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Article abstract

Research in science education has established the significance of collaborative concept mapping as a powerful strategy in fostering conceptual learning. During such collaboration, students talk about concept map features (i.e., concepts to include, linking words, and cross-links) in constructing a joint map. The quality of the concept map produced depends on the nature of discourses that happen in these collaborative interactions. We explored the nature of discourses between pairs of biology students collaborating on concept mapping and how these discourses contribute to the enhancement of different features of the concept maps. Six students individually constructed weekly individual maps on different topics and then came together in pairs to construct a joint concept map. Their discussions during collaboration were audio-recorded. Both the individual and joint concept maps were analyzed for knowledge of breadth, knowledge of depth, and knowledge of connectedness. To analyze the discussions and understand the nature of the discourses, both deductive and inductive coding approaches were used. The coded episodes were then categorised into the nine discourse patterns identified by Fu et al. (2016). We then matched the episodes with the concept map features that were discussed. Findings indicate that the biology students' collaboration exhibited mostly knowledge-sharing discourses when deliberating on the three features of a concept map. In turn, the number of valid concepts and propositions improved from individual to joint maps. Although the students' discussions of cross-links were characterized by knowledge-sharing discourses, most of the joint maps did not show improvement in terms of the number cross-links. We discuss these findings and provide implications regarding the value of understanding the intricacies of discourse patterns in collaborative concept mapping.

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Collaborative Concept Mapping: Investigating the Nature of Discourse Patterns and Features of a Concept Map

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Research in science education has established the significance of collaborative concept mapping as a powerful strategy in fostering conceptual learning. During such collaboration, students talk about concept map features (i.e., concepts to include, linking words, and cross-links) in constructing a joint map. The quality of the concept map produced depends on the nature of discourses that happen in these collaborative interactions. We explored the nature of discourses between pairs of biology students collaborating on concept mapping and how these discourses contribute to the enhancement of different features of the concept maps. Six students individually constructed weekly individual maps on different topics and then came together in pairs to construct a joint concept map. Their discussions during collaboration were audio-recorded. Both the individual and joint concept maps were analyzed for knowledge of breadth, knowledge of depth, and knowledge of connectedness. To analyze the discussions and understand the nature of the discourses, both deductive and inductive coding approaches were used. The coded episodes were then categorised into the nine discourse patterns identified by Fu et al. (2016). We then matched the episodes with the concept map features that were discussed. Findings indicate that the biology students' collaboration exhibited mostly knowledge-sharing discourses when deliberating on the three features of a concept map. In turn, the number of valid concepts and propositions improved from individual to joint maps. Although the students' discussions of cross-links were characterized by knowledge-sharing discourses, most of the joint maps did not show improvement in terms of the number cross-links. We discuss these findings and provide implications regarding the value of understanding the intricacies of discourse patterns in collaborative concept mapping.

La recherche dans le domaine de l'enseignement des sciences a établi l'importance de la cartographie conceptuelle collaborative en tant que stratégie puissante pour favoriser l'apprentissage conceptuel. Au cours de cette collaboration, les élèves discutent des caractéristiques de la carte conceptuelle (c'est-à-dire des concepts à inclure, des mots de liaison et des liens croisés) pour construire une carte commune. La qualité de la carte conceptuelle produite dépend de la nature des discours tenus lors de ces interactions collaboratives. Nous avons exploré la nature des discours entre des paires d'étudiants en biologie collaborant sur la cartographie conceptuelle et la façon dont ces discours contribuent à l'amélioration des différentes caractéristiques des cartes conceptuelles. Six étudiants ont construit individuellement des cartes hebdomadaires sur différents sujets et se sont ensuite réunis par paires pour construire une carte conceptuelle commune. Leurs discussions pendant la collaboration ont été enregistrées. Les cartes conceptuelles individuelles et communes ont été analysées du point de vue de la connaissance de l'étendue, de la connaissance de la profondeur et de la connaissance de la

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connexité. Pour analyser les discussions et comprendre la nature des discours, des approches de codage à la fois déductives et inductives ont été utilisées. Les épisodes codés ont ensuite été classés dans les neuf modèles de discours identifiés par Fu et al. (2016). Nous avons ensuite mis en correspondance les épisodes avec les caractéristiques de la carte conceptuelle qui ont été discutées. Les résultats indiquent que la collaboration des étudiants en biologie présentait principalement des discours de partage des connaissances lorsqu'ils délibéraient sur les trois caractéristiques d'une carte conceptuelle. Par ailleurs, le nombre de concepts et de propositions valides s'est amélioré entre les cartes individuelles et les cartes communes. Bien que les discussions des étudiants sur les liens croisés aient été caractérisées par des discours de partage des connaissances, la plupart des cartes conjointes n'ont pas montré d'amélioration en termes de nombre de liens croisés. Nous discutons de ces résultats et fournissons des implications concernant la valeur de la compréhension des subtilités des modèles de discours dans la cartographie conceptuelle collaborative.

Concept maps (CMs) are described as graphical tools usually used to organize knowledge (Novak & Cañas, 2008). Features of a CM include concepts that are usually enclosed in circles or boxes. These concepts are usually presented in hierarchical levels where the main concepts are presented first, then followed by the subordinate concepts and examples. Between the concepts of the same hierarchical level, there are lines with phrases that represent links. When two concepts are linked to each other using linking words, what is formed is a proposition (Novak & Cañas, 2008). Another important feature of a CM is cross-links that link concepts from different hierarchies. This feature is usually difficult to do as it reveals the conceptual complexity of knowledge and requires one to have a conceptual network (Bramwell-Lalora & Rainford, 2013; de Ries et al., 2022). Given that students must show links between concepts, CMs can reveal students' ways of working with knowledge; accordingly, they are a well-known learning tool in science education (Chen et al., 2018; Stevenson et al., 2017). When constructing CMs, students are either provided with a list of concepts or they must come up with their own (Cañas et al., 2013; Ruiz-Primo, 2000). The latter is called open concept mapping. There is evidence that supports the use of open concept mapping as an enabler of meaningful learning in science (Akcay, 2017; de Ries et al., 2022). This is because during open concept mapping students are tasked with coming up with concepts and differentiating subordinate concepts from main concepts and deciding on the relationships between these concepts. This kind of an exercise can, therefore, promote knowledge construction and building (de Ries et al., 2022). Because CMs can demonstrate knowledge building and construction, teachers have been using concept mapping as an approach to enhance meaningful learning and student understanding (Carr-Lopez et al., 2014; Kinchin, 2014). Although students can construct CMs individually, literature also supports collaborative concept mapping as an effective approach for students to discuss concepts for this knowledge construction (see for example Mochado & Carvalho, 2020; Tan et al., 2021). During collaboration, students can discuss their choice of concepts and their relationships in a given topic (Gijlers & de Jong, 2013; Kwon & Cifuentes, 2009, van Boxtel et al., 2002). These discussions can take many forms where students just agree with each other without cognitively engaging with the concept mapping. Studies have investigated interactions between students during collaborative concept mapping reporting on a variety of findings. For example, although Van Boxtel et al. (2002) found that students engaged in constructed reasoning during collaborative concept mapping, Chang et al. (2003) observed that only one member of the group reasoned while others tended to agree or disagree. Although studies support collaborative concept mapping, there is still a lack of studies that closely look into the interactions to characterise the discourses and how they lead to the improvement of CMs. In this study, we view this improvement in terms of the features of a CM described above. These features are concepts, propositions, and cross-links. This study contributes to the existing literature in the sense that we looked at individual features of CMs instead of the overall concept map improvement only as previously studied (e.g., Chen et al., 2018; Govendor, 2015). Specifically, we explored the nature of discourses between pairs of biology students collaborating on concept mapping and how these discourses contribute (if at all) to the enhancement of different features of the CMs. The following research questions guided this study:

- How do the biology students' individual and collaborative concept maps compare?
- What is the nature of discourse patterns in biology student collaboration during concept mapping?
- How do these discourses (if at all) contribute to the improvement of the concept map features?

Literature Review

Concept Mapping

The use of CMs in education dates back to the 1970s when Novak used concept mapping to track children's learning of science (Novak & Musonda, 1991). Since then, CMs have been used as teaching and learning tools to develop students' conceptual understanding, especially in science classrooms. According to Gurlitt and Renkl (2008), "concept maps provide an external network-like representation of knowledge structures" (p. 409); thus, by constructing CMs, science students can develop a holistic understanding of the content which might not be possible by reading only text. In support of this, Awofala (2011) found that concept mapping combines visual learning with the spatial representation of information to promote meaningful conceptual learning. Students can engage in traditional concept mapping (using pen and paper), or computer/web-based methods. Literature supports both approaches to student learning and map structuring (Mammen, 2016). Scholars in science education have investigated the use of CMs at the school level (see for example, Choudhary & Bano, 2022; Dhull & Verma, 2020) and higher education levels (e.g., Govendor, 2015; Kinchin, 2014). Choudhary and Bano (2022) worked with biology students and found that concept mapping improved students' learning of biology concepts. Udeani & Okafor (2012) illustrated that concept mapping can improve student understanding of biology concepts. By studying physics student teachers' CMs, Govendor (2015) concluded that concept mapping can be used as an activity to develop student teachers' content knowledge, especially when done collaboratively. These studies indicate that concept mapping can indeed improve student learning of science. Our interest was on the nature of discourse during the collaboration which can be illuminated by an extended restructuring of the map.

Collaborative concept mapping has many benefits. Firstly, it fosters student interaction and collaborative learning (Chen et al., 2018; Pudelko et al., 2012). In particular, when students first construct a CM individually and then do it collaboratively, there are high possibilities that the map produced after collaboration will improve (Riahi & Pourdana, 2017; Tan et al., 2021). This is because, during collaboration, students become aware of their peers' knowledge and gain other perspectives of representing knowledge (Engelmann et al., 2010). However, what is not clear in the literature is the kinds of discussions that lead to gaining of other peers' perspectives leading to the improvement of certain concept map features. As argued by Van Boxtel et al. (2002), it is in the discussions where students share the concepts they can use and the amending of the links that make propositions. Secondly, it promotes metacognition and shared awareness between students. In this way, students can draw from previous knowledge as well as self-assessing development (Gurlitt and Renkl, 2010). However, the way in which students draw from prior knowledge depends on the level of cooperation between the students and the kind of discourses that take place during the collaborative interactions (Van Boxtel et al, 2002). Hence, in this study, we aimed to characterize the kinds of discourses that support the improvement of specific features of a CM.

Student Talk and Discourses During Collaboration

There is no doubt that in collaborative spaces, how students communicate contributes to certain discourses. These discourses support learning (Fu et al., 2016). The term *discourse* refers to ways in which people communicate in interactional contexts. This includes their use of language and how they convey ideas and meaning (Kelly, 2015). Previous research in science education looked at different ways that can be used to characterize student talk and discourses in collaborative spaces like whole-class discussions (e.g., Hardman, 2020) and group discussions (e.g., Kittleson & Southerland, 2004). This specific study is positioned in the context where two students interact while constructing their joint CMs drawing from their individually constructed maps. A recent study by Fu et al. (2016) investigated how students were engaging in asynchronous online discussions and then classified the discourse patterns. Their study identified nine discourse patterns within three modes of discourse. We assumed that their framework could be applied to face-to-face collaborations between students to offer insights regarding student discourse patterns when constructing CMs. Table 1 summarises these discourse patterns.

Table 1

The Discourse Patterns Identified by Fu et al. (2016)

Mode of discourse	Discourse pattern	Description
Knowledge sharing	Fact-orientated (FO)	Asking fact-oriented questions and sharing factual information
	Cumulative (Cu)	The focus is on confirmation and repetition, and conflicting ideas being ignored and assimilated
	Repetitive (Rp)	Students merely respond to each other with no intensive interactions
	Simple argumentation (SA)	Students defend their positions with no rebuttals
	Disputation (Disp)	Students try to find out who is wrong and right and why.
Knowledge construction	Explanatory & problem-centred inquiry (EPCI)	Students pose problems and view ideas as worthy of further exploration
	Complex argumentation (CA)	Argumentations that include rebuttals
Knowledge building	Progressive inquiry	Students engage in deepening explanation and emerging questions for continual idea improvement; problem analysis and transfer
	Sustained discourse for community advance	Contributing to high-level ideas and problems producing knowledge that is relevant to the community members

As can be seen in Table 1, there are three modes of discourse. The first is knowledge sharing, where the discourse pattern is characterized by simple question-and-answer and sharing of information. However, reasoning can be there in this discourse mode. For example, in simple argumentation, a student must provide reasons for their claims. This mode is aligned with the informative, elicitative, and imperative communicative functions according to Erkens and Janssen's (2008) dialogue act system. The second mode of discourse is knowledge construction, where students work towards the construction of knowledge. This is aligned with the argumentative and responsive communicative functions of Erkens and Janssen's (2008) dialogue act system. The third is knowledge building, which is about sustained inquiry where ideas are improved for community advancement. Although Fu et al.'s (2016) characterization of discourses was in an online space, in this study, we envisaged that the discussions of each pair would exhibit some of these discourses to advance their concept mapping. In this study, we drew from the first two modes of discourse. We did not investigate the third mode because it is outside the scope of study.

Theoretical Framework

Collaboration is often associated with the construction of knowledge where two or more people come together to make meaning of something (Dillenbourg, 1999). In this study, we draw from the socioconstructivist theory of Vygotsky (1978). From this theory, we are drawing from the tenet that learning is socially mediated and that learning takes place in collaborative spaces. Collaboration fosters peer-to-peer learning and students' cognitive development (Erbil, 2020). In essence, Vygotsky stresses that meaningful learning cannot be separated from social contexts. An implication here is that the students need to be tasked in ways that allow them to work together to produce a final project through creating a collaborative community of learners. In these interactions, Vygotsky supports the use of dialogue to improve students' ability to construct knowledge and gain content understanding. According to Vygotsky (1978), when students are given a task and provided with a space to collaborate, learning takes place. Collaboration also allows shared cognition as students assist each other in completing the task at hand. In this study, the task for the students is to construct a joint concept map that emerges from collaboration. The socioconstructivist theory stresses that it is through the interactions that take place within the setting that learning occurs. According to Alexopoulou and Driver (1996), collaborative learning activities can engage students' participation, and interaction, working together toward a common academic goal and increasing the level of satisfaction and feelings of connection and community.

Research Design and Methodology

This was a qualitative study positioned within the interpretivism paradigm (Cresswell, 2012). In the interpretivist paradigm, knowledge is relative to individuals and can be gathered by engaging with the participants (Kivunja & Kuyini, 2017). Therefore, the researchers need to understand the uniqueness of the context to understand the phenomenon studied (collaborative concept mapping in this context). The qualitative study allowed us to understand the nature of discourses during student collaborative concept mapping. We used a case study design (Hancock, 2002). The case was third-year Life Sciences student teachers.

Context and Participants

The participants were six student teachers who were part of a semester-long Bachelor of Education biology content course at a South African university. There were six students registered in this course. Upon invitation, all the students agreed to participate in the study. In this university, the Life Sciences student teachers complete their main content course with the Bachelor of Science students in the science faculty. The course in which this study took place is offered in the third year in the faculty of education. The course is designed to bridge the gap between the content they did in the science faculty and what is taught in schools. A full description of this context is found in Khoza (2022). The lecturer of this course saw concept mapping as a technique that can be used for the student to learn the biology content knowledge found in the school curriculum. In the first quarter of the semester, the students were taught how to construct a concept map. In the lesson, features of a good CM were included. In addition to the hierarchical structure of CMs, students were taught that a good CM includes concepts that are circled and arrows pointing in the right direction with linking words between concepts to form propositions. The students were also told that concepts should not be included as linking words. The student teachers further constructed CMs on a continuous basis for the topics that were covered in the first quarter which is seven weeks long. We, therefore, assumed that the students had the skills to construct concept maps prior to data collection.

Data Collection

Data was collected through hand-constructed concept maps and audio recordings of the discussions that took place when the biology students collaborated towards constructing a joint CM in pairs. The data collection phase took place in the second quarter of the module. The students had to construct concept maps based on the topics of the nervous system (CM1), the human eye (CM2), the human ear (CM3), and population ecology (CM4). The student teachers were requested to construct CMs individually on a specific topic before it was covered in lecture. To create the CMs, students had to confine the content to what was appropriate for high school students. As such, they were responsible for reading high school biology curriculum documents and corresponding textbooks. The students then came to class with their individual CMs as a basis for their collaboration in pairs. It is important to note that the students were not provided with concepts that they needed to use to construct the map, thus, these were open CMs (see Cañas et al., 2013). In the end, we had 24 individual CMs (four per topic) to analyze. In class, the students discussed their CMs in pairs while constructing joint maps. There were three pairs of students: Paris and Meyron (Pair A), Rage and Nolly (Pair B), and Unathi and Lufuno (Pair C). The discussions between the six students were audio recorded and transcribed verbatim. There were 12 joint CMs produced altogether as well as 12 audio recordings (three per topic) of the discussions that occurred during collaboration which were also analyzed. The duration of these recordings was between 28 and 38 minutes.

Ethical Considerations

Ethical clearance was granted by the University of Pretoria, Faculty of Education Ethics Committee. The data used in this study was collected from participants who gave their consent to participate in this study.

Data Analysis

The purpose of this study was to understand student discourse during collaborative concept mapping and how these discourses enhance different CM features. We, therefore, had to analyse both the CMs and the discussion transcripts. The analysis procedure is described below.

Analysis of Concept Maps

To analyse the concept maps, we drew on the traditional approach to scoring developed by Novak and Gowin (1984). The traditional scoring has three features used to quantify the number of components in the concept maps: knowledge breadth, knowledge depth, and knowledge of connectedness. For the knowledge breadth component, we counted the number of concepts that were included in the concept map. In addition to the traditional scoring method, which does not generally consider the quality or correctness of the concepts, we included a measure of correctness by determining how many of the concepts were correctly identified as being associated with the topic. Furthermore, since the CMs were to be developed using the high school biology content, concepts that did not fall within the scope of the topic according to the curriculum were deemed irrelevant, thus incorrect in this case. For the knowledge depth component, we counted the number of valid propositions for each hierarchical level. A proposition in a concept map is shown by drawing a line between two concepts and describing the relationship with linking words. For connectedness, we counted the number of valid cross-links between two concepts that were not from the same hierarchical line (Cañas et al., 2013). To be considered valid, the propositions and cross-links needed to include linking words to connect the two concepts, but the scientific correctness of the linking words was not evaluated. Propositions and cross-links that included linking words composed of concepts that were already identified were considered invalid because concepts can only be included in circles and the linking words should be phrases that describe the connection between two concepts. Since some concept maps were “messy,” instead of coding on the maps like Kaseke and Nyamupangedengu (2019) did, we opted to extract the information and score it on a table (see Table 2). We first needed to identify the hierarchies so that the cross-links could be clear. In cases where there would be another line of hierarchy stemming from the main hierarchy, this line was considered a part of the main hierarchy. Figure 1 is a section of a student’s individual CM.

Figure 1 offers an example of a CM constructed by one of the participants. In Table 2, we illustrate the scoring process we used on the CM pictured in Figure 1.

In terms of the identified propositions, 11 were identified from the map and nine were valid. In terms of the concepts, we identified 22 concepts, and all were correct. In terms of the cross-links, only one was identified. Although correct, it is invalid because the link uses two concepts which are also identified as concepts in the map. To improve the validity of the scoring, the two authors independently scored the first two individual maps and discussed the scores. Since scoring concept maps requires an understanding of content knowledge, the first author acted as an expert: he is in biology education and used concept mapping as a data collection strategy in his PhD. It is important to note that we scored the concept maps to see the overall scores of individual and joint CM features.

Analysis of the Discussions in Pairs

To analyse the discussions and understand the nature of the discourses, we utilized both deductive and inductive approaches. Inductively, we coded the students' moves based on what the utterances were showing us (see the assigned codes Table 3 for examples). Based on the coding of specific student utterances, we then deductively categorised the discourses into the nine discourse patterns identified by Fu et al. (2016).
In the above-coded example, the prevailing discourse is that of knowledge sharing and simple argumentation with repetitions. We then matched the episodes during collaboration with the CM features that were discussed. An episode in this case was determined by looking at the prevailing point of discussion. For example, the students would discuss how to arrange concepts and then move to a discussion on linking words. In doing this, the challenge was that the students' interaction would display a certain discourse as they decide on concepts yet aspects of discussing linking words (and propositions) would emerge. In such cases, the episode was matched with the CM feature that prevailed in the discussion.

Results From Scoring the Concept Maps

Table 4 shows the results of scoring the students' CMs. For each CM, there are two rows. The first row of figures shows scores for individual CMs. The second row shows the scores for joint CMs.

Figure 1

An Example of How We Scored the Concept Maps

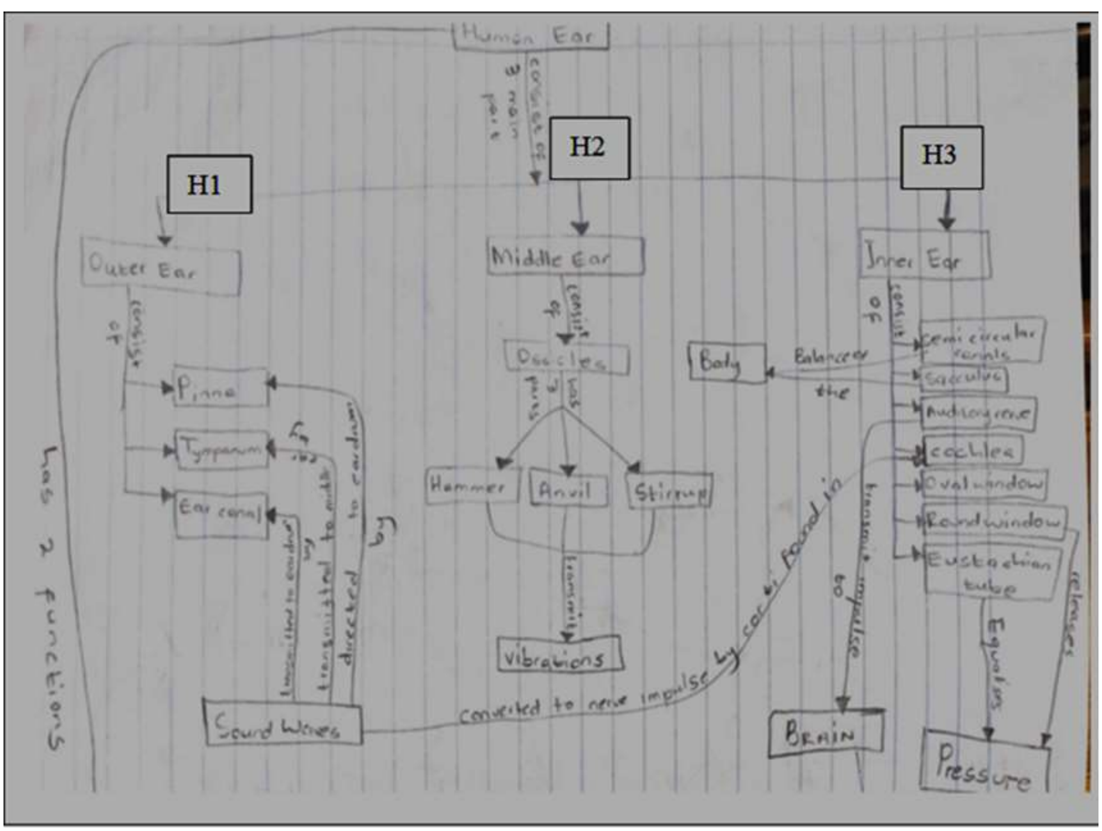

Table 2

Results of Scoring the Concept Map in Figure 1

	Description and scores
Identified hierarchies and propositions	3 hierarchical lines identified H1 linking words and propositions • Outer ear *consists of* pinna, tympanum, and ear canal **(valid)** • Sound waves *are transmitted to eardrum* ear canal ***(invalid: eardrum is a common name for tympanic membrane. So the same concept is used as both a concept and linking word)*** • Sound waves *directed to eardrum by* pinna ***(invalid - eardrum is a tympanic membrane—used as both a concept and linking word)*** H2 linking words and propositions • Middle ear *consists of* ossicles ***(valid)*** • Ossicles *have 3 parts:* hammer, anvil and stirrup ***(valid)*** • Hammer, anvil, and stirrup *transmit* vibrations ***(valid)*** H3 linking words and propositions • Inner ear *consists of* semicircular canals, sacculus, auditory nerve, cochlear, oval window, round window, eustachian tube ***(valid)*** • round window *releases* pressure ***(valid)*** • eustachian tube *equalises* pressure ***(valid)*** • auditory nerve *transmit* impulse to brain ***(all valid)***
Concepts	22 concepts identified and all the 22 are correct, relevant concepts: outer ear, inner ear, inner ear, pinna, tympanum, ear canal, sound waves, middle ear, ossicles, hammer, anvil, stirrup, vibrations, inner ear, semi-circular canal, saccule, auditory nerve, eustachian tube, round window, pressure, brain, body.
Cross-links	1 cross-link identified Sound waves *converted to nerve impulse by corti found in* cochlea ***(invalid—two concepts are used as linking words)***

In each cell, there are two figures, the first figure reveals, for example, the overall number of concepts for that CM and the second figure reveals the number of correct concepts.

From Table 4, in terms of the concepts, most individual CMs had many concepts, most were correct, especially from CM2. For example, in CM2, Meyron had 46 concepts and 41 of those concepts were correct (see A2). Nolly also identified 39 concepts in CM4 and 34 were correct (see B4). There were, however, exceptions where a student would identify many concepts and more than half of those would be incorrect (3 out of 24 cases). For example, Unathi's CM2 had 42 concepts and only 19 were valid (see C2) and Rage's CM1 had 61 concepts and only 21 were correct (see B1). Although this is the case with the individual CMs, the joint CMs reveal fewer concepts with less variance between the overall number of concepts and correct concepts. In other words, when the students did the CMs collaboratively they came up with fewer concepts than those that they had in their individual CMs. This is true for all the joint maps except for

Pair C CM1 (see C1). Furthermore, all the joint CMs included fewer incorrect concepts. For

Table 3

An Example of How We Coded the Pairs' Discussions

Speaker	Utterance	Assigned code	Prevailing discourse pattern
Rage	So, I divided the ear into the inner ear, middle ear and outer ear as my main concepts. I had a confusion with the tympanic membrane …	Sharing information	Knowledge sharing
Nolly	Yes … I also did not know where to put it, in the outer ear and inner ear.	Sharing information (supporting partner)	
Rage	Yah, I checked different textbooks, and some say middle and some say outer and went with the majority	Sharing information	
Nolly	And the majority is middle?	Seeking confirmation	
Rage	They say it is part of the middle ear	Sharing information	
Nolly	Yah … you know, I just took it as part of ossicles and said their functions are more or less similar, so I went with the middle ear	Stating reasons (simple argumentation)	Simple argumentation
Rage	Ohhh yeah, since the ossicles are in the middle ear	Agreeing with the partner	
Nolly	Okay, I get you	Confirming	
Rage	Even the oval and round windows are also confusing. Some textbooks say it is middle and some say inner.	Stating information	Knowledge sharing

example, in CM4, the difference between the number of identified concepts and correct concepts is one for Pair B (see B4). Although the students did not necessarily identify new correct concepts, the collaboration helped students to identify incorrect concepts that they had included in their individual maps. We attribute this observation to certain discourses that took place during student collaboration as we will later describe.

In terms of the propositions, there was both a decrease (five of the CMs) and an increase in the total number of propositions (eight of the CMs) from the individual to joint CMs. Furthermore, the validity of propositions after the students' collaboration improved where the difference between the identified propositions and valid propositions was three at most. For example, Pair C's CM4 had 24 propositions and 23 were valid (see C8). Similarly, we attribute this improvement to the kinds of discourses that took place during the collaboration.

In terms of the cross-links, there were generally fewer cross-links across the individual and joint CMs. In several cases students had more cross-links in their joint CMs than either of the individual CMs (see B10, C10, B11, B12, C11, A12 and C12)—which is seven out of the 12 joint CMs. However, the validity of cross-links in these cross-links in joint CM was seen in two of the five maps (see A11 and A12). Again, we later link this observation with student discourses during interactions.

Table 4

The Results From Scoring CMs

			A		B		C	
			Pair A		Pair B		Pair C	
	Concept Map Feature	Concept Map	Paris	Meyron	Rage	Nolly	Unathi	Lufuno
1	Concepts	CM1	67, 40 27, 21	38, 34	61, 21 33, 29	43, 36	39, 16 43, 36	40, 38
2		CM2	43, 36 34, 33	46, 41	56, 47 41, 39	46, 44	42, 19 39, 34	51, 40
3		CM3	32, 28 22, 21	27, 22	36, 15 33, 32	40, 35	37, 30 34, 30	39, 34
4		CM4	53, 48 39, 37	46, 41	48, 36 35, 34	39, 34	53, 32 39, 36	47, 38
5	Propositions	CM1	21, 13 19, 16	17, 11	28, 10 21, 18	19, 16	15, 11 26, 24	24, 19
6		CM2	22, 16 18, 17	26, 21	25, 18 23, 21	26, 20	21, 18 24, 21	27, 20
7		CM3	21, 18 19, 16	20, 19	18, 16 21, 19	24, 18	17, 11 19, 18	20, 18
8		CM4	21, 19 18, 17	22, 19	15, 9 21, 18	18, 12	23, 14 24, 23	20, 18
9	Cross-links	CM1	0 1, 0	1, 0	0 1,1	1,1	1,0 0	0
10		CM2	2, 2 2, 2	3, 2	1,0 5, 1	2,1	1,1 3,1	1,0
11		CM3	2,2 4,3	4,3	1, 0 5,2	2,1	1,1 4,1	1, 0
12		CM4	3,2 7, 6	3,1	1,1 3, 2	2,1	1,0 2, 1	1,1

Results From Coding the Transcripts for Discourses

Table 5 shows the prevalence of episodes that are characterized by certain discourses and concept mapping features. Where there are two episodes of discourse and only one concept mapping aspect/task is given, it means the two episodes were about that one concept mapping task.

The prevailing discourses are those that are aimed at knowledge-sharing. Within the knowledge sharing discourses, cumulative, repetitive, simple argumentation, and disputation were the most common. Such discourses were prevalent when the students were discussing the concepts and linking words in propositions. Fewer episodes were characterised by knowledge construction discourse: the majority occurred when discussing cross-links on the map, except Pair B's CM1. We illustrate how such discourses unfolded in the section to follow.

Table 5

The Prevalence of Discourses During the Collaborations

Pair	CM	Discourses and aspects of the concept map discussed						
		Knowledge sharing					*Knowledge construction*	
		FO	*Cu*	*Rp*	*SA*	*Disp*	*EPCI*	*CA*
A	CM1	1: concepts	1: concepts	1: concepts	2: linking words	1: linking words		
	CM2		1: concepts	2: linking words, cross-links	2: concepts	1: concepts		
	CM3		2: concepts	2: concepts	1: linking words	2 concepts	1: cross-links	1: cross-links
	CM4		1: concepts	2: concepts, cross-links	2: linking words	2: linking words	1: cross-links	
B	CM1	1: concepts	1: concepts	1: linking words			1: concepts	
	CM2	1: concepts	1: concepts	1: concepts	2: linking words, cross-links	2: concepts, cross-links		
	CM3		2: concepts, cross-links	2: concepts, linking words	1: linking words	1: cross-links		
	CM4		2: concepts	2: concepts	2: linking-words			
C	CM1	1: concepts	1: concepts	2: linking words	2: concepts, linking words			
	CM2		2: concepts, cross-links	2: concepts, linking words	2: linking words	1: concepts		
	CM3	2: concepts, linking words	2: concepts	1: concepts	1: concepts	1: cross-links		
	CM4		2: concepts, linking words	1: concepts	2: concepts, linking words	2: concepts, cross-links		

Linking Discourses to the Concept Mapping Features: Concepts

Most of the identified episodes from the data were characterised by knowledge-sharing discourses, especially cumulative and repetitive patterns. These discourses were prevalent where the students were re-listing concepts and deciding on which specific concepts to include in their joint CMs. To illustrate this, we use three examples.

Example 1: Paris's and Meyron's CM4

This example comes from an interaction between Paris and Meyron during their construction of a joint CM4 about population ecology. In this conversation, Paris had just finished explaining her concept map and Meyron started the interaction by asking her why she had certain concepts in her individual map.

(1) Meyron:	I think some of these can be used as linking words, like, just from the top of my head, something includes components, includes components as your linking word.
(2) Paris:	Okay, I think I get you. So what do you suggest?
(3) Meyron:	Let us write our concepts down separately then we discuss them
	[After 7 minutes]
(4) Meyron:	I have population density, survivorship curve, and mortality (Lists all her concepts).
(5) Paris:	Okay, I have listed all the ones I have here (her CM).
(6) Meyron:	Let us start with yours (they start ticking which ones are relevant and which ones are not).
(7) Paris:	We put competition here…
(8) Mayron:	Okay, then have density this side.
(9) Paris:	And this side we put characteristics like dispersion.
(10) Meyron:	Should we include species?
(11) Paris:	Yes, it defines populations.

In the above extract, the students were in a knowledge-sharing discourse mode characterized by providing information to each other. After Meyron listed some of the concepts they could include in their CM, they wrote down all the population ecology concepts from their individual maps (see Line 3). After Line 3, the students spent another 10 minutes refining concepts from both their lists. This resulted in a discourse where they both suggested concepts and where their concepts could fit in the joint map, resembling a cumulative discourse (see Lines 4 to 11). The result of this episode is seen in Table 4 (A4) where the number of concepts in the joined map was reduced but the difference between the total number of concepts and the number of correct concepts was less. Spending time sharing knowledge and seeking clarity from each other, although without extensive reasoning, contributed to this improvement. An example of the removal of incorrect concepts occurred later in the same discussion.

Example 2: Paris and Meyron CM4

(1) Paris:	Why do you have genes as a concept here?
(2) Meyron:	Ohhh … is it not genes that affect populations?
(3) Paris:	Yeah, but not quite…unless you say variation.
(4) Meyron:	Did you have in your draft?
(5) Paris	No, but we can link variation to population density.
(6) Meyron:	Okay…I will put it here…

This discussion illustrates how the two students made decisions to remove an incorrect concept. Unlike the concept of variation, the concept of gene was considered to be incorrect in this case because it is not included as part of population ecology in the curriculum. As can be seen in Example 1 above, the discourse was still characterized by knowledge-sharing discourse with a bit of provision of reasons (see Line 3). The conversation would have been a problem-centred inquiry if the pairs would have explored why the concept of genes cannot be part of the CM. Instead, Meyron did not question Paris further.

Example 3: Rage and Nolly CM3

This example comes from Pair B (Nolly and Rage) when constructing the first joint CM on the topic of the nervous system. Just like Meyron and Paris's interaction shown above, Nolly also asked his partner how she selected her concepts.

(1) Nolly:	How did you go about deciding on the concepts? Like how do you describe the functions? How do you include the functions in your concept map?
(2) Rage:	So, for example, I will say "peripheral" consists of autonomic and somatic then from there, I know the meaning of somatic and I know the meaning of autonomic then that is when I will break down everything …
(3) Nolly:	But like, it does not explain the function. You are just defining the concept in a box that should have a concept. I mean the function …
(4) Rage:	I did state involuntary …
(5) Nolly:	You know, I struggled when doing mine because I think it is difficult, like the function of a receptor, sensory neuron, I struggled on how I was going to link everything.
(6) Rage:	My way is explaining everything …
(7) Nolly:	Yeah, you have the whole description in a box. Is that allowed? Are we allowed to have a full sentence?
(8) Rage:	I am not sure, but it says they are functions.
(9) Nolly	Even in point form, this is what I struggle with because I do not know whether I should make them linking words and all that. I decided to make the word impulse to be in a box then receptors to be linking words … in a way, that is a function of a receptor. So, what is in the box is impulse then "converts stimulus to" would be my linking word.
(10) Rage:	Oh yeah, you're right. This means I did not get it. maybe let us first write down the concepts and sort them out. It seems like most of mine are not concepts.

In the above extract, Nolly raises a question regarding how to condense and represent information on a CM. Rage provides her with information on how she did it (see Line 2). However, Nolly is not convinced since Rage did not understand the positioning of concepts and linking words in a CM. The discourse resembled in this extract is cumulative. Instead of Rage justifying enclosing statements as concepts, she reiterates her positioning. The expectation in such interactions is that Nolly would dominate the discussion and explain to Rage how it is done;

however, Nolly also shared his struggle of identifying concepts that relate to functions of certain structures (see Line 5). However, from analysis of her CM, Nolly had identified the concepts well (see B3 of Table 4). In fact, she constructed the concepts in ways that summarize the function of a certain structure. As shown in Line 10, Rage finally understood how to identify and/or construct concepts. This led to a further discussion where they both shared concepts from scratch in constructing the new CM. The results of this interaction are found in Table 4. Again, the cumulative discourse characterised by the sharing of information improved the number of correct concepts that were used to construct the joint CM.

Propositions

Analysis of the students' interaction transcripts reveals some aspects of argumentation and disputation between the students. Such discourses were prevalent when students mainly focused on linking the concepts. Below, we illustrate two examples of such instances. Example 1 is from Pair C and Example 2 is from Pair B.

Example 1: Lufuno's and Nathi's CM2

(1) Lufuno:	Where is the brain?
(2) Nathi:	Here it is…so the brain works with the retina.
(3) Lufuno:	You should have included the concept that comes from the retina to the brain.
(4) Nathi:	Huh?
(5) Lufuno:	You said retina and brain then you have an arrow going from brain to retina…why?
(6) Nathi:	The brain gets messages from the retina.
(7) Lufuno	Yes, I agree but why is the arrow going that side? [from the brain to the retina]
(8) Nathi	Oh, so I should change the arrow?
(9) Lufuno:	Do you get my point?
(10) Nathi:	I am not sure if I understand your point.
(11) Lufuno:	Okay, when you read in that direction, you say the brain sends messages to the retina. It is the other way around.
(12) Nathi:	Ohh yeah!
(13) Lufuno:	Yes, the impulses are coming from the retina then sent to the brain…so you can add impulses.
(14) Nathi:	I think we can also have optic nerves because…
(15) Lufuno:	Exactly, the optic nerve carries impulses from the brain. Let us put it like that in our concept map.

In this example, we see a simple argumentation episode characterised by the students providing reasons for their decisions to use certain linking words that form a proposition. Lufuno begins by asking Nathi a question regarding the concept of a brain. Although Lufuno's concern seems to be related to the inclusion of a concept, it was that of a linking word/proposition. This is because, in Line, 5, she asks Nathi why he has a proposition with an arrow going in a certain direction. Nathi's question was important as the direction of an arrow affects the proposition. In this case, the proposition was considered invalid even though the concepts were correct. Nathi's question led to an interaction where the students further refined their propositions. The number of valid propositions improved (see B7 in Table 4).

Example 2: Rage's and Nolly's CM1

Rage and Nolly were discussing the cross-links that they needed to put between concepts in their nervous system map. The following interaction took place.

(1) Nolly:	Now the next step is to think of linking words chomi [my friend]!
(2) Rage:	Maybe an arrow between a reflex action and a reflect arc?
(3) Nolly:	Yes, we say reflex action happens through a reflex arc.
(4) Rage:	Examples?
(5) Nolly:	We can take this down and write examples include ...
(6) Rage:	Then we have sympathetic this side ... how about a link between (inaudible)
(7) Nolly:	I don't think it will work.
(8) Rage:	Why? If we link the...
(9) Nolly:	Sympathetic is part of the peripheral nervous system. So this means we destroy the coherence this side.
(10) Rage:	Ohh yeah, let's deal with this side first.
(11) Nolly:	Uyabona manje ... [you see now], we need to move the spinal cord to this side.
(12) Rage:	And say what?
(13) Nolly:	If we say reflex action involves only the spinal cord?
(14) Rage:	Yes, then we will easily link the spinal cord and brain.

As can be seen in the conversation above, the students agree on the possible links that can be made. Not only do they agree with each other but also dispute each other's suggestions. For example, in Line 7, Nolly thinks the link that Rage suggested will not work because it disturbs the hierarchy of the concepts that they have developed already. She also gives a reason for this dispute in Line 9, resembling a simple argumentation discourse. Through engaging in argumentation and providing reasons for their positions, the number of valid propositions improved (see B5 in Table 4).

Cross-Links

Unlike concepts and propositions that are revealed by linking words, there were fewer discourses characterized by students discussing possible cross-links than discourses involving concepts and linking words (see Table 5). Generally, where the discourse only involved knowledge-sharing, the number of total cross-links increased, but the number of valid cross-links did not. However, when the pairs discussed their cross-links in constructing a joint CM, there were two examples of both knowledge-sharing discourses and knowledge-construction discourses (CM3 and CM4 from Pair A). Below, we illustrate the two cases with examples.

Example 1: Rage's and Nolly's CM2

This example comes from Rage and Nolly's discussion of their CM2 about the human ear. The two students were just accepting each other's contributions regarding the cross-links on the joint CM without problematizing the ideas.

(1) Rage:	So, I suggest a link from sound waves to cochlea …
(2) Nolly:	Okay … we can write converted to nerve impulse by corti found in cochlear.
(3) Rage:	Yes, that will work. What other links?
(4) Nolly:	I think between balance and cerebellum.
(5) Rage:	Then say what? We can say ….
(6) Nolly:	The cerebellum sends impulses to the muscles and the muscles restore the balance …
(7) Rage:	Okay … then I see another link here … we can make an arrow …

In the above episode, Rage begins by suggesting a possible link between sound waves and cochlear. Although this link was correct, it was not valid because they used concepts as linking words (see Line 2). Instead of Rage questioning Nolly regarding the linking phrase, she just accepts the response resembling a cumulative discourse where individuals just accept each other's contributions. The result of this is an increase in the number of cross-links where many were not valid.

Example 2: Paris's and Meyron's CM 4

This example comes from Paris and Meryron's discussion of their CM 4 about population ecology. They had completed formulating propositions and started discussing other links they could make.

(1) Meyron:	Are we done with the linking words?
(2) Paris:	What other links can we make between density and interactions?
(3) Meyron:	Why not have a cross-link between interactions and dispersion? I am looking at the connection, like saying "Density affects interactions." If we say that, then we are explaining how a lot of individuals in a population can lead to competition. So, we can have another smaller linking line between competition and density.
(4) Paris:	But competition and density are on the same line.
(5) Meyron:	What do you mean by the same line?
(6) Paris:	Sir calls it hierarchies … you remember, like from the main concept …
(7) Meyron:	Oh yes, I think that is what I struggled with throughout.
(8) Paris:	So, I suggest that we first, from this new map, start by separating our hierarchies (laughs) … you know I can't believe this could have been what we needed with the other map, should …
	[Separation of hierarchies continued for 6 minutes]
(9) Paris:	Alright, so, I suggest a line from the logistic model to competition under interactions.

(10) Meyron: Would that work?

(11) Paris I think so. My point is that there is competition at some point in logistic growth. Now we might struggle to decide on the direction of the arrow and how to link the two.

After noticing that they may not have made all the possible links, in Line 2, Paris asks a question that requires some analysis of the links they already have in their joint CM. Meyron then proposes a possible link that she thinks would qualify as a cross-link. She further provided an extended explanation for her position. This is an indicator of an explanatory inquiry. In

Line 4, Meyron outlines what she thinks the issue is, thus, viewing ideas as problems that need further inquiry. Instead of Paris just accepting what Meyron is saying, in Line 7, she acknowledges that the issue is what she has been struggling with. It is important to note that what Paris was arguing for was reflected in her individual CM. This exchange of trying to construct knowledge led to this realization and discovery of a new strategy that can help in deciding on cross-links. Although they found a way of easily constructing cross-links, Paris poses another problem that needs further inquiry. After Line 13 the students spent another 15 minutes discussing possible cross-links. Contrary to the first example presented above, the result of this episode is not only an increase in the total number of cross-links but also valid cross-links.

Discussions and Conclusions

In this article, we have demonstrated that during collaborative concept mapping, certain discourses prevail when students are discussing different CM features. Knowledge-sharing discourses prevail when students have to decide on the concepts they need to include in their map. In this mode, cumulative, repetitive, and simple argumentation discourse patterns prevailed more. Although knowledge-sharing is associated with learning as the transmission of ideas (Fu et al., 2016), the students here shared the concepts that they had identified, thus assisting each other in refining suitable concepts to be included in the joint map. We have shown that during collaboration, students reduced the number of incorrect concepts resulting in better CMs. This conclusion resonates with Gijlers and de Jong's (2013) findings that during collaboration, students exchanged ideas and reached a consensus on the concepts to include in the CMs. Providing students with an opportunity to decide on their concepts and the prevalence of these discourses not only leads to the reduction of concepts included in the map but also the correctness of the concepts improved in some cases. Gillies (2003) noted that when working collaboratively students can explain their understanding of valuable information to complete a task at hand. Explaining their understanding to each other is an important endeavour in collaborative concept mapping (Kinchin, 2014). Therefore, when students are provided with opportunities to collaboratively refine their own individual maps, the process serves as a way of validating the selection of concepts, thus improving the correctness of concepts included in the joint map.

When the students were discussing propositions, the prevalent discourse patterns were disputations and simple argumentations—categorized as knowledge-sharing by Fu et al. (2016). Through disputing each other's already made links the difference between the number of propositions and valid propositions was reduced. This suggests that students were able to collectively identify valid propositions leading to CMs that better followed the formatting requirements. According to de Ries et al., (2022), to develop good CMs, students must understand and show the relative importance of each concept within the overall topic. In this study, we have illustrated that during collaboration, through interactions characterised by disputation and argumentative discourse patterns (Fu et al., 2008), students can come up with well-networked maps. This is because, during collaboration, incorporation of what students had in their individual maps is facilitated through clarifying present thoughts and raising issues that lead to the improvement of the map (Engelmann & Hesse, 2010). This study, therefore, supports Hilbert and Renkl's (2008) as well as Govendor's (2015) work that students learnt from concept mapping when they had constructed the maps individually before collaboration. From an interaction point of view—that interactions need to be prompted by using tools (Vygotsky, 1978)—the individual constructed propositions served as diagnostic tools, therefore, drawing their attention to what they already did that might have been misunderstood. This is an important aspect of Vygotsky's (1978) theory of constructivism. By drawing on each other's individual maps, the students focused each other's attention on the difficulties regarding the plausible integration of concepts or the specification of relationships, and concept maps, thus helping them to recognize knowledge gaps in their maps and flawed logic. We conclude that the students' deliberate disputations during interactions contributed to this improvement.

Students' interactions where the focus was on formulating cross-links primarily involved knowledge-sharing discourses with a few examples of knowledge-construction discourses. However, the knowledge-sharing types of discourses had minimal effect to the number and validity of cross-links, yet the cross-links are what determine the structural complexity and quality of CMs (Cañas et al., 2013). This can be attributed to the demands of formulating cross-links. These demands would require students' creativity (Bramwell-Lalora & Rainford, 2013; Novak and Cañas, 2008) which can be achieved by inquiring deeper into each other's thinking. We argue that the validity of concepts and propositions improved due to just knowledge-sharing discourses because of the less cognitive demand of these tasks. For example, although the students had to decide on linking words to form propositions, the propositions represent a linear relationship in a hierarchy. Contrary to deciding on concepts and linking words to form propositions, cross-links in a CM are what represent knowledge in an integrated manner. This means that the ability of students to formulate cross-links may in turn foster conceptual development needed in science subjects like biology. According to Krieglstein et al (2020), the cognitive demand of making cross-links cannot be underestimated. Students require extensive analytic skills and open thinking to make cross-links that are valid. As Fu et al. (2016) and Erkens and Janssen (2008) stated, in dialogues, knowledge construction discourses resemble a high level of interaction that supports meaning-making and student learning. Of course, it is difficult to anticipate the kinds of discourses that unfold during collaborative concept mapping. However, since we had assumed that the collaboration could improve their cross-links, the non-prevalence of knowledge construction discourses suggests that the students may have avoided complex argumentations that involve analyzing the relationships between the science concepts and how they fit together to make a coherent science story. Given that cross-links may reveal an understanding of the subject at deeper levels, one can argue that the students may not have understood the content well. Although seeking reasons to justify this finding was beyond the scope of the study, a possible reason can be that the students avoided digging deeper and unpacking the relationships between concepts that are not necessarily of a linear hierarchy. In this article, we have illustrated and argued that this depends on the nature of interactions that happen when students are collaborating to construct a joint CM as shown earlier.

Summary and Implications

This study shed some insights into how students organize their knowledge in pairs through collaborative concept mapping. Particularly, we linked the improvement of features of CMs to the discourses that took place during student collaboration using a framework by Fu et al. (2016). One of the major findings in this study was that knowledge construction discourses were minimal during student collaboration when developing joint CM. Using the framework by Fu et al. (2016) to analyze student interaction in an online platform, we were able to illustrate the discourse patterns that were used when students discussed specific CM features. As such, we argued that the framework can be a useful tool to also look at patterns of interactions in face-to-face contexts. Although this study was conducted with biology students, the findings have implications regarding concept mapping in the educational contexts in general and our further research agenda. Seeing that collaborative concept mapping is a valuable activity for student learning, not only knowledge-sharing should be encouraged but also student talk that allows knowledge construction. Encouraging students to question each other on deeper levels and problematizing uncertainties in terms of where links can be made is a call for action. We argued that discourses that characterise knowledge construction can support students to reveal cross-links (as features that show students' deeper understanding). In terms of research, we have not delved much into how the dynamics of these discourses are linked to different CM features, during collaborations that lead to meaningful learning. As such, further studies can look in this direction.

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