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THE CONVERSATION HUB: EXPLAINING STUDENTS' TRANSITION FROM SURFACE TO DEEP MATHEMATICS LEARNING

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Abstract

The transition from surface-oriented learning to deep learning remains a significant challenge in mathematics education, particularly in understanding how students develop deeper conceptual engagement through authentic classroom experiences. This study aimed to develop a substantive theoretical explanation of how Grade 12 students transition from surface-oriented learning toward deep learning in mathematics classrooms. A Constructivist Grounded Theory approach was employed, using semi-structured interviews to collect data from Grade 12 students. Data were analyzed through iterative coding procedures, including initial, focused, and theoretical coding, to identify recurring categories and generate an emerging theoretical model. The findings revealed that students' progression toward deep learning was facilitated through continuous mathematical conversations, enabling them to connect prior knowledge, collaboratively construct conceptual understanding, reflect on mathematical reasoning, and apply knowledge in meaningful contexts. These interconnected learning experiences culminated in the emergence of the Conversation Hub, identified as the core category explaining students' transition from surface-oriented learning to deep learning. This study contributes to mathematics education by providing a substantive theoretical explanation of students' learning processes and offers a practical framework for designing mathematics classrooms that foster collaborative dialogue, conceptual understanding, and meaningful learning.

INTRODUCTION

Across educational systems worldwide, mathematics education is increasingly expected to cultivate learners who can reason mathematically, construct conceptual understanding, communicate mathematical ideas effectively, and apply their knowledge flexibly in unfamiliar situations rather than merely execute procedures accurately or memorize formulas. This expectation reflects a significant shift in educational priorities from emphasizing procedural proficiency toward fostering higher-order thinking, conceptual reasoning, and transferable problem-solving competencies that prepare students for the complex demands of the twenty-first century (Kilpatrick et al., 2001; National Council of Teachers of Mathematics, 2014).

Accordingly, contemporary mathematics curricula emphasize that successful learning involves more than obtaining correct answers; it requires students to justify mathematical arguments, establish meaningful relationships among concepts, evaluate alternative solution strategies, and use mathematical knowledge to solve authentic problems. These expectations are further reinforced by international educational frameworks, which identify critical thinking, analytical reasoning, and adaptive problem solving as essential competencies for lifelong learning and active participation in modern society (Organisation for Economic Co-operation and Development, 2023). Consequently, mathematics classrooms are increasingly encouraged to create learning environments that promote active cognitive engagement, conceptual inquiry, collaborative knowledge construction, and reflective thinking instead of passive information acquisition. From this perspective, meaningful mathematical learning is understood as a continuous process through which learners integrate new ideas with prior knowledge, reorganize existing cognitive structures, and progressively develop coherent conceptual frameworks that can be transferred across diverse mathematical contexts (Bransford et al., 2000; Kilpatrick et al., 2001). This evolving perspective has fundamentally influenced contemporary mathematics education research, shifting attention beyond what students learn toward understanding how meaningful mathematical understanding develops and which classroom conditions most effectively facilitate the transition to deeper learning.

Understanding how students engage with learning has become a central concern in educational research, leading to the development of the distinction between surface and deep approaches to learning, one of the most influential theoretical perspectives for explaining differences in students' learning experiences across educational contexts. Originating from the seminal phenomenographic studies of (Marton & Säljö, 1976a;1976b), this perspective argues that variations in learning outcomes are determined not merely by students' intellectual abilities or the quantity of information acquired but, more importantly, by the quality of their cognitive engagement with learning tasks.

Learners adopting a surface approach generally concentrate on memorizing isolated facts, reproducing information for assessment purposes, and meeting minimum academic requirements with limited conceptual engagement. In contrast, learners adopting a deep approach actively seek to understand underlying meanings, integrate new knowledge with prior understanding, establish meaningful relationships among ideas, and critically evaluate information to construct coherent conceptual frameworks. Expanding this perspective, (Biggs, 1987)introduced the Student Approaches to Learning (SAL) framework, emphasizing that learning approaches should not be regarded as fixed learner characteristics but rather as context-dependent responses shaped by teaching practices, classroom environments, students' motivation, and assessment demands. Consequently, students may shift between surface and deep approaches depending on how learning experiences are designed and interpreted, highlighting that meaningful learning is strongly influenced by educational contexts rather than individual ability alone (Biggs & Tang, 2011). This dynamic perspective has become increasingly influential in mathematics education because it provides a theoretical foundation for understanding why students exposed to similar instructional environments often demonstrate markedly different levels of conceptual understanding, reasoning ability, and long-term knowledge retention.

Within mathematics education, the distinction between surface and deep approaches to learning becomes particularly significant because meaningful mathematical learning depends not only on procedural fluency but also on learners' ability to construct coherent conceptual relationships among mathematical ideas. Mathematics is inherently cumulative and relational; consequently, understanding increasingly complex concepts requires students to integrate prior knowledge with new mathematical experiences rather than rely solely on memorized procedures. This perspective is closely reflected in (Skemp, 1976)influential distinction between instrumental understanding, defined as the ability to apply mathematical rules without understanding the underlying reasons, and relational understanding, which involves knowing both what to do and why mathematical procedures are valid through recognizing meaningful relationships among concepts. Although instrumental understanding may enable students to solve routine problems efficiently, relational understanding supports mathematical reasoning, conceptual flexibility, and the transfer of knowledge to unfamiliar situations. The close correspondence between Skemp's theory and the Student Approaches to Learning framework suggests that students who primarily depend on memorization and procedural reproduction are more likely to demonstrate characteristics of surface learning, whereas those who actively construct conceptual connections are more likely to engage in deep learning (Marton & Säljö, 1976a;1976b).

This relationship is further supported by research indicating that conceptual understanding enables learners to justify mathematical reasoning, evaluate alternative solution strategies, and solve non-routine problems more effectively than procedural knowledge alone (Hiebert & Carpenter, 1992; Rittle-Johnson et al., 2015). Likewise, mathematics classrooms that promote discussion, collaborative problem solving, and reflective reasoning create opportunities for students to engage more deeply with mathematical ideas and strengthen their conceptual understanding (National Council of Teachers of Mathematics, 2014). Consequently, fostering relational understanding has become a central objective of contemporary mathematics education. Nevertheless, despite widespread agreement regarding its importance, many secondary school students continue to rely predominantly on procedural and memorization-based learning strategies, indicating that facilitating the transition from surface to deep learning remains one of the most persistent challenges in mathematics education.

Despite the growing consensus regarding the educational value of deep learning and conceptual understanding, translating these theoretical principles into everyday mathematics classroom practice remains a persistent challenge. A substantial body of research has demonstrated that instructional approaches emphasizing conceptual inquiry, collaborative learning, and mathematical reasoning can improve students' learning outcomes. Nevertheless, many secondary mathematics classrooms continue to be characterized by instructional practices that prioritize procedural fluency, repetitive exercises, and examination performance over conceptual understanding and reflective thinking (Kilpatrick et al., 2001; Rittle-Johnson et al., 2015). As a result, students often demonstrate competence in solving familiar routine problems while experiencing considerable difficulty when confronted with unfamiliar tasks requiring mathematical justification, conceptual connections, or flexible problem-solving strategies.

This challenge becomes particularly evident during upper secondary education, where learners are expected to integrate procedural knowledge with mathematical reasoning, communication, and conceptual understanding in preparation for increasingly complex learning demands(National Council of Teachers of Mathematics, 2014). Although previous studies consistently emphasize the importance of classroom discussion, inquiry-based learning, collaborative problem solving, and mathematical argumentation, these instructional practices are frequently examined as isolated pedagogical interventions designed to improve achievement rather than as interconnected learning experiences that gradually transform students' approaches to learning. Consequently, while substantial evidence exists regarding the effectiveness of various instructional strategies, considerably less attention has been devoted to understanding how students themselves experience the gradual transition from procedural and memorization-based learning toward deeper conceptual engagement. This limitation suggests that the challenge of promoting deep learning extends beyond selecting effective teaching methods and requires closer examination of the learning processes through which students actively construct mathematical understanding within authentic classroom contexts.

Despite the substantial body of research investigating mathematics teaching and learning, important questions remain regarding the processes through which students gradually develop deeper forms of conceptual engagement. Existing studies have generated valuable evidence concerning the effectiveness of instructional approaches, classroom interventions, and pedagogical strategies for improving mathematical achievement and conceptual understanding (Kilpatrick et al., 2001; National Council of Teachers of Mathematics, 2014). However, much of this research has primarily focused on evaluating educational outcomes or examining relationships among instructional variables, providing comparatively limited insight into how students progressively transform their ways of thinking and engaging with mathematics.

This limitation is particularly evident in upper secondary mathematics, where students are expected to integrate procedural fluency with conceptual reasoning, mathematical communication, and reflective thinking while simultaneously preparing for high-stakes examinations. In examination-oriented educational contexts, these competing demands often create tension between achieving procedural success and developing meaningful conceptual understanding, making the transition from surface-oriented learning to deeper conceptual engagement especially challenging (Rittle-Johnson et al., 2015). Although inquiry-based instruction, collaborative learning, mathematical discussion, and argumentation have consistently been recognized as important conditions for promoting meaningful learning (National Council of Teachers of Mathematics, 2014), they are frequently examined as isolated instructional interventions rather than as interconnected learning experiences through which students gradually reconstruct mathematical understanding.

Consequently, relatively little is known about how learners themselves interpret classroom experiences, negotiate mathematical meaning, and progressively transform their approaches to learning during authentic classroom activities. Addressing this gap requires a research approach that examines learning as a dynamic, context-dependent, and socially constructed process rather than merely measuring predefined instructional variables or learning outcomes(Charmaz, 2014). Therefore, to address this gap, the present study adopts a Constructivist Grounded Theory approach to generate a substantive theoretical explanation of how Grade 12 students experience the transition from surface to deep learning in mathematics classrooms.

Understanding how students gradually move from surface-oriented learning toward deeper conceptual engagement requires a perspective that recognizes learning as an active process of knowledge construction rather than the passive acquisition of information. This perspective is grounded in constructivist learning theory, which posits that learners continuously construct and reconstruct understanding by integrating new experiences with existing cognitive structures through reflection, dialogue, and social interaction (Piaget, 1970; Vygotsky, 1978). Within mathematics education, conceptual understanding develops as learners test mathematical ideas, negotiate meanings, confront misconceptions, justify mathematical reasoning, and refine their thinking through sustained interaction with teachers, peers, and authentic learning activities. Such a perspective complements the Student Approaches to Learning framework and Skemp's notion of relational understanding by emphasizing that meaningful mathematical learning emerges through active participation in knowledge construction rather than through procedural reproduction alone. Consequently, investigating students' transition from surface to deep learning requires more than evaluating instructional effectiveness or measuring academic achievement; it requires an in-depth exploration of how learners interpret classroom experiences, construct mathematical meaning, and gradually transform their approaches to learning within authentic educational contexts. From this epistemological perspective, Constructivist Grounded Theory provides a coherent methodological framework because it assumes that theoretical understanding emerges inductively through the co-construction of meaning between researchers and participants rather than from predetermined conceptual frameworks (Charmaz, 2014). Therefore, Constructivist Grounded Theory provides an appropriate methodological foundation for explaining how Grade 12 students experience and interpret their transition from surface to deep learning in mathematics classrooms.

The present study was conducted in Grade 12 mathematics classrooms in Kampong Cham Province, Cambodia, a context that provides valuable opportunities for exploring students' learning experiences during a critical stage of secondary education. As the final year of upper secondary schooling, Grade 12 represents an important transition period during which students prepare for the National Upper Secondary School Examination. This assessment plays a significant role in determining access to higher education. Consequently, mathematics instruction at this level is shaped not only by curricular expectations but also by the demands of examination performance. Although recent educational reforms in Cambodia have promoted student-centred learning, competency-based curricula, and the development of higher-order thinking skills (Ministry of Education, Youth and Sport, 2024), classroom practices continue to face challenges in balancing procedural achievement with the development of conceptual understanding and mathematical reasoning.

This challenge is particularly pronounced in Grade 12, where students are expected to demonstrate increasingly sophisticated mathematical reasoning while simultaneously preparing for high-stakes examinations. Under these examination-oriented conditions, learners frequently experience tension between achieving procedural success and engaging in the deeper conceptual learning expected by contemporary mathematics curricula. Consequently, understanding how students negotiate this transition within authentic classroom settings is essential for explaining how meaningful mathematical learning develops under examination-oriented educational conditions. Moreover, relatively few qualitative studies have examined students' lived experiences of learning mathematics in Cambodian upper secondary classrooms from the perspective of learning processes and meaning construction. Most existing research has concentrated on curriculum implementation, teacher quality, or student achievement, leaving the processes through which students construct deeper mathematical understanding comparatively underexplored. Therefore, examining Grade 12 mathematics classrooms in Kampong Cham not only addresses an important contextual gap in the literature but also provides insights that may inform mathematics teaching and learning in other examination-oriented educational settings.

In response to these theoretical, methodological, and contextual gaps, the present study aims to explore how Grade 12 students experience the transition from surface to deep learning in mathematics classrooms in Kampong Cham Province, Cambodia. Rather than examining the effectiveness of a particular instructional intervention or testing predetermined hypotheses, this study seeks to develop a substantive theoretical explanation of the learning processes through which students construct mathematical understanding, negotiate meaning, and progressively engage in deeper forms of conceptual learning. To achieve this objective, the study adopts a Constructivist Grounded Theory approach, which is particularly suited to generating theory inductively from participants' lived experiences while recognizing that meaning is co-constructed through interactions between researchers and participants (Charmaz, 2014).

The study is expected to contribute to the growing body of mathematics education research in three important ways. First, it extends the Student Approaches to Learning literature by providing an empirically grounded explanation of how students' learning approaches evolve during authentic classroom experiences. Second, it demonstrates the application of Constructivist Grounded Theory as a methodological framework for investigating learning processes in mathematics education. Finally, the resulting theoretical insights are expected to inform teachers, curriculum developers, and educational policymakers in designing classroom environments that more effectively facilitate students' transition from procedural learning toward deeper conceptual understanding. Collectively, these contributions offer a contextually grounded perspective that may inform future research and educational practice in examination-oriented secondary education settings.

METHODS

Research Design

This study employed a Constructivist Grounded Theory (CGT) design to explore how Grade 12 students experienced the transition from surface to deep learning in mathematics classrooms. Constructivist Grounded Theory was selected because the primary aim of the study was to develop a substantive theoretical explanation of students' learning experiences rather than to test predetermined hypotheses or evaluate the effectiveness of a particular instructional intervention. Consistent with the constructivist paradigm, this approach assumes that knowledge and meaning are co-constructed through interactions between researchers and participants, allowing theoretical explanations to emerge inductively from participants' lived experiences (Charmaz, 2014).

Constructivist Grounded Theory is particularly appropriate for investigating educational processes because it emphasizes understanding how participants interpret experiences, construct meaning, and negotiate social interactions within specific contexts. In mathematics education, the transition from surface to deep learning is not viewed as a fixed outcome but as a dynamic learning process shaped by students' interactions with teachers, peers, classroom activities, and mathematical tasks. Therefore, this methodology provides an appropriate framework for examining how Grade 12 students progressively construct conceptual understanding and transform their approaches to learning mathematics. Through systematic coding and constant comparison of participants' narratives, the study sought to generate an empirically grounded theoretical explanation of students' learning transitions (Charmaz, 2014; Corbin & Strauss, 2015; Creswell & Poth, 2018).

Population and Sampling

The population of this study comprised Grade 12 students enrolled in mathematics classes at selected high schools in Kampong Cham Province, Cambodia. Grade 12 students were considered appropriate for this study because they represent the final stage of upper secondary education, during which mathematics learning requires increasingly sophisticated conceptual reasoning while students simultaneously prepare for the National Upper Secondary School Examination. This educational context provides an appropriate setting for investigating students' experiences of transitioning from surface-oriented learning to deep learning in mathematics.

From this population, 48 Grade 12 students were purposively selected to participate in the study. The researcher applied a purposive sampling strategy to recruit participants who could provide rich descriptions of their learning experiences in mathematics classrooms. The sampling process sought to include students with diverse academic achievement, learning characteristics, and levels of classroom participation to obtain a broad range of perspectives on the transition from surface to deep learning. Participation in the study was entirely voluntary, and all participants were informed of the purpose of the research before data collection commenced. To protect participants' privacy, all information obtained during the study was treated confidentially and used exclusively for research purposes(Creswell & Poth, 2018; Patton, 2015).

Data Collection

Data for this study were collected primarily through semi-structured interviews with Grade 12 mathematics students. Semi-structured interviews were selected because they enabled participants to describe their learning experiences in their own words while allowing the researcher to explore issues that emerged during the interview process. The interview questions focused on students' experiences of learning mathematics, their approaches to understanding mathematical concepts, classroom interactions, learning difficulties, and the factors that influenced their movement from surface-oriented learning toward deeper conceptual understanding. This flexible interview format allowed participants to provide detailed descriptions of their personal experiences while ensuring the discussion remained aligned with the study's objectives(Creswell & Poth, 2018).

The interviews were conducted individually with the 48 participating students, and participants were encouraged to reflect on authentic learning situations they had experienced in their mathematics classrooms. Throughout the interviews, the researcher used probing questions to clarify responses and encourage participants to elaborate on their experiences whenever necessary. The interview data were subsequently organized and prepared for analysis through a systematic coding process. This procedure enabled the researcher to obtain rich qualitative data describing how students experienced the transition from surface to deep learning in mathematics and provided the empirical foundation for the development of categories and theoretical interpretations (Charmaz, 2014;Patton, 2015).

Table 1. Summary of Data Collection

Data Source	Participants	Purpose
Semi-structured interviews	48 Grade 12 students	To explore students' experiences of learning mathematics and their transition from surface to deep learning
Interview records	48 interview records	To support the identification of codes, categories, and theoretical interpretations

Data Analysis

The interview data were analyzed using an iterative coding process consistent with the principles of Constructivist Grounded Theory (Charmaz, 2014). Data analysis began with repeated reading of the interview records to gain a comprehensive understanding of participants' experiences in learning mathematics. During this process, meaningful words, phrases, and statements describing students' experiences of surface and deep learning were identified and assigned initial codes. The coding process was conducted systematically to ensure that the emerging concepts remained closely connected to the participants' descriptions and experiences.

Following the initial coding stage, conceptually related codes were compared and grouped into broader categories representing common patterns across participants' learning experiences. These categories were continuously refined through repeated examination of the interview data until coherent conceptual relationships emerged. The resulting categories were then interpreted to develop a substantive theoretical explanation of how Grade 12 students experienced the transition from surface-oriented learning toward deeper conceptual engagement in mathematics classrooms. Throughout the analysis, the interpretation remained grounded in participants' perspectives to ensure that the emerging explanation accurately reflected their lived learning experiences (Charmaz, 2014; Corbin & Strauss, 2015; Creswell & Poth, 2018).

Table 2. Data Analysis Process

Analysis Stage	Description
Data Familiarization	Reading the interview records repeatedly to understand participants' learning experiences.
Initial Coding	Identifying meaningful words, phrases, and statements related to surface and deep learning.
Category Development	Grouping conceptually similar codes into broader categories.
Interpretation	Examining relationships among categories to explain students' learning experiences.
Theory Development	Developing a substantive theoretical explanation of students' transition from surface to deep learning.

Trustworthiness

To enhance the trustworthiness of the findings, this study followed established principles for ensuring rigor in qualitative research. Throughout the research process, careful attention was given to maintaining consistency between the research objectives, data collection, and data analysis. The interview data were examined systematically through an iterative coding process, and the emerging categories were continuously reviewed to ensure that they accurately represented participants' experiences and perspectives. Maintaining close connections between the data and the emerging interpretations helped strengthen the credibility of the findings (Creswell & Poth, 2018);(Lincoln & Guba, 1985).

Furthermore, detailed descriptions of the research context, participant selection, and analytical procedures were provided to enable readers to understand how the findings were developed and to evaluate their potential transferability to similar educational settings. Throughout the analysis, the researcher sought to maintain transparency in interpreting participants' accounts by ensuring that the resulting theoretical explanation remained grounded in the empirical data rather than personal assumptions. These procedures contributed to the credibility, dependability, confirmability, and transferability of the study, which are widely recognized as essential criteria for establishing trustworthiness in qualitative research (Lincoln & Guba, 1985).

RESULT AND DISCUSSION

RESULT

Emergence of the Conversation Hub

The analysis of interview data revealed an emerging theoretical model describing how Grade 12 students experienced the transition from surface-oriented learning toward deeper conceptual engagement in mathematics classrooms. Through the iterative coding process, students consistently described mathematical conversations as the central mechanism through which conceptual understanding was developed. Rather than occurring as an individual cognitive process, the transition toward deep learning was shaped through interactions among students, classroom discussions, collaborative problem solving, and opportunities to explain mathematical ideas. These findings led to the development of the Conversation Hub, which represents the core category emerging from participants' learning experiences.

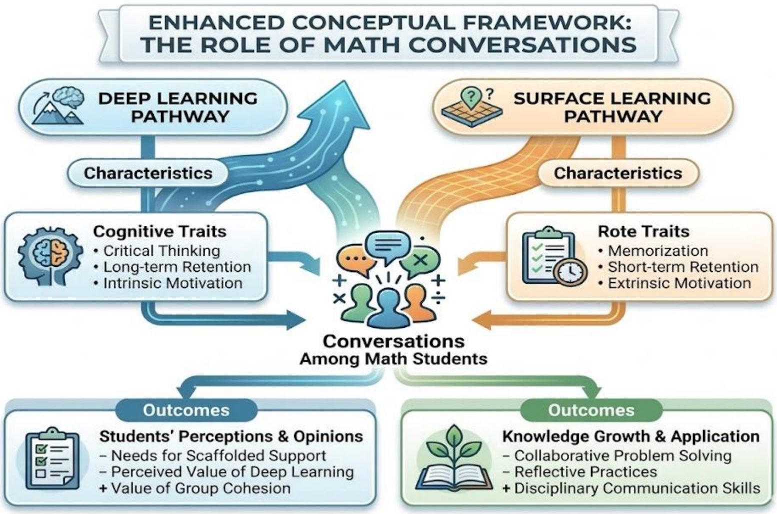

Figure 1. An Emerging Theoretical Model of Students' Transition from Surface to Deep Learning through Mathematical Conversations

Figure 1 illustrates the emerging theoretical model developed from participants' learning experiences during the coding process. The model demonstrates that students entered mathematics learning with different learning orientations. Some participants initially relied on memorization, procedural practice, and examination-focused strategies, reflecting characteristics of surface-oriented learning. In contrast, others demonstrated greater conceptual engagement through reasoning, critical thinking, and knowledge integration. Regardless of these initial differences, participants consistently described mathematical conversations as the central mechanism through which understanding was negotiated, misconceptions were clarified, and mathematical ideas were progressively reconstructed. Rather than functioning merely as classroom interaction, these conversations enabled students to explain their reasoning, question alternative solutions, and collaboratively construct conceptual understanding. Consequently, the Conversation Hub emerged as the core category linking students' initial learning approaches with deeper conceptual engagement and meaningful learning outcomes.

To further explain the emerging theoretical model, the coding process identified several categories that collectively describe how students experienced the transition from surface to deep learning in mathematics. These categories were derived from repeated analysis of participants' interview records and represent recurring patterns across students' learning experiences. Each category comprises a set of related codes, supported by representative participant statements, providing empirical evidence for the development of the emerging theoretical model. The identified categories are presented in Table 3.

Table 3. Core Category, Categories, Representative Codes, and Representative Participant Statements

Core Category	Category	Representative Codes	Representative Participant Statement
Conversation Hub	Prior Mathematical Knowledge	Building on prior knowledge; Connecting prior and new concepts	"The students must have a solid understanding of positive numbers before learning negative numbers."
Conversation Hub	Collaborative Mathematics Learning	Classroom discussion; Peer interaction; Collaborative problem-solving	"Students investigate different methods together and learn by discussing alternative solutions."
Conversation Hub	Relational Conceptual Understanding	Connecting mathematical concepts; Flexible reasoning; Understanding conceptual relationships	"Students connect new mathematical ideas with what they already know and apply these connections in subsequent learning."
Conversation Hub	Mathematics in Everyday Life	Real-world application; Interdisciplinary connections	"Deep learning helps students relate mathematics to everyday situations and other fields of knowledge."
Conversation Hub	Learning Resources and Mediating Tools	Visual representations; Manipulatives; Textbooks; Number lines	"Students use visual materials and hands-on resources to better understand mathematical concepts."
Conversation Hub	Learning Strategies	Active participation; Multiple learning approaches; Reflection	"Students participate through discussion, collaborative work, visual activities, and other learning experiences."
Conversation Hub	Learning Goals	Understanding learning objectives; Awareness of expected outcomes	"Students clearly understand what they are expected to learn during mathematics lessons."
Conversation Hub	Knowledge Application	Applying mathematical concepts; Transfer of learning	"I use multiplication not only in mathematics but also in real-life situations where it is useful."

Categories Supporting the Conversation Hub

Building Conceptual Understanding

The findings indicate that students' transition toward deep learning began with the development of conceptual understanding built upon their existing mathematical knowledge. Participants consistently emphasized that meaningful learning occurred when new mathematical concepts were connected to previously acquired knowledge rather than memorized as isolated procedures. Several students explained that understanding prerequisite concepts enabled them to comprehend more advanced mathematical ideas with greater confidence and accuracy. For example, one participant stated, "Students must have a solid understanding of positive numbers before learning negative numbers," illustrating the important role of prior knowledge in supporting conceptual development.

Beyond activating prior knowledge, participants described deep learning as a recognizing meaningful relationships among mathematical concepts rather than treating them as isolated pieces of information. Classroom discussions encouraged students to compare different solution strategies, justify their reasoning, and connect newly introduced concepts with previous learning experiences. Through these interactions, participants gradually reconstructed their mathematical understanding and became increasingly capable of explaining concepts using their own reasoning rather than relying solely on memorized procedures. These findings indicate that conceptual understanding developed progressively through meaningful connections among mathematical ideas, providing an essential foundation for students' transition from surface-oriented learning toward deeper conceptual engagement.

Participants further explained that their conceptual understanding was strengthened when they were encouraged to explain their reasoning and evaluate alternative mathematical solutions during classroom interactions. Such opportunities enabled students not only to refine their own understanding but also to appreciate multiple perspectives in solving mathematical problems. Within the emerging theoretical model, these experiences constitute an essential component of the Conversation Hub, where mathematical conversations continuously support the reconstruction of conceptual understanding and facilitate students' progression from surface-oriented learning toward deep learning.

Learning Through Mathematical Conversations

The findings revealed that mathematical conversations played a central role in facilitating students' transition from surface-oriented learning toward deeper conceptual engagement. Participants consistently described classroom discussions as opportunities to exchange ideas, compare different solution strategies, and clarify mathematical concepts through interaction with their peers. Rather than viewing learning as an individual activity, students emphasized that meaningful understanding emerged through collaborative dialogue, where alternative perspectives were shared, questioned, and refined. These interactions enabled students to recognize misconceptions, strengthen their reasoning, and develop greater confidence in explaining mathematical concepts.

Participants further explained that active participation in classroom discussions encouraged them to become more engaged in the learning process. Instead of relying solely on teacher explanations or memorizing solution procedures, students reported that discussing mathematical problems with classmates helped them understand the reasoning behind different approaches. Collaborative problem-solving activities encouraged students to justify their answers, evaluate alternative solutions, and construct mathematical understanding collectively. As a result, learning became a process of shared meaning-making rather than the passive acquisition of information.

The findings also indicate that students employed a variety of learning strategies to support these collaborative interactions. Participants described engaging in group discussions, cooperative problem-solving, visual learning activities, and peer explanations, all of which contributed to a deeper understanding of mathematical concepts. These learning experiences encouraged students to become active contributors rather than passive recipients of knowledge, allowing them to integrate different perspectives while developing more flexible mathematical reasoning.

Within the emerging theoretical model, these findings demonstrate that mathematical conversations served as the central mechanism linking students' collaborative learning experiences to the development of conceptual understanding. The Conversation Hub therefore represents more than classroom discussion alone; it reflects a dynamic process through which interaction, reasoning, reflection, and shared problem-solving collectively support students' progression from surface-oriented learning toward deep learning.

Connecting Mathematics Beyond the Classroom

The findings indicate that students perceived deep learning as extending beyond classroom activities and formal mathematical procedures. Participants consistently described meaningful mathematics learning as the ability to connect mathematical concepts with real-life situations and apply their understanding in different contexts. Rather than viewing mathematics as a collection of isolated rules or formulas, students emphasized the importance of recognizing how mathematical knowledge could be transferred to everyday experiences and other areas of learning. This broader perspective enabled participants to appreciate mathematics as a meaningful and practical discipline rather than merely a subject for examination.

Participants further explained that opportunities to relate mathematical concepts to authentic situations enhanced both their motivation and conceptual understanding. When classroom discussions encouraged students to consider practical applications of mathematical ideas, they became more confident in interpreting problems, selecting appropriate solution strategies, and explaining their reasoning. Several participants indicated that applying mathematical concepts outside the classroom strengthened their understanding because they were required to adapt previously learned knowledge to new situations rather than simply recalling memorized procedures.

The findings also suggest that the application of mathematical knowledge reinforced students' ability to integrate conceptual understanding with practical reasoning. Participants viewed mathematics as a tool for solving problems encountered in everyday life, allowing them to recognize meaningful relationships between classroom learning and real-world experiences. These learning experiences encouraged students to transfer their knowledge across different contexts, thereby strengthening both conceptual understanding and problem-solving abilities.

Within the emerging theoretical model, the application of mathematical knowledge represents an important outcome of the Conversation Hub. Mathematical conversations not only supported students in constructing conceptual understanding but also enabled them to extend that understanding beyond classroom learning through reflection, discussion, and authentic problem-solving experiences. Consequently, knowledge application emerged as a key indicator of students' successful transition from surface-oriented learning toward deep learning.

Supporting Conditions for Deep Learning

The findings indicate that students' transition toward deep learning was further supported by the availability of appropriate learning resources and clearly defined learning objectives. Participants explained that visual representations, textbooks, number lines, and other instructional materials assisted them in understanding abstract mathematical concepts by providing concrete illustrations and multiple ways of representing mathematical ideas. These learning resources enabled students to explore concepts more independently while supporting classroom discussions and collaborative problem-solving activities.

Participants also emphasized the importance of understanding the objectives of each mathematics lesson. Clearly communicated learning goals helped students recognize what they were expected to achieve and encouraged them to monitor their own learning progress throughout classroom activities. Rather than focusing exclusively on obtaining correct answers, students reported that explicit learning objectives motivated them to understand the underlying mathematical concepts and reasoning processes. This greater awareness contributed to more purposeful engagement during classroom discussions and problem-solving activities.

The findings further suggest that learning resources and clearly articulated learning goals functioned as important supporting conditions that enhanced the effectiveness of mathematical conversations. By providing opportunities for exploration, reflection, and collaborative reasoning, these conditions strengthened students' participation in the Conversation Hub and facilitated the gradual development of deeper conceptual understanding. Consequently, although these factors did not directly determine students' learning approaches, they created learning environments that supported meaningful engagement with mathematical ideas and promoted the transition from surface-oriented learning toward deep learning.

The Emerging Theoretical Explanation

The findings of this study culminated in the development of the Conversation Hub, an emerging theoretical model that explains how Grade 12 students progressively transitioned from surface-oriented learning toward deep learning in mathematics classrooms. Rather than viewing this transition as a linear cognitive process, the model demonstrates that conceptual understanding developed through continuous interactions among students during classroom discussions, collaborative problem-solving activities, and opportunities to explain and justify mathematical reasoning. These interactions enabled students to question existing ideas, negotiate meaning, and gradually reconstruct their understanding of mathematical concepts.

The emerging theoretical model further indicates that the transition toward deep learning was influenced by the interaction of several interconnected categories. Prior mathematical knowledge provided the conceptual foundation for new learning, while collaborative mathematical learning created opportunities for students to exchange ideas and evaluate alternative solution strategies. The application of mathematics in authentic contexts strengthened students' ability to transfer conceptual understanding beyond classroom activities, whereas appropriate learning resources and clearly defined learning objectives created conditions that supported meaningful engagement with mathematical ideas. Rather than functioning independently, these categories interacted dynamically through the Conversation Hub, which facilitated the continuous construction and refinement of conceptual understanding.

The Conversation Hub therefore represents the central mechanism through which students transformed their approaches to learning mathematics. Through mathematical conversations, learners became increasingly capable of integrating prior knowledge, articulating mathematical reasoning, evaluating multiple perspectives, and applying conceptual understanding to unfamiliar situations. This process reflects a gradual progression from memorization and procedural performance toward reflective, collaborative, and conceptually oriented learning.

Overall, the emerging theoretical model suggests that deep learning is not achieved solely through individual cognitive effort but develops through socially mediated interactions that encourage students to construct mathematical meaning actively. The Conversation Hub therefore provides a substantive theoretical explanation of how classroom interactions support students' transition from surface-oriented learning toward deep learning and serves as the principal theoretical contribution of this study.

DISCUSSION

Mathematical Conversations as the Core Mechanism for Deep Learning

The findings of the present study demonstrate that mathematical conversations constitute the central mechanism through which Grade 12 students progressively transition from surface-oriented learning toward deep learning. Unlike traditional perspectives that primarily emphasize individual cognitive processes, the emerging theoretical model developed in this study suggests that conceptual understanding is constructed through continuous interaction, collaborative reasoning, and shared mathematical dialogue. The Conversation Hub identified in this study represents the central process through which students externalize their thinking, question alternative perspectives, negotiate mathematical meaning, and gradually reconstruct conceptual understanding.

These findings are consistent with social constructivist perspectives, which argue that meaningful learning develops through collaborative interaction and shared knowledge construction rather than through individual knowledge acquisition alone (Hesse et al., 2014);(Sawyer, 2005). Classroom dialogue provides opportunities for learners to articulate mathematical reasoning, receive immediate feedback, and refine their conceptual understanding through collaborative engagement. Likewise, previous studies have emphasized that deep learning is strengthened when students actively participate in collaborative learning environments that encourage inquiry, reflection, and meaningful knowledge construction (Dolmans et al., 2016);(Perrotta & Selwyn, 2020).

An important contribution of the present study is the identification of the Conversation Hub as the core category emerging from students' learning experiences. While previous studies have acknowledged the educational value of classroom discussion and collaborative learning, they have generally examined these elements as separate instructional approaches. In contrast, the present study conceptualizes mathematical conversations as the integrative process through which prior mathematical knowledge, collaborative learning, conceptual understanding, learning resources, and knowledge application interact dynamically to facilitate students' progression toward deep learning. This perspective extends existing research by providing a substantive theoretical explanation of how deep learning develops through authentic mathematical interactions.

Deep Learning as a Socially Constructed Process

The findings of this study suggest that the transition from surface-oriented learning toward deep learning should not be understood solely as an individual cognitive process but rather as a socially constructed learning experience. The emerging theoretical model demonstrates that students developed conceptual understanding through continuous interaction with their peers, where mathematical ideas were questioned, refined, and reconstructed through discussion. This finding supports the view that knowledge is actively constructed through social participation and collaborative engagement rather than being transmitted directly from teacher to student (Charmaz, 2014);(Sawyer, 2005).

The present findings also reinforce previous research indicating that deep learning develops when students actively participate in learning environments that encourage reflection, reasoning, and collaborative problem-solving (Dinsmore & Alexander, 2012);(Dolmans et al., 2016). However, unlike earlier studies that primarily examined deep learning as an individual learning approach or instructional outcome, the present study demonstrates that students' movement toward deep learning emerged through an ongoing process of collaborative meaning-making. Within this process, mathematical conversations enabled learners to externalize their thinking, negotiate conceptual understanding, and progressively reconstruct mathematical knowledge through interaction with others.

An important distinction emerging from this study is that the Conversation Hub functions not merely as a pedagogical strategy but as the central mechanism through which the various dimensions of learning become interconnected. Prior mathematical knowledge, collaborative learning experiences, conceptual understanding, learning resources, and knowledge application were not isolated factors; instead, they interacted dynamically through mathematical conversations that supported students' conceptual development. This finding provides a more integrated explanation of deep learning than models that primarily focus on individual cognitive characteristics or instructional techniques.

These findings therefore contribute to the growing body of research on mathematics education by proposing that deep learning should be understood as a dynamic and socially mediated process. Rather than emphasizing memorization or procedural performance, the emerging theoretical model highlights dialogue, collaboration, and shared reasoning as the mechanisms through which students gradually develop meaningful conceptual understanding. Consequently, the Conversation Hub offers a substantive theoretical explanation that complements existing perspectives on deep learning while extending current understanding of how conceptual learning develops in secondary mathematics classrooms.

Educational Implications for Mathematics Teaching

The findings of this study have important implications for mathematics teaching, particularly in supporting students' transition from surface-oriented learning toward deep learning. The emerging theoretical model suggests that meaningful mathematical understanding is more likely to develop when classroom instruction provides opportunities for students to participate actively in mathematical conversations rather than relying primarily on teacher-centered explanations or procedural practice. Learning environments that encourage students to explain their reasoning, justify solution strategies, and evaluate alternative perspectives can promote deeper conceptual engagement and strengthen mathematical understanding (Dolmans et al., 2016;Hattie, 2009).

The present findings also suggest that mathematics instruction should create opportunities for collaborative problem-solving in which students are encouraged to construct knowledge collectively through dialogue and reflection. Rather than emphasizing memorization and routine procedural exercises alone, teachers should design learning experiences that allow students to connect new mathematical concepts with their prior knowledge, discuss multiple solution strategies, and apply mathematical reasoning to authentic contexts. Such learning experiences create conditions that enable students to develop conceptual understanding while strengthening communication, collaboration, and critical thinking skills (Perrotta & Selwyn, 2020; OECD, 2019).

Furthermore, the Conversation Hub provides a practical framework that can guide teachers in organizing classroom interactions to support meaningful learning. By facilitating structured mathematical discussions, encouraging peer explanations, and providing opportunities for reflective reasoning, teachers can foster learning environments that promote students' active participation, conceptual growth, and mathematical reasoning (Boaler, 2016; Hesse et al., 2014). These findings therefore suggest that classroom dialogue should be viewed not merely as a supplementary instructional activity but as an essential component of effective mathematics instruction that supports students' progression toward deep learning.

Theoretical Contribution of the Conversation Hub

The principal theoretical contribution of this study lies in the development of the Conversation Hub as a substantive theoretical explanation of how students progressively transition from surface-oriented learning toward deep learning in mathematics classrooms. While previous research has emphasized the importance of prior knowledge, collaborative learning, conceptual understanding, and classroom discussion, these elements have generally been investigated as separate constructs or instructional strategies. The present study integrates these dimensions into a coherent theoretical model, demonstrating that their educational value emerges through continuous mathematical conversations that facilitate conceptual understanding and collaborative meaning-making.

Unlike existing perspectives that primarily conceptualize deep learning as an individual learning approach or as the outcome of effective instructional practices, the Conversation Hub positions mathematical conversations as the central mechanism through which learning develops. Through sustained dialogue, collaborative reasoning, reflection, and shared problem-solving, students progressively reconstruct their mathematical understanding while negotiating meaning with others. This interpretation is consistent with sociocultural perspectives that view learning as a communicative and socially mediated process while extending existing research by providing a substantive explanation of how these interactions collectively support deep learning (Charmaz, 2014); (Mercer, 2000);(Sfard, 2008).

The emerging theoretical model also contributes to mathematics education by providing an integrated framework that explains how multiple dimensions of learning become interconnected during authentic classroom practice. Rather than treating prior mathematical knowledge, conceptual understanding, collaborative learning, learning resources, and knowledge application as isolated constructs, the Conversation Hub demonstrates how these dimensions continuously interact through mathematical discourse to support students' progression toward deep learning. This integrated perspective complements previous sociocultural and constructivist perspectives on mathematics learning by emphasizing the central role of communication in conceptual development (Cobb & Yackel, 1996; Wenger, 1998).

Finally, the Conversation Hub offers a useful theoretical lens for future qualitative research investigating students' conceptual learning across different educational contexts. Future studies may examine the applicability of this emerging theoretical model in different grade levels, mathematical topics, and cultural settings, thereby refining and extending the substantive theory developed in the present study.

CONCLUSION

This study explored how Grade 12 students experience the transition from surface-oriented learning toward deep learning in mathematics classrooms using a Constructivist Grounded Theory approach. The findings demonstrate that students' conceptual understanding develops through a dynamic process of interaction rather than through individual cognitive effort alone. The emerging theoretical model identified mathematical conversations as the central mechanism through which students collaboratively construct understanding, negotiate mathematical meaning, and progressively develop deeper conceptual engagement. This process was conceptualized as the Conversation Hub, representing the core category that integrates prior mathematical knowledge, collaborative learning, conceptual understanding, learning resources, and knowledge application into a coherent explanation of students' learning experiences.

The study contributes to mathematics education by providing a substantive theoretical explanation of how deep learning develops through authentic classroom interactions. Unlike previous studies that have typically examined collaborative learning, conceptual understanding, or classroom discussion as separate instructional components, the present study demonstrates how these dimensions interact continuously through mathematical conversations to facilitate students' progression toward deep learning. The Conversation Hub therefore offers both a theoretical framework for understanding conceptual learning and a practical perspective for designing mathematics classrooms that promote meaningful dialogue, collaborative reasoning, and reflective thinking.

This study has several limitations. The substantive theory was developed from participants in a specific educational context and is therefore not intended for broad statistical generalization. Instead, its value lies in providing an in-depth explanation of the learning processes participants experience. Future research may examine the applicability of the Conversation Hub across different educational levels, mathematical topics, cultural contexts, and instructional settings to refine further and extend the emerging theoretical model.

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Declarations

Author Contribution Statement

Bora Phan: Conceptualization and study design, methodology, data collection, data analysis and interpretation, and drafting the original manuscript.

Gema Hista Medika: Manuscript revision, response to reviewers, critical revision, language editing, and final preparation of the manuscript.

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The data generated and/or analyzed during this study are available from the corresponding author upon reasonable request. Access to the data may be restricted to protect participants' confidentiality and privacy.

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The authors declare no competing interests.

AI Use Statement

[1] During the preparation of this manuscript, the authors used **ChatGPT (GPT-5.5, OpenAI)** for language editing (grammar, clarity, and readability). The authors reviewed, revised, and verified the final text and take full responsibility for the content of the publication.

[2] During the preparation of this manuscript, the authors also used ChatGPT **(GPT-5.5, OpenAI)** to support the drafting and structuring of parts of the manuscript. All AI-assisted outputs were critically reviewed, rewritten where necessary, and verified against the study data and cited sources. The authors remain fully accountable for the accuracy, originality, and integrity of the manuscript.

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