as group work, will enhance students' motivation and reduce feelings of isolation by fostering social connections and promoting engagement with both peers and instructors.

LITERATURE REVIEW

Sociocultural Theory

The global upheaval caused by the COVID-19 pandemic presented a significant challenge for educators in adapting sociocultural learning practices to virtual environments. Lev Vygotsky's Sociocultural Theory of cognitive development emphasizes the pivotal role of social context in shaping a child's cognitive growth [22]. According to Wibowo et al. [23], Vygotsky's theory underscores the interdependence of social and individual processes in the co-construction of knowledge, a dynamic that is equally applicable to online learning contexts.

A core concept of Vygotsky's sociocultural theory is the Zone of Proximal Development (ZPD), which delineates the gap between a learner's ability to perform a task independently and their ability to achieve the same task with guidance from a more capable peer or teacher. This concept is closely linked to collaborative learning, as it emphasizes the value of peer interactions in learning tasks that may be too challenging for an individual learner to accomplish alone [24]. Another crucial aspect of Vygotsky's theory is the notion of mediation, which posits that tools such as language, technology, and instructional support play essential roles in facilitating learning [25], [26], [27]. Although Vygotskian frameworks are frequently applied in online learning settings, there remains a limited body of literature specifically addressing how virtual learning environments can be structured around sociocultural theory [28], [29]. This gap highlights the need for further exploration of how online learning platforms can effectively integrate Vygotskian principles to enhance cognitive development through social interaction and mediated learning.

Motivation and Self-Determination Theory

Motivation is a fundamental factor in effective learning, influencing students across all types of courses [30], [31]. Self-Determination Theory (SDT) offers a comprehensive framework for understanding the various factors that shape motivation. According to SDT, students are intrinsically motivated when they are driven by curiosity and a genuine desire to learn content or acquire skills [32], [33]. In contrast, extrinsic motivation arises when students are motivated by external rewards, such as grades. Several factors influence motivation, including competence, which refers to students' perceptions of their abilities relative to others or to their own previous efforts; autonomy, which concerns students' control over their learning processes; and relatedness, which pertains to students' sense of connection with others during their learning experiences [34], [35], [36]. Amotivation, as defined by Guzzardo et al. [37], is the state in which students lack value for an activity, feel incapable, or do not see the purpose of a task. In the context of online group work, motivated students are likely to believe in their abilities, perceive themselves as having control over assessments, and find ways to connect with their peers. Ryan and Deci [38] argue that SDT can also address the basic psychological needs essential for fostering motivation and well-being within virtual environments.

Weiner [39] identifies additional factors influencing motivation and emotion, specifically locus, stability, and controllability, which impact students' emotional responses to learning. These factors suggest that any changes in students' perceptions of these dimensions can significantly affect their motivation and emotions before, during, and after completing a task. Educators can influence students' motivation by emphasizing effort, strategy, and by addressing any barriers to success, ultimately shaping students' expectations of success [40].

Collaborative Learning

Collaborative learning is an instructional approach that involves students working together in small groups or pairs to achieve a common academic goal or solve a shared problem. It emphasizes the active participation of all group members, promoting interdependence, communication, and mutual support. Unlike traditional learning, where students work independently, collaborative learning fosters peer-to-peer interactions, where students exchange ideas, negotiate meaning, and co-construct knowledge. Previous studies on collaborative learning have highlighted its ability to increase student engagement, improve academic performance, and alleviate feelings of loneliness [41], [42], [43]. Research has shown that students' inquiry and communication within online environments help establish common ground for social interaction, which, in turn, enhances both their emotional and academic well-being [44], [45]. Also, engagement in collaborative learning has been linked to heightened motivation and stimulation, as students often feel a sense of responsibility to their peers [46].

However, several gaps persist in the existing literature on collaborative learning within virtual environments. One significant gap is the focus on adult learners or higher education students, with limited attention given to secondary education students. Adolescents, with their unique developmental challenges, such as concerns with belongingness and self-worth, may experience online learning differently. These factors are likely to influence their feelings of loneliness and motivation in virtual settings. Also, the role of digital tools as mediators of collaboration has been explored in existing research but often overlooks critical cultural and contextual factors. These include disparities in access to technology, as well as variations in digital literacy among students

and educators. These factors can significantly influence the effectiveness of collaborative learning in virtual environments and warrant further exploration.

METHODS

Research Design

This study adopted a qualitative research approach [47] to explore the experiences of adolescents during virtual collaborative learning. Semi-structured interviews and surveys were employed to complement each other, capturing participants' perceptions, and providing a comprehensive understanding of their experiences.

Population and Sample

The participants in this study were adolescent students aged 13 to 18 years, drawn from diverse geographic regions and educational environments. Purposive sampling [48] was used to select twelve students from Grades 6 to 12, representing a variety of nationalities, genders, ethnicities, and academic achievements. The participants included adolescents from the United States, Saudi Arabia, and Pakistan with additional representation from countries such as France, Egypt, Great Britain, China, Korea, Nigeria, India, and others. This global representation ensured that the study captured a wide array of cultural, social, and educational contexts, providing a rich basis for exploring the influences of these factors on students' virtual learning experiences. Purposive sampling was particularly valuable in selecting participants who had varied levels of experience with virtual learning, including those from face-to-face, blended, and fully online classrooms. This diversity allowed for a broader examination of how students' individual academic backgrounds and learning contexts influenced their perceptions of motivation and loneliness in virtual settings. Also, the selection of participants based on gender identities, including female, male, non-binary, and gender-fluid, ensured that the study accounted for a diverse spectrum of experiences related to virtual learning. The purposive sampling method allowed the researcher to specifically select students whose experiences and characteristics were relevant to answering the research questions, making it an effective approach for gathering rich, contextually relevant data.

Research Instrument

Data was gathered through a combination of semi-structured interviews and surveys. The semi-structured interviews allowed for in-depth exploration of students' experiences and perceptions during virtual collaborative learning tasks. The interview questions focused on themes such as students' interactions with peers, feelings of loneliness in virtual environments, and their levels of motivation. In addition to the interviews, online surveys were administered to collect quantitative data on students' attitudes toward virtual learning. The surveys used a Likert scale to assess perceived loneliness, the impact of collaborative tasks on motivation, relatedness, and the challenges faced in virtual learning. Both instruments were designed to complement each other, with the interviews providing detailed personal insights and the surveys capturing broader trends.

Data Collection Procedure

To facilitate participation across different time zones, all interviews were conducted via Zoom. The interview questions focused on students' interactions with peers during collaborative learning tasks,

their feelings of loneliness in virtual environments, and their motivation levels. The interviews were semi-structured, lasting 15-20 minutes, allowing for flexibility in the responses while maintaining focus on key research themes. In addition to the interviews, questionnaires were also used in the online mode to obtain quantitative data regarding participants' attitudes toward virtual learning. The surveys employed a Likert scale, which included questions about perceived loneliness, the impact of collaborative tasks on motivation and relatedness, and challenges faced in virtual learning. To enhance the validity and reliability of the study, a triangulation approach [49] was used. Triangulation involves the use of multiple data collection methods to cross-validate findings and reduce biases. In this study, triangulation was achieved through the combination of interviews, surveys, and participant observations during collaborative tasks. This multi-method approach helped to capture a comprehensive view of the students' experiences by considering both their subjective perceptions (from interviews) and more generalizable trends (from surveys). By comparing data from these different sources, the researcher was able to identify consistent patterns and themes, thereby strengthening the credibility and validity of the findings.

Data Analysis

The interview data were transcribed verbatim and analysed using thematic analysis. The analysis followed an inductive reasoning approach, where themes were derived from the data rather than imposed by pre-existing theoretical frameworks. The process began with an initial review of the transcripts to capture first impressions. Next, focused text segments related to the core themes of motivation, isolation, and collaborative learning were identified and coded. These codes were then clustered into superordinate themes and subthemes. Finally, the themes were reviewed and refined to ensure alignment with the research questions.

To analyse the language use during collaborative tasks, the researcher specifically focused on how participants used language in their interactions with peers. The digital tools employed during virtual collaboration, such as Zoom, Google Docs, and discussion boards, were examined to identify how they facilitated linguistic exchanges. Particular attention was given to how students used language to negotiate meaning, clarify ideas, and provide feedback during collaborative tasks. This included both synchronous (e.g., chat, voice, and video interactions) and asynchronous (e.g., written exchanges on shared documents) communication. The digital tools served as mediating devices in these interactions, shaping the types of language used, as well as the frequency and depth of communication. Instances of students' active engagement, collaborative problem-solving, and peer feedback were analysed to understand how language use was influenced by these tools and how such interactions contributed to students' feelings of connectedness or isolation.

In addition to interview data, responses from the surveys and observations made during the collaborative tasks were also triangulated [50]. The Likert scale responses were analysed to provide a numerical representation of students' attitudes toward collaboration and virtual learning. The most common responses were identified using mode and median analyses, offering insight into the general trends in motivation and isolation. These quantitative findings complemented the qualitative interview data and helped contextualize the students' experiences. The integration of interview data, surveys, and observations allowed for a deeper understanding of the relationship between virtual collaboration and students' motivation and feelings of isolation. This triangulation provided a comprehensive view of how collaborative learning in virtual environments, mediated by digital tools, impacted students' language use, social interactions, and emotional engagement.

RESULTS AND DISCUSSION

This section presents the findings of the study, addressing the primary research questions: (1) How does collaborative learning in virtual environments impact students' motivation? (2) How does collaborative learning influence students' feelings of isolation in virtual settings? (3) What are the challenges and benefits of collaborative learning in virtual environments for students? The data, gathered through semi-structured interviews, surveys, and participant observations, were analysed to provide an in-depth understanding of adolescents' experiences within virtual collaborative learning environments.

Table 1. Interview Results on Students' Motivation and Isolation in Virtual Collaborative Learning Environments

Theme	Codes	Findings / Interpretation	Notes / Implications
Motivation through Collaboration	Higher motivation with friends Positive peer influence Real-life applications valued	- Most students felt more motivated during online collaborative tasks, especially with friends. - Peer influence uplifted or diminished group motivation. - Students valued meaningful, real-life linked tasks.	Motivation is socially driven; relevance increases engagement.
Feelings of Isolation	Less isolation in group work Group composition matters Camera/mic usage helps connection Cultural restrictions	- Less isolation was reported during group work than in solo tasks. - Familiar group members reduced isolation. - Camera/mic use increased connection. - Cultural restrictions (e.g., no camera) caused isolation.	Social presence and group familiarity reduce isolation; cultural context matters.
Challenges in Collaboration	Subject-dependent engagement Need clear instructions Balance guidance & autonomy	- Engagement varied by subject and task type. - Lack of clear instructions led to frustration and isolation. - Students preferred a mix of structure and autonomy.	Clear task design and balanced facilitation are essential for engagement.
Benefits of Collaboration	Improved social well-being Better skill development Interactive engagement Enhanced concept retention	- Improved social well-being and reduced loneliness. - Enhanced teamwork, communication, and problem-solving skills. - Breakout rooms increased participation. - Discussions improved concept retention.	Collaboration boosts both cognitive and social outcomes.
Fluctuation in Motivation	Daily motivation varies Teacher feedback important Autonomy increases engagement	- Motivation fluctuated daily due to task design and repetition. - Timely, specific teacher feedback boosted motivation. - Autonomy increased motivation for some learners.	Dynamic motivation requires thoughtful design and regular feedback.

The above table 1 outline the key findings based on the patterns and themes that emerged from the analysis, offering insight into how virtual collaboration influences student motivation, feelings of isolation, and the perceived advantages and challenges of this learning approach. These results contribute to a broader understanding of the dynamic interplay between digital tools, social interaction, and student engagement in virtual learning environments.

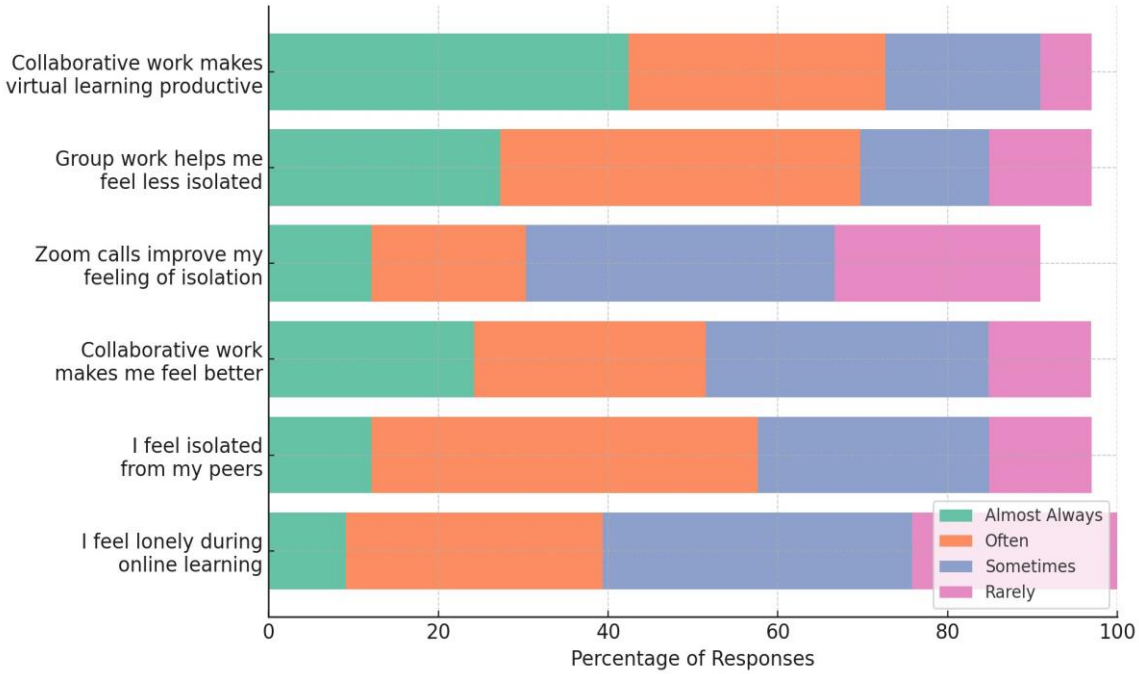

Figure 1. Survey Results on Students' Motivation and Isolation in Virtual Collaborative Learni Environments

Impact of Collaborative Learning on Students' Motivation

The study findings (Table 1) indicate that positive student motivation is strongly associated with collaborative learning, particularly when tasks assigned are authentic and peer interactions are encouraging. According to Vygotsky [22], sociocultural development is the process by which learners acquire knowledge through interactions with others within the zone of proximal development, where the learner performs better when supported by a peer or a teacher than when working alone. This was evident in the findings, where many students expressed heightened motivation when working with familiar peers. One student shared, "When I worked with my friends, I felt excited, and time flew by," illustrating how collaboration with peers can scaffold engagement and enhance motivation. Survey data reinforced these findings, with 42.4% of students reporting that collaborative work made virtual learning feel more productive "almost always," and 33.3% saying "often." The mode for this statement was "almost always," and the median was 4 (often), further emphasizing the positive impact of collaborative learning on motivation (Figure 1).

As noted by Ryan and Deci [38] Self-Determination Theory, autonomy is a key factor in enhancing intrinsic motivation. In line with this theory, tasks that allowed students some degree of autonomy were perceived as more motivating. One participant commented, "I liked being able to learn at my own pace without feeling rushed," reinforcing the importance of autonomy in fostering motivation. Peer dynamics also played a significant role in motivation, with students reporting that the motivation of their peers influenced their own motivation. A student noted, "It felt good to work

with peers who were focused, but working with unmotivated students was frustrating." This finding aligns with Walker et al. [51] research on co-regulation, suggesting that motivation within groups varies depending on the collective actions and attitudes of group members. However, not all experiences were uniformly positive. Some students noted that monotonous tasks or unclear instructions led to disengagement. One participant mentioned, "Some days I felt really motivated, but on other days, it felt repetitive and boring." Additionally, the timing of teacher feedback was found to influence motivation, as students were more likely to exert effort when they knew the teacher was monitoring their progress. One student remarked, "I worked harder when I knew the teacher was checking our progress online," further supporting Vygotsky [22] concept of scaffolding, where teacher support facilitates learner engagement and growth.

While older theories often emphasize motivation as an individualistic process, this study suggests that motivation is closely linked to social interactions. Consistent with Muñoz-Carril et al. [52] assertion that learning and motivation are inherently social, the study found that students' motivation in collaborative settings was positively influenced by their interactions with others. This further aligns with Jeong et al. [53] sociocultural perspectives on assisted learning and peer collaboration, where motivation is shaped by social dynamics within the group. Therefore, this study demonstrates that collaborative learning not only boosts motivation but also helps sustain it through social interaction and peer engagement.

Influence of Collaborative Learning on Students' Feelings of Isolation

The results also revealed that collaborative learning helped reduce feelings of isolation among students in virtual learning environments. Vygotsky [22] emphasized that learning is inherently social, and many students reported greater feelings of social connection during collaborative tasks. One participant shared, "That gave me the feeling that I am not alone, especially when we are collecting ideas," illustrating how group work helped combat isolation. Survey results also supported this, with 42.4% of students reporting "often" and 27.3% responding "almost always" to the statement, "Group work helps me feel less isolated." The mode was "often," and the median was 4 (often), suggesting that collaborative work played a significant role in reducing loneliness. Additionally, 33.3% of students indicated that group work improved their mood, with 27.3% responding "often," further emphasizing the positive emotional impact of collaboration, consistent with Self-Determination Theory's focus on relatedness [38].

However, the reduction of isolation was not experienced equally by all students. Social context was a factor again because the students who were grouped with other students did not feel isolated. Some participants expressed discomfort when working with unfamiliar peers. One student stated, "I felt uncomfortable to work with people I did not know; I liked working with my friends." This finding aligns with Main et al. [9] perspective on the importance of positive relationships during adolescence, which play a critical role in identity formation and social connection. The role of technology was also highlighted as a significant factor in reducing isolation. Students who used video and microphone functions during collaborative tasks felt more engaged, with one participant noting, "When everyone turned on their cameras, it felt like a real classroom experience." However, cultural taboos or personal discomfort with using cameras increased feelings of isolation for some learners.

Survey data also revealed variability in students' experiences of loneliness during virtual learning. For the statement, "I feel lonely during online learning," 36.4% of students responded

"sometimes," and 30.3% responded "often." The mode for this statement was "sometimes," and the median was 3 (sometimes), suggesting that while collaborative learning mitigated isolation for many students, the process was contingent on factors such as group dynamics, teacher interventions, and individual preferences. The absence of social bonds and extracurricular activities, typically present in physical schools, was a significant factor contributing to students' feelings of isolation. These findings suggest that the design of virtual learning activities should focus on fostering social connections and engaging collaborative tasks that promote intrinsic motivation. The findings also indicated that the use of digital tools like Google Docs, Padlet, and Kahoot helped students engage in collaborative learning and foster a new social environment. These tools enabled students to work together, enhancing communication, creativity, and critical thinking, in line with Vygotsky [22] social constructivism, which emphasizes the role of collaborative interactions in learning.

Opportunities & Barriers of Collaborative Learning

While the positive effects of collaborative learning, including social well-being, teamwork, and problem-solving, were evident, several challenges hindered the learning process. Some students reported confusion due to unclear instructions. One participant mentioned, "Often we were confused whether to do what we were doing or not, and it was like twiddling our thumbs and getting bored." This indicates that clearer task directions could enhance the effectiveness of collaborative work. Another student emphasized the importance of teacher guidance, noting, "I liked when teachers gave clear steps for group work, but some students liked to figure things out on their own." Balancing teacher guidance and student autonomy is critical in maximizing the benefits of collaborative learning.

Despite these challenges, students highlighted several benefits of collaboration. One participant noted, "Working on group projects helped me learn how to express my ideas clearly," demonstrating the development of communication skills through collaboration. The use of breakout rooms in Zoom was another positive aspect, as students found these spaces more engaging and interactive. One participant shared, "Breakout rooms during Zoom calls made the class more interesting and interactive," underscoring the value of creating dynamic learning environments that promote interaction and engagement. These findings align with Sahi et al. [54] observation that adolescence is a period of significant social and emotional development, where peer groups play a critical role in learning. Group work meets the social needs of adolescence by offering a framework of how students should relate, communicate and create friendships. Vygotsky theory of mediation [55] provides a framework for understanding how tools, such as Zoom breakout rooms and shared documents, mediate collaborative learning by facilitating communication and interaction. These digital tools, as materialized culture, serve as scaffolds that support students in achieving higher-level learning outcomes through social interaction and collaboration.

CONCLUSION

This study demonstrates that collaborative learning, enhanced by digital tools like Zoom, Google Docs, and Padlet, significantly reduces isolation and boosts motivation among adolescents in virtual environments. The findings support both Vygotsky's Sociocultural Theory and Self-Determination Theory, highlighting the importance of peer interaction and autonomy in fostering engagement. Collaborative tasks, when well-structured, can promote intrinsic motivation while mitigating feelings of isolation, making them a key strategy in virtual learning. The study also underscores the

importance of culturally sensitive learning designs and the need for teacher training in using digital tools effectively. Future research should explore the long-term effects of virtual collaboration and investigate the role of emerging technologies like AI and virtual reality in enhancing collaboration and motivation across diverse educational contexts. By integrating both social interaction and autonomy, this research provides valuable insights into optimizing virtual learning environments for adolescent students.

LIMITATIONS

This study has several limitations, including a small, regionally limited sample, which affects the generalizability of the findings. Additionally, reliance on self-reported data may introduce bias, and the study did not explore the impact of emerging technologies like virtual reality or artificial intelligence on collaborative learning. Furthermore, the role of instructor facilitation was not fully addressed, and future research could explore its influence on virtual collaboration effectiveness.

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AUTHOR CONTRIBUTION

S.H. and A.A. designed the study and developed the research framework. S.H. conducted the interviews, analyzed the data, and led the interpretation of the findings. A.A. contributed to the survey design and assisted in data analysis. Both authors collaboratively wrote and revised the manuscript. S.H. supervised the overall project and provided critical revisions to the final draft.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DECLARATION OF USE OF AI IN SCIENTIFIC WRITING

The authors used ChatGPT during the preparation of this manuscript to assist with grammar improvement. Following the use of the tool, the authors thoroughly reviewed and revised the content as needed, assuming full responsibility for the final manuscript and its publication.

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