Correlation Between Uncertainty Management and Transactive Communication in Elementary Team Learning

Leonore van der Zee

Dr. Chandan Dasgupta & Dr. Alieke van Dijk

Department of Psychology, University of Twente

202000384 – M12 BSc Thesis Psychology

5 July 2024

Word Count: 8538

Abstract

This study investigates the correlation between uncertainty management propensities (UMP) and transactive communication of elementary students, as well as their use of uncertainty management strategies (UMS) and transactive communication in collaborative learning. Transactive communication is an important factor for fostering effective collaboration. Furthermore, the effectiveness of collaboration is influenced by how uncertainty is managed. There are four UMS: reduce, maintain, increase, and *ignore* uncertainty. Students are often prone to express certain behaviors and use certain UMS when faced with uncertainty. This can be categorized in five UMP: *Seek Plausible Explanation, Pause for Reflection, Request Help, Take Action*, and *Deny Uncertainty*. It was expected that there are correlations between certain UMP of elementary school students and their use of transactive communication, as well as their use of certain UMS and transactive communication. Furthermore, it was expected that the UMP *Seek Plausible Explanation* and *Pause for Reflection* were positively correlated with the use of transactive communication. Whereas the UMP *Request Help*, *Take Action*, and *Deny Uncertainty* would show no correlation with the use of transactive communication. This study utilized a secondary data set of thirteen video recordings of 40 elementary students working in groups of four to design a house on the moon. The students' behaviors were coded with three coding schemes to code their usage of UMS, UMP, and transactivity. The results show that all UMS are significantly and positively correlated with transactive communication. Among the UMP, the propensities *Seek Plausible Explanation*, *Pause for Reflection*, and *Take Action* showed significant results for a positive correlation with transactive communication. The UMP *Request Help* and *Deny Uncertainty* showed no correlation. Therefore, only the hypothesis that the UMP *Taking Action* is not correlated with the use of transactive communication in elementary school students can be rejected. However, limitations of this study should be considered when using these results for future reference.

Correlation Between Uncertainty Management and Transactive Communication in Elementary Team Learning

Collaborative learning is widely known by educational psychologists to be a beneficial method for students when implemented correclty (e.g., Pantiz, 1999; Soller & Lesgold, 2007; Laal & Ghodsi, 2012). Collaborative learning can be explained as an approach to learning where groups of students work together to solve a problem, complete a task, or create (Laal & Ghodsi, 2012). This type of learning has around 50 benefits for students, and they can be grouped into social, academic, and psychological advantages (Johnson & Johnson, 1994; Pantiz, 1999; Soller & Lesgold, 2007; Laal & Ghodsi, 2012). Laal and Ghodsi (2012) even state that collaborative learning shows better results than learning in the form of a competition or individually. However collaborative learning should be done correctly to substantiate these claims. While there is no consensus on what the vital elements are exactly, most research mention the benefits of communication in the form of explanation (Soller & Lesgold, 2007; Van Dijk et al., 2020), criticism (Soller & Lesgold, 2007), promotive interactions (Roger & Johnson, 1994), transactivity (Van Dijk et al., 2020), and regulation (Hogenkamp et al., 2021).

Transactivity

Transactive communication (also referred to as transactivity) is one form of communication that has been found to be beneficial in collaborative learning (e.g., Homer Arthur, 2005; Jurkowski & Hänze, 2015; Wang et al., 2017). Transactivity is defined as a type of communication that builds upon, doubts, or argues the idea or opinion mentioned earlier in the conversation by someone else to promote understanding and problem solving (Van Dijk et al., 2014; Wang et al., 2017). Wang et al. (2017) explain that this is because knowledge integration, or transactivity, helps to trigger cognitive conflict that could result in cognitive restructuring and thus learning. This type of communication has been shown to positively impact learning of the individual and the group but also the quality of the end product (Jurkowski & Hänze, 2015). However, in a study of Homer Arthur (2005) it was found that only around 7% of the dialogue of high school students in collaborative learning was transactive. It is expected that younger students exhibit even less transactive dialogue as their critical thinking and reasoning are less developed (Fitzgerald, 2009).

Uncertainty in Collaboration

Learning is largely done through solving uncertainty (O'Reilly, 2013; Jordan, 2015). Jordan (2015, p. 1) explains uncertainty as: "an individual's subjective experience of wondering, doubting, or being unsure about how the future will unfold, what the present

means, or how to interpret the past". Uncertainty as a means of learning is the basis of multiple learning theories that explain that learning happens when conflicts, or uncertainties, are resolved by thinking, reflecting, and searching for knowledge which leads to changes in mental schemas (e.g., Dewey, 1933; Festinger, 1957; Piaget, 1965). Therefore, uncertainty is an integral part of learning that should be considered in its effectiveness.

Social interactions in collaborative learning influences this uncertainty (Jordan, 2010). For one, social interactions add new uncertainty related to questioning their social role in the group or whether the input of other students is correct and how that new information fits into their own mental schemes (Jordan, 2010). Social interaction not only adds uncertainty, but it also influences how the student presents their uncertainty. They might question whether it is socially acceptable to acknowledge the uncertainty towards the other students (Jordan, 2010). Consequently, social interactions in collaborative learning not only introduce new uncertainty but also shape how students handle and express these uncertainties within the group context.

Jordan and McDaniel (2014) identified four uncertainty management strategies (UMS) that refer to the behaviors students exhibit when faced with uncertainty in collaborative learning. First, the UMS *Reduce* refers to behaviors that are aimed at reducing uncertainty by closing their own knowledge gap or that of others. Examples of these behaviors include asking/answering questions, experimenting, and consulting textbooks (Jordan & McDaniel, 2014; Chen et al., 2019). Second, the UMS *Increase* refers to behaviors that purposefully increase the uncertainty with the intention to get a deeper understanding of the problem and possible solutions. Examples of these behaviors include asking new questions that broaden the scope of the problem or finding/mentioning inconsistencies in possible solutions (Jordan & McDaniel, 2014; Chen et al., 2019). Third, the UMS *Maintain* refers to behaviors that acknowledge the uncertainty and/or examine possibilities without the intention to increase or reduce the uncertainty. This can help the student with improving reasoning for certain decisions or ideas. Examples of these are generating and maintaining multiple solutions or options (Jordan & McDaniel, 2014; Chen et al., 2019). And last, the UMS *Ignore* refers to behavior that indicates that the person disregards the uncertainty. Examples of these behaviors include engaging in off-task behavior and dismissing the presented uncertainty (Jordan & McDaniel, 2014). These four UMS encompass the behaviors students exhibit when faced with uncertainty.

Theoretical Model of Propensities in Uncertainty Management in Collaboration

Jordan (2015) found that there was a connection between what UMS elementary school students often use and whether they use ample tactics to address the uncertainty. This

forms the foundation for five different propensities that students use to manage uncertainty in collaboration; (1) *Seek Plausible Explanation*, (2) *Pause for Reflection*, (3) *Request Help*, (4) *Take Action*, and (5) *Deny Uncertainty*. The uncertainty management propensity (UMP) that a student demonstrates, predicts the reaction that the student is prone to have when faced with uncertainty.

First, students that *Seek a Plausible* explanation in the face of uncertainty may want to resolve the uncertainty immediately so they can achieve the task. However, they also choose to maintain or increase the uncertainty if they believe that that is best. While they feel uncomfortable with uncertainty, it is not threatening to them. Instead, they acknowledge the uncertainty and seek solutions by creating plausible explanations for it and use that to rationalize their next possible action. Furthermore, they rely on confirmation and support from peers heavily. This could suggest that they communicate well with their group mates and implement transactive communication in their conversations.

Second, students that *Pause for Reflection* in the face of uncertainty delay their actions to think, collect information, and reflect on the past, present, and future of the assignment in order to see how it fits in the bigger picture. These students use multiple tactics, often acknowledging and maintaining uncertainty till later, and do not hesitate to ask questions. This could suggest that they seek communication with their peers and make active use of transactive communication.

Third, students that *Request Help* in the face of uncertainty are prone to rely on their group mates and often fail to explore texts and materials for more information. They acknowledge the uncertainty but frequently try to reduce it by passing it to other group mates or maintain it by mentioning the uncertainty and taking no further action to resolve it themselves. While they talk about the uncertainties with the other groupmates, they rarely engage in the topic by expressing curiosity or making hypotheses. While these students seek communication with their group mates, it is not thought that the communication consists of transactive communication.

Fourth, students that *Take Action* in the face of uncertainty are prone to reduce the uncertainty immediately or ignore it. Where some other students seek a plausible explanation for it, students with this propensity make use of trial-and-error experimentation. Rather than analyzing possible actions and explanations to justify their next action, they act immediately. Furthermore, they often do not acknowledge the uncertainty and instead show confidence in their actions towards others. The immediate act of action reduces their consultation about the

decisions with their other group mates. This could indicate that these students do not communicate well with their group mates and make little use of transactive communication.

And lastly, students that *Deny Uncertainty* often ignore uncertainty or blame external sources, such as their groupmates. Instead of acknowledging the uncertainty they make confident claims about their abilities showcasing that there is no uncertainty. This goes as far as them saying that they already knew the solution when other group mates share it. When this is not the case, they often pass on the task to others. Whereas students that seek help do this more openly mentioning the uncertainty, these students instead keep silent till other students take over. They were most likely to withdraw from participation or start engaging in off-task behavior when they encountered uncertainty. This could suggest that they do not communicate well with their group mates and make little use of transactive communication.

Research Gap

While Jordan (2014) explains the important connection between communication and the uncertainty management of students, transactive communication and uncertainty management are not yet discussed. And as indicated earlier, transactive communication is an important factor in collaborative learning as it improves learning not only on a group level but also of the individual students (e.g., Homer Arthur, 2005; Jurkowski & Hänze, 2015; Wang et al., 2017). Therefore, it is of interest to investigate whether there is a connection between transactivity and the UMP, as well as investigating the connection between transactivity and the UMS. This dual focus on both the UMP and the UMS will help gain more insights into their relationship with transactive communication as the UMP are partly build upon the UMS.

Therefore, this study wants to research whether the UMP and the use of UMS in elementary school students are correlated with their use of transactive communication. Thus, this study asks the question: “To what extent are uncertainty management strategies and propensities of elementary school students related to their use of transactivity?”. This will be researched by coding the data of elementary school students in collaborative learning environments and performing correlational analyses between the UMP and transactivity, as well as the UMS and transactivity. It is expected that there are correlations between certain UMP of elementary school students and their use of transactive communication, as well as their use of certain UMS and transactive communication. The secondary hypotheses tested in this study are:

1) There is a positive correlation between the UMP *Seek Plausible Explanation* and transactive communication.

Students that *Seek a Plausible Explanation* actively try to seek information for possible solutions to manage their uncertainty. Furthermore, it is thought that these students communicate well and that they use the information shared by others to better understand the problem and find possible solutions. This could suggest that the UMP *Seek Plausible Explanation* is positively correlated with the use of transactive communication.

2) There is a positive correlation between the UMP *Pause for Reflection* and transactive communication.

It is thought that students that *Pause to Reflect*, collect information from their group mates by listening and asking questions and using this information to get an understanding of the assignment. This could suggest that they make use of transactive communication to make more substantiated decisions.

3) There is no correlation between the UMP *Request Help* and transactive communication.

Students that *Request Help* often communicate their uncertainty towards their group mates but do not take further action to address their uncertainty. This could suggest that they make little use of transactive communication to build upon, doubts, or argues the idea or opinion of their group mates.

4) There is no correlation between the UMP *Take Action* and transactive communication.

Students that *Take Action* often start acting without consulting their group mates suggesting little communication. This it is therefore expected that they do not actively use or engage in the ideas and opinions of their group mates to substantiate their decision but rather start trial-and-error experimentation. Thus, it is expected that students that are prone to *Take Action* make little use of transactive communication.

5) There is no correlation between the UMP *Deny Uncertainty* and transactive communication.

Students that *Deny Uncertainty* often keep silent or engage in off-task behavior instead of actively participating in the discussion. When they do participate, they will often claim that they can easily solve or fix the uncertainty instead of admitting the uncertainty towards their group mates. This could suggest that they make use little transactive communication.

Methodology

Design and Context

A correlational design was used in this study to investigate whether there are correlations between elementary school student's UMP and usage of UMS and their degree of transactivity in learning environments.

A secondary dataset was used that was obtained by an earlier study published by Van Dijk et al. (2020). The goal of that paper was to study the effects of a worksheet that structured groupwork in heterogeneous groups by presenting four steps that guided the group members to share information in a structured and effective manner (Van Dijk et al., 2020). It is important to note that the current study only used the data of the groups that worked without a worksheet. The data consisted of video recordings of groups of four elementary school students that collaborated to create a livable house on the moon.

Before the data collection started, students participated in three two-hour lessons given in a digital learning environment that activated prior knowledge which they could use to create the livable moon house. This was done using the jigsaw method, which entails that the students were first divided into one of four specializations and participated in lessons teaching them about that specialization (Van Dijk et al., 2020). As a result, each student in the heterogeneous group later assembled, obtained different prior knowledge. The four specializations consisted of water, oxygen, light and heat, and nutrition. The students were allocated to a specialization according to their learning abilities. After the three lessons about one of the specializations, the students did a knowledge test that tested them on all four topics. Then, the students were grouped into their heterogeneous group consisting of four students, each trained in a different specialization. Their design task was to inform the other students about their specialization and discuss what they deemed necessary to create a house on the moon where a family of four could live. This collaboration was videotaped and used as data in this current study.

Participants

This current study included a sample of 40 elementary school students from six different schools based in the same medium-sized city in The Netherlands. The students consisted of 23 girls (56,3%) and 17 (43,7%) boys with a mean age of 10.94 years (*SD* = 0.86).

The students were first categorized based on their learning abilities (high-, average-, and low-ability). This was done with the use of their CITO scores, a Dutch rating system used to objectively measure the performance of elementary school students (*Voor Ouders | Primair*

Onderwijs, 2024). Subsequently, the students were divided into one of the four specializations according to their learning abilities. High-ability students specialized in light and heat, average-ability students studied either oxygen or water, and low-ability students examined nutrition. Then heterogeneous groups were created by assigning four students together, each specialized in a different specialization. The groups consisted of one low-ability, two average-ability, and one high-ability students.

Consent was given by all the children's parents for their child to participate in the study from 2020, for them to be recorded during the study, and for the usage of the data for future research purposes (Van Dijk et al., 2020).

Materials

The data consisted of video recordings of elementary school students that worked in a collaborative learning setting. Each group had their own camera and microphone that recorded their actions and conversations (Van Dijk et al., 2020). This made it possible to code the behavior and dialogue of all the four students effectively as it was possible to take the setting into account.

Procedure

The data collection started when the students were placed in their heterogeneous groups for the first time. They got the instructions to discuss what they had learned about their specialization and what they thought was important for building a moon house for a family of four. They had around 35 minutes to finish their discussion.

Data analysis

This study used three coding schemes that made it possible to code the students' use of UMS, UMP and transactive communication during a collaborative learning task. In total, 13 video recordings, each between the 5 and 35 minutes long, were coded by two coders using the program ELAN (ELAN, 2023). This is a coding tool that displays both the video and the audio simultaneously. Speaking turns were used as coding segments, which the original study by Van Dijk et al. (2020) had already prepared. This provided a systematic and objective basis for the segments that could be coded.

Coding Scheme of the UMS

The coding scheme of the UMS in Table 1 is a combination of the coding schemes of Chen et al. (2019) and Jordan and McDaniel (2014). These coding schemes are based on the theory of Jordan (2010) about what influences the response towards uncertainty and the four UMS identified in that paper.

Jordan (2010) explains that people respond both cognitively and emotionally to uncertainty, with responses being primarily influenced by environmental factors. When faced with uncertainty, emotional responses can be negative such as anxiety, worrying, or fear. But they can also be positive like excitement and pleasure when, for example, someone sees their uncertainty as a fun challenge (Jordan, 2010). The cognitive reaction towards uncertainty can range from searching for causes or solutions to impairing cognitive functioning and prohibiting the person from acting. These reactions, emotional and cognitive, are influenced by the context of the uncertainty. For example, responses may vary depending on whether there is academical or social pressure to solve it or if it stems from leisurely activities.

Both Chen et al. (2019) and Jordan and McDaniel (2014) created coding schemes that identify behaviors that correspond to the UMS mentioned by Jordan (2010). However, Chen et al. (2019) sought to understand how teachers could enhance the productive use of UMS in students in a collaborative argument. As a result, their coding scheme only studied the productive behaviors of reducing, maintaining, and increasing uncertainty to promote shared understanding in argumentation. Examples of sub-codes from the UMS *Increase* are 'Shares what he/she does not understand' and 'Mentions inconsistencies and weaknesses in arguments'. On the other hand, Jordan and McDaniel (2014) created a coding scheme taking behaviors from all four UMS into account even if they are unproductive. Examples of sub-codes from the UMS *Maintain* is 'Delays decisions' and from the UMS *Ignore* is 'Discounts negative information'. These behaviors combined make up the (sub)codes in the UMS coding scheme.

The codes in the UMS coding scheme are as follows; (1) *Reduce,* diminishing the unknown, (2) *Maintain*, acknowledging the unknown but avoiding making premature choices, (3) *Increase*, deliberately creating or seeking the unknown, and (4) *Ignore*, choosing not to address the unknown and/or its significance.

Table 1

Codes for Uncertainty Management Strategies

Uncertainty Management Strategies	Concrete and Observable Behavior	Explanation	Example
Reduce	Answers questions/ Clarifies statements.	Student clarifies statement from themselves or others.	"My topic was oxygen."
	Solves inconsistency/ weakness.		"No, it can with a little spacesuit."
	Explains the problem/topic to others.	Student explains their train of thought or ideas to others.	"Okay, so we need at least something like a compressor."
Maintain	Delays decisions.		"Shall we maybe read this individually first."
	Generates and/or maintains multiple options.		"Scissors, bathtub, shower."
	Talks about the shared understanding of the task.	Student checks if they are on the same page, such as giving a summary. Student shares information that was already known.	"The rest is about the moon house, and we didn't hear anything about that."
Increase	Asks new questions to try to answer them.		"Okay but what if there is an accident on the moon? What then?"
	Mentions inconsistencies and weaknesses in arguments.	Student critiques input of others.	"That one cannot live there."
	Shares what he/she does not understand.		"Then why are we even doing it?"
Increase	Points out when something does not match with prior knowledge.	Student refers to the prior knowledge of the student.	"No but I learned that night lasts a month so then solar panels will not work."
	Asks a teacher or groupmate for information.	Student asks a person or states that a person needs to give information.	"But what topic did you have?"

Table 1 (Continued)

Uncertainty Management Strategies	Concrete and Observable Behavior	Explanation	Example
Ignore	Exhibits off-task behaviour.	Coded when at least two of the group members are still working on the assignment and this student is not.	The student talks about something else. Student annoys another group member.
	Discounts negative information.	Student discredits the source. Student compares the current situation to a past instance of failed prediction.	Other student shares an uncertainty "Just leave it. Look this is the house."
	Avoids/ignores information.	Student suppresses currently held knowledge, such as thought suppression.	"Yes that's what I thought."

The UMS coding scheme was used to code five videos (38,5% of all videos, consisting of three groups) by two coders and an interrater reliability coefficient was conducted using Cohen's Kappa. The UMS coding scheme showed an interrater reliability of k = .20. Because the scores were low, the coding schemes were rediscussed, and two codes of the strategies were adapted. One video of 26 minutes was recoded, and the interrater reliability coefficient had increased to k = .24. While this is still insufficient, the decision was made to continue with the new coding schemes without any additional changes due to a lack of time.

A possible reason for the low score is that the differences between the codes are too small creating unclarity for the coders. For example, the codes; 'Mention inconsistencies and weaknesses in arguments' and 'Shares what he/she does not understand' from the UMS *Increase*. Both codes show that the student disagrees with the option or comment. However, when the student refers to their prior knowledge, the disagreement stems from something they had learned earlier, whereas mentioning inconsistencies stems from the student's logical and critical thinking. These small differences between the UMS could be a possible cause for unclarity in the existing coding scheme.

The coding scheme used in this study first asked the question; "Is the uncertainty increased, decreased, maintained, or ignored?". Then the correct behavior was coded within that category. Furthermore, two hierarchies were added, one in the UMS *Increase* and one in the UMS *Reduce*, to resolve overlap between sub-codes within those UMS. First, for the UMS

Increase, the code 'mentions inconsistencies and weaknesses in arguments' was chosen when a student gives critique. This was done because when a student critiques input given earlier in the conversation, they increase the uncertainty of themselves as well as that of the other student. Furthermore, in the UMS *Reduce*, when there is an overlap between 'answers questions/clarifies statements' and 'solves inconsistency/weakness', the code 'answers questions/clarifies statements' is chosen. This is because it solves their own uncertainty in addition to that of other students.

Coding Scheme of the UMP

The coding scheme for the UMP elementary school use is based on the research paper by Jordan (2015). Jordan (2015) identified and described five propensities that students have towards managing uncertainty. These propensities explain the behavior and strategies that a student is overall prone to use when faced with uncertainty. The description that Jordan gives for these five propensities is summarized to observable behavior and is placed in a coding scheme (see Table 2).

One code was adapted to fit the data used for this study. The code 'Trial-and-error experimentation' was explained by Jordan (2015) as starting to work or experiment without thoroughly thinking the action through and instead finding the solution by trial-and-error. The data of this study, however, consists of children discussing possible actions for the moon house but not yet performing the actions. Therefore, when a child mentions only an option or idea for an action to see the reaction of the other children, the behavior was coded as 'trial-and-error experimentation'.

Table 2

Codes for Uncertainty Management Propensities

Uncertainty Management Propensities	Concrete and Observable Behavior	Explanation	Example
Seek Plausible Explanations.	Justify next action to be taken.	The student shares a possible decision and explains why.	"We need a cow farm cause then we can have milk and meat."
	Comparing multiple perspectives to create plausible explanations observed and hypothesized outcomes.		"We can do a big house cause the moon is big" *other student talks* "but we need also room for the animal farm."
	Seeking confirmation for potential actions.	Presents an option to the group showing doubt or when curious to the opinion of others.	"Maybe we should have fruit trees then." "I think it should be half"
	Mentioning inconsistencies in ideas of others.		"Those thin poles cannot keep up the entire house"
	Collect more information.	Asking new questions/searching for information to be able to resolve uncertainty themselves.	"Pigs eat garbage right? Cause then we can take those with us too."
Pause for Reflection	Delaying action in order to think.		"Wait" "Could you slowdown"
	Reflect prior to proceeding.	Student reflects on the effect the decision has on the future.	"But if the cows do that over and over again, then there is no water anymore."
		Student uses past events/knowledge as explanation/argument to justify the next action.	"I learned that the nights last a month so we should save energy as well."

Table 2 (Continued)

Uncertainty Management Propensities	Concrete and Observable Behavior	Explanation	Example
Request for Help	Seeking assistance to resolve immediately presenting uncertainty.		"Miss, what do we need to do?"
	Passing a task to someone else, directly.		"(name of student), you need to tell us about your specialization first."
Take Action	Trial-and-error experimentation.	Presents an option to the group, only mentioning that option.	"A towel! Toilet paper!"
	Makes a decision.	Gives a demand of the next action that should be taken according to them without justification.	"We also need a PS4."
Take Action	Makes a decision.	Gives a demand of the next action that should be taken according to them without justification.	"We also need a PS4."
Deny Uncertainty	Avoid acknowledging uncertainty.		"No, that works!"
	Expressing great certainty that a bad outcome was imminent.		"That is not going to work!"
	Blames external sources for bad outcome.		

Cohen's Kappa was calculated for the UMP coding scheme using the same five videos as were used for the UMS coding scheme. The UMP coding scheme showed an interrater reliability coefficient of .30. This low score may be attributed to the high discrepancy between the number of segments that the two coders had coded. This discrepancy likely occurred because the UMP codes often extended across multiple segments, leading to instances where the codes overlapped with each other. The coders recoded one video together, and it seemed that there was greater consensus on the UMP codes. However, a second interrater reliability

test done on a separately recoded video of 26 minutes and showed an even lower score than before (k = .15). Due to a lack of time, the UMP coding scheme was still used.

It is still believed that the UMP codes spanning over multiple segments contributed to the interrater problems. There was still a high difference in the number of segments coded in the separately recoded video. A solution could be that rules are established that produce clarity about how often the same code can be used in different segments. However, as mentioned, a lack of time hindered implementation of solutions.

The second potential problem is that the codes are too dependent on the interpretation of the situation. For example, the code 'Seeking assistance to resolve immediately presenting uncertainty' depends on when the uncertainty first occurred. If the student refers to the same uncertainty at a later point, then it does not qualify as an immediately presenting uncertainty anymore.

Transactivity Coding Scheme

Table 3 shows a pre-existing coding scheme from Van Dijk et al. (2014) that was used to code transactivity. This coding scheme is based on the theory from Fischer and Weinberger (2006) of how collaborative knowledge is co-constructed. They identified five processes of collaborative knowledge construction. First and second, *externalization* and *elicitation* which are mentioned in Table 3. Third, *Quick Consensus Building* which is defined as 'Agreement' in Table 3. Fourth, *integration-oriented consensus building* which refers to the learner adopting and integrating their group mate's input, resulting in a change in their own opinion or ideas. And fifth, *conflict-oriented consensus* which refers to the learner challenging their group mate's input by critiquing and debating, aiming to change their group mate's opinion or ideas. Van Dijk et al. (2014) added 'Disagreement' to the coding scheme (see Table 3) as a form of transactive communication to this theory.

The coding scheme from Van Dijk et al. (2014) was already modified towards elementary school students. It includes a hierarchy based on how transactive the behavior is. The sub-codes in the category 'Information Sharing' are seen as the lowest form and the sub-codes in the category 'Transactivity' as the highest form of transactive communication. When two or more codes occurred in a segment, the highest form of transactive communication was chosen.

Table 3

Codes for Transactivity

Transactive Communication	Concrete and Observable Behavior	Explanation	Example
Information sharing	Externalization	Giving information without referring to their partner's input	"We also need a PS4."
	Elicitation	Asking one's partner for information	Other student: "Then we use an air bottle for that." "What is an air bottle?"
Quick Consensus	Agreement	Unconditioned pseudo-acceptance of partners' suggestions	"Yes, yes"
	Disagreement	Disagreeing without showing comprehension	"No"
Transactivity	Integrating	Evidence that the speaker learned from partner	"Ah, like that."
	Critiquing	Critiquing or correcting input from partner	"Those thin poles cannot keep up the entire house"

Note. Coding scheme adopted from Van Dijk et al. (2014)

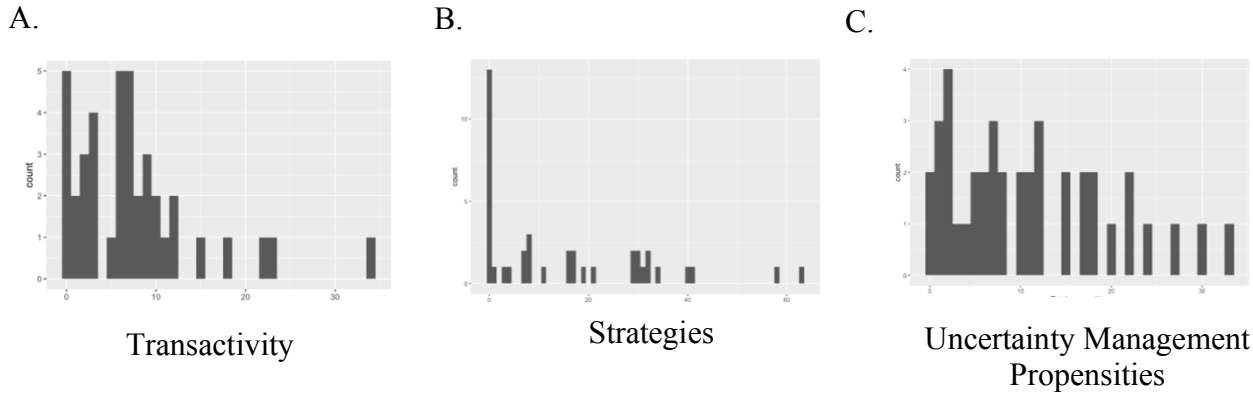
The same five videos used for the UMP and UMS coding schemes to conduct the Cohen's Kappa were also used for the transactivity coding. The coding scheme showed an interrater reliability of .02. The coders rediscussed the definitions of the transactive communication codes and recoded one video together to find examples and go over possible misinterpretations. It appeared that there was an improved consensus on the transactivity codes. However, Cohen's Kappa was reconducted on a separately coded video of 26 minutes video and showed little improvement (k = .11). It is recommended that more time is spent on training the coders in future research (Shuyan, 2011; McHugh, 2012). The research paper from Van Dijk et al. (2014) that created this coding scheme had an interrater reliability of .84 indicating that the coding scheme can be used correctly.

Data Organisation and Assumption Testing

After coding the data, the data was organized, the descriptive statistics were obtained, and the assumptions were checked to gain insights into the coded behaviours. Subsequently, correlational analyses were performed between transactivity and UMP, as well as transactivity and UMS.

Figure 1

Normality Tested of Transactivity



Frequency coding was used to organize the behaviors of every student into an CSV file, which was then analyzed with Rstudio. Thereafter, the assumptions were checked. As shown in Figure 1, none of the three variables meet the normality assumption. Therefore, Spearman's rho was used to study the correlation between the variables and a $p < .05$ was chosen (Schober et al., 2018).

Results

This research paper aims to study to what extent elementary school students' UMP and their use of UMS are correlated with their use of transactive communication. It is expected that there are correlations between certain UMP of elementary school students and their use of transactive communication, as well as their use of certain UMS and transactive communication.

First, to gain insights into the coded behaviors, the descriptive statistics of the UMP, UMS, and transactivity are shown. Then multiple correlational coefficients (Spearman's rho) are computed between the transactivity and the UMS, as well as between transactivity and the UMP.

Frequency Statistics of UMS, UMP, and Transactive Communication

The frequency tables display how often certain behaviors were coded by all students combined in all thirteen coded videos. The mean shows how often, on average, each student exhibited UMS, UMP, and transactive communication behaviors.

Frequency Statistics of UMS

Table 4 shows how often students exhibited the four UMS and their corresponding behaviors. In total, 702 segments were coded, each with a subcode indicating the student's use of one of the UMS. Students were most likely to reduce uncertainty when faced with it.

Almost half (47%) of all coded segments showed students using this UMS. Most often, students reduced uncertainty by asking questions or by explaining the problem/topic to other group mates. Conversely, students were least likely to use the UMS 'Ignore' which was coded in only 10% of all coded segments. When students ignored their uncertainty, they were most likely to engage in off-task behavior. Furthermore, students used the UMS 'Increase' 15% and the UMS 'Maintain' in 27% of all coded segments.

Table 4

Descriptive Statistics of the Uncertainty Management Strategies

	Mean	Sd	Min	Max	Total
Ignore	1.33	2.41	0.00	10.00	73
Exhibits off-task behavior.	1.58	2.15	0.00	8.00	63
Discounts negative information.	0.08	0.27	0.00	1.00	3
Avoids/ignores information.	0.18	0.45	0.00	2.00	7
Maintain	4.60	5.47	0.00	20.00	192
Delays decisions.	0.08	0.35	0.00	2.00	3
Generates and/or maintains multiple options.	3.43	4.05	0.00	17.00	137
Talks about the shared understanding of the task.	1.30	2.82	0.00	17.00	52

Table 4 (Continued)

	Mean	Sd	Min	Max	Total
Increase	2.28	3.31	0.00	16.00	106
Asks new questions to try to answer them.	0.40	0.93	0.00	5.00	16
Mentions inconsistencies and weaknesses in arguments.	1.68	1.99	0.00	9.00	67
Shares what he/she does not understand.	0.40	0.67	0.00	2.00	16
Points out when something does not match with prior knowledge.	0.176	0.45	0.00	2.00	7
Reduce	7.10	0.76	0.00	39.00	331
Asks a teacher or groupmate for information.	2.78	3.50	0.00	15.00	111
Answers questions/ Clarifies statements.	1.93	2.00	0.00	9.00	77
Solves inconsistency/ weakness.	0.90	1.32	0.00	6.0	36
Explains the problem/topic to others.	2.68	4.72	0.00	26.00	107

Note. n = 40

Frequency Statistics of UMP

Table 5 shows how often students exhibited behaviors indicating the five UMP. In total, 433 segments were coded, each with a subcode indicating the student's use of one of the UMP. Students most often showed behaviors that correspond with the UMP 'Seek Plausible Explanation' with 44% of all segments coded with this UMP. Students were most likely to exhibit the sub-code 'Justify next action to be taken' with this being 18% of all coded segments. The second most frequently occurring UMP was 'Take Action' with 35% of segments coded with this UMP. Moreover, students exhibited behaviors indicating the UMP 'Pause for Reflection' 10% and the UMP 'Request Help' 11% of all coded segments. Lastly, the UMP 'Deny uncertainty' did almost not occur. Only 1% of all coded segments were coded with this UMP. The subcode 'Blames external sources for bad outcome' was not exhibited by any child at all.

Table 5

Descriptive Statistics of the Uncertainty Management Propensities

	Mean	Sd	Min	Max	Total
Seek Plausible Explanation	4.73	4.88	0.00	19.00	189
Justify next action to be taken.	2.00	3.27	0.00	18.00	80
Comparing multiple perspectives to create plausible explanations observed and hypothesized outcomes.	0.13	0.33	0.00	1.00	5
Seeking confirmation for potential actions.	0.63	1.25	0.00	5.00	25
Mentioning inconsistencies in ideas of others.	1.33	1.2	0.00	5.00	53

Table 5 (Continued)

	Mean	Sd	Min	Max	Total
Collect more information.	0.65	0.92	0.00	3.0	26
Pause for Reflection	1.05	1.63	0.00	8.00	42
Delaying action in order to think.	0.125	0.33	0.00	1.00	5
Reflect prior to proceeding.	0.93	1.56	0.0d0	8.00	37
Request for Help	1.15	1.61	0.00	7.00	46
Seeking assistance to resolve immediately presenting uncertainty.	1.03	1.54	0.00	7.00	41
Passing a task to someone else, directly.	0.13	0.40	0.00	2.00	5
Take Action	3.75	3.04	0.00	13.00	150
Make a Decision.	1.98	2.56	0.00	11.00	79
Trial-and-error experimentation.	1.78	1.72	0.00	6.00	71
Deny Uncertainty	0.15	0.43	0.00	2.00	6
Avoid acknowledging uncertainty.	0.15	0.33	0.00	1.00	5
Expressing great certainty that a bad outcome was imminent.	0.03	0.16	0.00	1.00	1

Table 5 (Continued)

	Mean	Sd	Min	Max	Total
Blames external sources for bad outcome.	0.00	0.00	0.00	0.00	0

Note. n = 40

Frequency Statistics of Transactive Communication

Table 6 shows how often students exhibited behaviors indicating transactive communication. In total, 300 segments showed children using transactive communication. The most frequently occurring category was 'Transactivity' with more than half of the segments (59%) coded with this form of transactive communication. Students exhibited 'Information Sharing' in 28% of the coded segments. The category 'Quick Consensus' was used least often, with 14% of the codes being coded with this form of transactive communication. Students most often critiqued each other's ideas and decisions with that sub-code being coded 38% of all segments.

Table 6

Descriptive Statistics of Transactivity

	Mean	Sd	Min	Max	Total
Information sharing	2.08	2.32	0.00	11.00	83
Externalization	0.98	1.61	0.00	8.00	39
Elicitation	1.1	1.45	0.00	6.00	44
Quick Consensus	1.03	1.25	0.00	5.0	41
Agreement	0.58	0.81	0.00	3.00	23
Disagreement	0.45	1.01	0.00	5.00	18
Transactivity	4.40	4.74	0.00	21.00	176
Integrating	1.55	3.10	0.00	16.00	62
Critiquing	1.85	2.83	0.00	12.00	114

Note. n = 40

Correlational Test (Spearman's Rho)

Fifty correlational analyses were computed between the five UMP and transactivity, as well as forty correlational analyses between the four UMS and transactivity.

Correlational Analyses Between the UMS and Transactivity

Table 7 shows that all the UMS are significantly correlated with transactivity. However, the UMS code 'Ignore' correlates significantly almost exclusively with the transactivity categories 'Agreement' and 'Critiquing'. Meanwhile, the remaining three UMS codes – 'Maintain', 'Increase', and 'Reduce' – demonstrate significant correlations across nearly all the same categories of transactive communication.

Table 7

Correlational Test with Spearman's Rho between UMS and Transactive Communication

	Ignore	**Maintain**	**Increase**	**Reduce**
Information Sharing	0.16 (p = .332)	0.37 (p = .018) *	0.44 (p = .004) *	0.342 (p = .031)
Externalization	0.069 (p = .671)	0.05 (p = .767)	0.22 (p = .176)	0.082 (p = .616)
Elicitation	0.19 (p = .248)	0.44 (p = .005) *	0.45 (p = .003) *	0.41 (p = .009) *
Quick consensus	0.24 (p = .131)	0.14 (p = .397)	0.25 (p = .124)	0.21 (p = .185)
Agreement	0.47 (p = .002) *	0.39 (p = .013) *	0.35 (p = .027)	0.42 (p = .008) *
Disagreement	-0.17 (p = .291)	-0.19 (p = .248)	0.01 (p = .0.961)	-0.09 (p = .563)
Transactivity	0.39 (p = .013) *	0.53 (P < .001) *	0.73 (p < .001) *	0.63 (p < .001) *
Integrating	0.26 (p = .110)	0.39 (p =.012) *	0.41 (p = .009) *	0.44 (p = .005) *
Critiquing	0.47 (p = .002) *	0.47 (P = .002) *	0.77 (p < .001) *	0.59 (p < .001) *
Total	0.36 (p = .021) *	0.47 (p = .002) *	0.66 (p < .001) *	0.55 (p < .001) *

*Note. n = 40, * p < .05 showing a significant correlation*

Correlational Analyses Between the UMP and Transactivity

Table 8 shows that the UMP codes 'Seek Plausible Explanation', 'Pause for reflection', and 'Take Action' are all significantly correlated with transactive communication.

These three UMP codes show consistently significant correlations with the code 'Information Sharing', as well as ‘Transactivity’ and its related subcategories ‘Integrating' and 'Critiquing'.

Additionally, both the UMP codes ‘Deny Uncertainty’ and ‘Request for Help’ show no significant correlation with transactive communication overall. However, 'Request for Help' does exhibit one significant correlation with the subcategory 'Elicitation'.

Table 8

Correlational Test with Spearman’s Rho between UMP and Transactive Communication

	Seek Plausible Explanation	**Pause for Reflection**	**Request for Help**	**Take Action**	**Deny Uncertainty**
Information Sharing	0.48 (p = .002) *	0.39 (p = .013) *	0.23 (p = .156)	0.41 (p = .008) *	-0.09 (p = .572)
Externalization	0.17 (p = .285)	0.12 (p = .468)	-0.19 (p = .250)	0.30 (p = .060)	-0.06 (p = .728)
Elicitation	0.56 (p < .001) *	0.41 (p = .009) *	0.46 (p = .003) *	0.33 (p = .037) *	-0.01 (p = .931)
Quick consensus	0.09 (p = .563)	0.18 (p = .277)	0.18 (p = .258)	0.29 (p = .071)	0.13 (p = .438)
Agreement	0.04 (p = .802)	0.33 (p = .036) *	0.13 (p = .426)	0.26 (p = .107)	0.22 (p = .168)
Disagreement	0.10 (p = .531)	-0.13 (p = .437)	0.09 (p = .574)	0.24 (p = .136)	-0.01 (p = .966)
Transactivity	0.68 (p < .001) *	0.63 (p < .001) *	0.20 (p = .222)	0.56 (p < .001) *	0.09 (p = .601)
Integrating	0.41 (p = .008) *	0.39 (p = .0125) *	-0.05 (p = .737)	0.53 (p < .001) *	0.11 (p = .514)
Critiquing	0.65 (p < .001) *	0.63 (p < .001) *	0.30 (p = .063)	0.44 (p = .004) *	0.10 (p = .527)
Total	0.61 (p < .001) *	0.55 (p < .001) *	0.23 (p = .147)	0.56 (p < .001) *	0.09 (p = .567)

*Note. n = 40, * p < .05 showing a significant correlation*

Discussion

This research paper aimed to study to what extent elementary school students' UMP and their UMS use are correlated with their use of transactive communication. It is expected that there are correlations between certain UMP of elementary school students and their use of transactive communication, as well as between their use of certain UMS and transactive communication.

This study analyzed 13 video recordings of elementary school students discussing in groups of four the requirements for creating a livable house on the moon. Two coding schemes were developed to code the UMP and UMS, while transactivity was assessed using an existing coding scheme. Then, forty correlational analyses were performed between the UMS and transactivity, as well as fifty correlational analyses between the UMP and transactivity. In addition, five secondary hypotheses predicted the correlations between the UMP and transactive communication.

The first secondary hypothesis states: "There is a positive correlation between the UMP *Seek Plausible Explanation* and transactive communication". This was expected as these students communicate well, and they use the information given by others to better understand the problem and find possible solutions. The results show a significant positive correlation accepting this hypothesis.

The second secondary hypothesis states: "There is a positive correlation between the UMP *Pause for Reflection* and transactive communication". This was expected as these students collect information from their group mates by listening and asking questions. Then they use that information to generate an understanding of the assignment. The results show a significant positive correlation accepting this hypothesis.

The third secondary hypothesis states: "There is no correlation between the UMP *Request Help* and transactive communication". This was expected as these students often communicate their uncertainty towards their group mates but cease to take further action to address the uncertainty. This suggest that they do not build upon, doubts, or argue the ideas or opinions of their group mates. The results show no correlation accepting this hypothesis.

The fourth secondary hypothesis states: "There is no correlation between the UMP *Take Action* and transactive communication". This was expected as these students often start acting without consulting their group mates indicating little communication. This suggests that they do not actively use or engage in the ideas and opinions of their group mates to substantiate their decisions but rather start trial-and-error experimentation. Unexpectedly, the results show a significant positive correlation rejecting the hypothesis. This outcome could be due to the data, which were video recordings of group discussions and not of creating the actual design on paper. Therefore, to reduce their uncertainty, they needed to communicate and participate in the discussion rather than work independently and start acting. This could suggest that students with the UMP *Take Action* are typically not prone to communicate, but when they are required to do so, they make use of transactive communication.

The fifth secondary hypotheses states: “There is no correlation between the UMP *Deny Uncertainty* and transactive communication.” This was expected as these students often keep silent or engage in off-task behavior instead of actively participating in the discussion. The results show no significant correlation accepting the hypothesis.

A possible factor for which UMP are positively correlated to the use of transactive communication is the participation level of students when they are faced with uncertainty. The students with the UMP *Request Help* and *Deny Uncertainty* are most likely to pass on the task to other students and engage in off-task behavior when faced with uncertainty (Jordan, 2015). Whereas no other UMP is linked to this behavior and instead use tactics such as searching for information or trial-and-error experimentation (Jordan, 2015). Therefore, participation level of students could be a possible factor influencing which UMP correlates to the use of transactive communication.

The results of the correlational analyses between the UMS and transactive communication show that all UMS are significantly and positively correlated. The UMS ignoring uncertainty shows a significant positive correlation particularly with critiquing and unconditionally accepting the input of other students. One possible theory could be that a student's motivation to ignore uncertainty may predict their use of transactive communication. In other words, some students might choose to ignore uncertainty not because of the uncertainty itself but due to the possible opinions of their group mates (Jordan, 2010). Jordan and Babrow (2013) explain that communication during brainstorming sessions is largely influenced by the student's sense of identity and their relationships with their group mates. This influence is even more apparent when students feel discomfort in the face of uncertainty. For instance, a student might be too proud to acknowledge uncertainty, choosing instead to criticize others as a way to assert dominance and competence (Ares, 2008). Alternatively, a student might agree unconditionally with others because they feel too vulnerable to express their own opinions (Azmitia & Montogemery, 1993). Therefore, students who choose to ignore uncertainty but still engage in agreeing unconditionally and critiquing might do so as they feel uncomfortable to acknowledge their own uncertainty in front of their group mates.

Strengths

One strength is that this study’s data contained data from a narrow age group. The data consists of students in grades four till six. Van Dijk et al. (2014) stresses the importance of an intervention design to increase transactive communication that is tailored to specific age groups. Therefore, the narrow age range of this data provided more applicable data for elementary school students.

Limitations and Future Research

The first limitation that should be considered in this study is that the *UMP Deny Uncertainty* was almost not present throughout the data. This lack of occurrences is a challenge for Spearman's rho as it becomes less effective and more susceptible to increased variability with little data. Still performing the correlational analyses creates less stable and potentially less reliable results (De Winter et al., 2016). This should be taken into account when using the results to draw conclusions about students that are prone to deny uncertainty and their use of transactive communication.

The second limitation in this study is the interrater reliability of the coding schemes used in this study. The interrater reliability of all three coding schemes were too low to ensure reliable results (Hallgren, 2012). The lack of consensus between coders indicates that the coders and coding schemes lack quality and accuracy (Shuyan, 2011). Consequently, the variables measures could be incorrectly represented hurting the validity of the results and the statistical inferences done (McHugh, 2012). Therefore, the low interrater reliability coefficient negatively impacts both the reliability and the validity of the results of this study and should be considered before being used for future references.

Furthermore, some UMS that students used in the videos could have been under-observed. Jordan (2010) studied UMS by using a coding scheme and interviewing students afterward. In the interviews, it became clear that students had frequently used strategies that were initially not observed. This could suggest that in this current study, which relied solely on video recordings, may have missed important behaviors indicating the use of UMS. Consequently, this under-observation could negatively affect the validity of the findings by not fully capturing the UMS used by the students.

It is recommended that a replication study is performed with improved coding schemes and an additional interview before conclusions can be drawn about the correlation between the UMS and transactivity, as well as between the UMP and transactivity. The improved coding scheme could benefit from clearer rules about how often a repeated code can be coded in proximate segments, clearer differences between similar codes, and more use of descriptive coding instead of interpretative coding. Lastly, the coders could also benefit from more training to get familiar with the coding schemes (Shuyan, 2011; McHugh, 2012). Implementing these suggestions will help to improve the interrater reliability and validity of the results.

Furthermore, future research is recommended to explore the relationship between the UMS *Ignore* and social influences. This study postulates that students that choose to ignore

uncertainty might do so because of social influences. They might feel too threatened or unsafe to share their uncertainty (Ares, 2008; Jordan, 2010; Jordan and Babrow, 2013). However, this study was unable to confirm this, indicating a need for further research to explore this potential relationship more thoroughly.

Lastly, future research is recommended to explore intervention designs that aim to enhance communication throughout assignments, thereby encouraging students with the UMP *Take Action* to engage more actively in communication and increasing their transactive communication as well. This study postulates that students with the UMP *Take Action* are not prone to communicate but that when they do, they make use of transactive communication. Therefore, promoting communication overall would help to promote transactive communication for these students as well. A possible approach for students with the UMP *Take Action* could be to limit the possibility of them starting the assignment without a discussion prior. This was done in the assignment of this study as well, where they first needed to discuss their knowledge and possible actions before they could perform them. It is thought that because of this, the students with the UMP *Take* Action, who would initially communicate minimally and preferred to engage in trail-and-error experiments, would now be encouraged to communicate more.

Conclusion

To conclude, this research aimed to study to what extent elementary school students' UMP and their use of UMS are correlated with their use of transactive communication. The results show that all UMS are significantly and positively correlated with transactive communication. Among the UMP, the propensities *Seek Plausible Explanation*, P*ause for Reflection*, and *Take Action* showed significant results for a positive correlation with transactive communication. The UMP *Request Help* and *Deny Uncertainty* showed no correlation. These results were according to the expectations except for the UMP *Take Action*. It was thought that this UMP would show no correlation with transactive communication. However, these results should take the multiple limitations into account. The study faced low interrater reliability of the coding schemes, which could have affected the reliability of the findings. Therefore, a replication study should be conducted to address these issues with refined coding schemes and an additional interview to enhance the reliability and validity of the results.

References

Ares, N. (2008). Appropriating roles and relations of power in collaborative learning. *International Journal of Qualitative Studies in Education, 21*(2), 99–121. https://doi.org/10.1080/09518390701256472

Azmitia, M., & Montgomery, R. (1993). Friendship, transactive dialogues, and the development of scientific reasoning. *Social development, 2*(3), 202-221.

Chen, Y., Benus, M. J., & Hernandez, J. (2019). Managing uncertainty in scientific argumentation. Science Education, 103(5), 1235–1276. https://doi.org/10.1002/sce.21527

ELAN (Version 6.7) [Computer software]. (2023). Nijmegen: Max Planck Institute for Psycholinguistics, The Language Archive. Retrieved from https://archive.mpi.nl/tla/elan

Fitzgerald, D. L. (2009). How Development Affects Learning: Lessons Learned from Developmental, Cognitive, and Natural Science. In *A Blueprint for Promoting Academic and Social Competence in After-School Programs* (pp. 21–42). Springer US. https://doi.org/10.1007/978-0-387-79920-9_2

Hallgren, K. A. (2012). Computing inter-rater reliability for observational data: An overview and tutorial. Tutorials in Quantitative Methods for Psychology, 8(1), 23–34. https://doi.org/10.20982/tqmp.08.1.p023

Hogenkamp, L., van Dijk, A. M., & Eysink, T. H. S. (2021). Analyzing socially shared regulation of learning during cooperative learning and the role of equal contribution: A grounded theory approach. *Education Sciences*, *11*(9), 512. https://doi.org/10.3390/educsci11090512

Homer Arthur, R. (2005). Transactive discourse during assessment conversations on

science learning. *Dissertation, Georgia State University* https://doi.org/10.57709/1061126

Jordan, M. E., & Babrow, A. S. (2013). Communication in creative collaborations: The challenges of uncertainty and desire related to task, identity, and relational goals. *Communication Education,* 62(2), 210–232. https://doi.org/10.1080/03634523.2013.769612

Jordan, M. E., & McDaniel, R. R. (2014). Managing uncertainty during collaborative problem solving in elementary school teams: The role of peer influence in robotics engineering activity. *Journal of the Learning Sciences*, 23(4), 490–536. https://doi.org/10.1080/10508406.2014.896254

Jordan, M. E. (2015). Variation in students' propensities for managing uncertainty. *Learning and Individual Differences,* 38, 99–106. https://doi.org/10.1016/j.lindif.2015.01.005

Jurkowski, S., & Hänze, M. (2015). How to increase the benefits of cooperation: Effects of training in transactive communication on cooperative learning. *British Journal of Educational Psychology,* 85(3), 357–371. https://doi.org/10.1111/bjep.12077

Laal, M., & Ghodsi, S. M. (2012). Benefits of collaborative learning. *Procedia - Social and Behavioral Sciences,* 31, 486–490. https://doi.org/10.1016/j.sbspro.2011.12.091

O'Reilly, J. X. (2013). Making predictions in a changing world—inference, uncertainty, and learning. *Frontiers in Neuroscience, 7*. https://doi.org/10.3389/fnins.2013.00105

Panitz, T. (1999). The motivational benefits of cooperative learning. *New Directions for Teaching and Learning*, 1999(78), 59–67. https://doi.org/10.1002/tl.7806

Roger, T., & Johnson, D. W. (1994). An overview of cooperative learning. *Creativity and Collaborative Learning* 14(2), 1-21

Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation coefficients: Appropriate use

and interpretation. *Anesthesia & Analgesia*, 126(5), 1763–1768. https://doi.org/10.1213/ANE.0000000000002864

Sun, S. (2011). Meta-analysis of Cohen's kappa. *Health Services and Outcomes Research Methodology*, 11(3–4), 145–163. https://doi.org/10.1007/s10742-011-0077-3

Soller, A., & Lesgold, A. (2007). Modeling the process of collaborative learning. *The Role of Technology in CSCL* (pp. 63–86). https://doi.org/10.1007/978-0-387-71136-2_5

Van Dijk, A. M., Eysink, T. H. S., & de Jong, T. (2020). Supporting cooperative dialogue in heterogeneous groups in elementary education. *Small Group Research*, 51(4), 464–491. https://doi.org/10.1177/1046496419879978

Van Dijk, A. M., Gijlers, H., & Weinberger, A. (2014). Scripted collaborative drawing in elementary science education. *Instructional Science*, 42(3), 353–372. https://doi.org/10.1007/s11251-013-9286-1

Voor Ouders | Primair Onderwijs. (2024). Cito. https://cito.nl/onderwijs/primair-onderwijs/voor-ouders/

Wang, X., Wen, M., & Rosé, C. (2017). Contrasting explicit and implicit support for transactive exchange in team oriented project based learning. *Philadelphia, PA: International Society of the Learning Sciences,* 1.

De Winter, J. C., Gosling, S. D., & Potter, J. (2016). Comparing the Pearson and Spearman correlation coefficients across distributions and sample sizes: A tutorial using simulations and empirical data. *Psychological methods*, *21*(3), 273. https://doi.org/10.1037/met0000079

Appendix A

R-Studio Codes

```
# loading libraries
library("tidyverse")
library("foreign")
library("ggplot2")
library("janitor")
library("stats")
library("dplyr")
library(“irr”)



# interrater reliability
## transactivity interrater reliability
### loading the data set
data.transactivity <-
read.csv("/Users/leonorezee/Downloads/M12/M12_interrater/M12_transactivity_all_merged5
.csv", sep = ";", stringsAsFactors = TRUE, check.names = FALSE)

###transactivity codes
transactivity1 <- data.transactivity$'Transactivity'
transactivity2 <- data.transactivity$'transactivity'

###Calculate Cohen's kappa
kappa_transactivity <- kappa2(cbind(transactivity1, transactivity2))
print(kappa_transactivity)

## propensities interrater reliability
### loading the data set
data.propensities <-
read.csv("/Users/leonorezee/Downloads/M12/M12_interrater/M12_propensities_all_merged5.
csv", sep = ";", stringsAsFactors = TRUE, check.names = FALSE)
```

```
### propensity codes
propensities1 <- data.propensities$'Propensities'
propensities2 <- data.propensities$'propensities uncertainty magement'

### Cohen's Kappa
kappa_propensities <- kappa2(cbind(propensities1, propensities2), "unweighted")
print(kappa_propensities)

##strategies interrater reliability
### load the data set
data.strategies <-
read.csv("/Users/leonorezee/Downloads/M12/M12_interrater/M12_strategies_all_merged4.cs
v", sep = ";", stringsAsFactors = TRUE, check.names = FALSE)

### strategy codes
strategies1 <- data.strategies$'Strategies uncertainty'
strategies2 <- data.strategies$'strategies uncertainty management'

### Cohen's Kappa
kappa_strategies <- kappa2(cbind(strategies1, strategies2))
print(kappa_strategies)

# Statistics
## Load the data
        outcome_trans <-
read.csv("/Users/leonorezee/Downloads/M12/M12_outcome_transactivity(2).csv", sep = ";",
stringsAsFactors = TRUE, check.names = FALSE)
        outcome_strategies <-
read.csv("/Users/leonorezee/Downloads/M12/M12_outcome_strategies.csv", sep = ";",
stringsAsFactors = TRUE, check.names = FALSE)
        outcome_propensities <-
read.csv("/Users/leonorezee/Downloads/M12/M12_outcome_propensities.csv", sep = ";",
stringsAsFactors = TRUE, check.names = FALSE)
```

```
## descriptive statistics transactivity
        outcome_trans %>% select(Externalization) %>% summary()
        outcome_trans %>% select(Elicitation) %>% summary()
        outcome_trans %>% select(Agreement) %>% summary()
        outcome_trans %>% select(Dissagreement) %>% summary()
        outcome_trans %>% select("Transactive integration") %>% summary()
        outcome_trans %>% select(Critiquing) %>% summary()
        outcome_trans %>% select("Information sharing") %>% summary()
        outcome_trans %>% select("Quick Consensus") %>% summary()
        outcome_trans %>% select(Transactivity) %>% summary()

        outcome_trans <- outcome_trans %>% slice(1:(n() - 1))
        outcome_trans %>%
          select(-Participant) %>%
          map(sd)

## checking assumptions
        outcome_trans  %>%
          ggplot(aes(x = Total)) +
          geom_histogram(binwidth = 1)

        outcome_strategies  %>%
          ggplot(aes(x = 'Total strategies')) +
          geom_histogram(binwidth = 1)

        outcome_propensities  %>%
          ggplot(aes(x = 'Total propensities')) +
          geom_histogram(binwidth = 1)



##correlation tests strategies and transactivity
        cor.test(outcome_strategies$`Ignore`, outcome_trans$'Information sharing',
                 method = "spearman",
```

```
        exact = FALSE)
    cor.test(outcome_strategies$`Ignore`, outcome_trans$Externalization,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Ignore`, outcome_trans$Elicitation,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Ignore`, outcome_trans$Agreement,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Ignore`, outcome_trans$Dissagreement,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Ignore`, outcome_trans$`Quick Consensus`,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Ignore`, outcome_trans$`Transactive integration`,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Ignore`, outcome_trans$Critiquing,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Exhibit off-task behaviour`, outcome_trans$'Information
sharing',
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Exhibit off-task behaviour`,
outcome_trans$Externalization,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Exhibit off-task behaviour`, outcome_trans$Elicitation,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Exhibit off-task behaviour`, outcome_trans$Agreement,
```

```
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Exhibit off-task behaviour`,
outcome_trans$Dissagreement,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Exhibit off-task behaviour`, outcome_trans$`Quick
Consensus`,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Exhibit off-task behaviour`, outcome_trans$`Transactive
integration`,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Exhibit off-task behaviour`, outcome_trans$Critiquing,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Discounts negative information`,
outcome_trans$'Information sharing',
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Discounts negative information`,
outcome_trans$Externalization,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Discounts negative information`,
outcome_trans$Elicitation,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Discounts negative information`,
outcome_trans$Agreement,
        method = "spearman",
        exact = FALSE)
```

```
        cor.test(outcome_strategies$`Discounts negative information`,
outcome_trans$Dissagreement,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$`Discounts negative information`, outcome_trans$`Quick
Consensus`,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$`Discounts negative information`,
outcome_trans$`Transactive integration`,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$`Discounts negative information`,
outcome_trans$Critiquing,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$`Avoids/ignores information`,
outcome_trans$'Information sharing',
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$`Avoids/ignores information`,
outcome_trans$Externalization,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$`Avoids/ignores information`, outcome_trans$Elicitation,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$`Avoids/ignores information`, outcome_trans$Agreement,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$`Avoids/ignores information`,
outcome_trans$Dissagreement,
                 method = "spearman",
                 exact = FALSE)
```

```
        cor.test(outcome_strategies$`Avoids/ignores information`, outcome_trans$`Quick
Consensus`,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$`Avoids/ignores information`,
outcome_trans$`Transactive integration`,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$`Avoids/ignores information`, outcome_trans$Critiquing,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$Maintain, outcome_trans$'Information sharing',
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$Maintain, outcome_trans$Externalization,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$Maintain, outcome_trans$Elicitation,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$Maintain, outcome_trans$Agreement,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$Maintain, outcome_trans$Dissagreement,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$Maintain, outcome_trans$`Quick Consensus`,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$Maintain, outcome_trans$`Transactive integration`,
                 method = "spearman",
                 exact = FALSE)
        cor.test(outcome_strategies$Maintain, outcome_trans$Critiquing,
                 method = "spearman",
```

```
        exact = FALSE)
    cor.test(outcome_strategies$`Delays decisions`, outcome_trans$'Information sharing',
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Delays decisions`, outcome_trans$Externalization,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Delays decisions`, outcome_trans$Elicitation,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Delays decisions`, outcome_trans$Agreement,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Delays decisions`, outcome_trans$Dissagreement,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Delays decisions`, outcome_trans$`Quick Consensus`,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Delays decisions`, outcome_trans$`Transactive
integration`,
        method = "spearman",
        exact = FALSE)
    cor.test(outcome_strategies$`Maintain`, outcome_trans$Total,
        method = "spearman",
        exact = FALSE)


## transactivity and strategies correlation in a table
    # Convert all columns to numeric, except the 'Participant' column
    trans_columns <- c('Externalization', 'Elicitation', 'Information sharing', 'Agreement',
'Dissagreement', 'Quick Consensus', 'Transactive integration', 'Critiquing', 'Transactivity',
'Total')
    strategies_columns <- c('Ignore', 'Exhibit off-task behaviour', 'Discounts negative
information', 'Avoids/ignores information', 'Maintain', 'Delays decisions', 'Generates and or
```

```
maintains multiple options', 'Talks about the shared understanding of the task', 'Increase',
'Asks new questions', 'Mention inconsistencies in arguments', 'Shares what is not understood',
'Point out when something does not match with prior knowledge', 'Reduce', 'Ask a teacher or
groupmate for information', 'Answer/clarify statements', 'Solve inconsistency/weakness',
'Explain the problem to others', 'Total strategies')

    outcome_trans[trans_columns] <- sapply(outcome_trans[trans_columns], function(x)
as.numeric(as.character(x)))
    outcome_strategies[strategies_columns] <-
sapply(outcome_strategies[strategies_columns], function(x) as.numeric(as.character(x)))

    results <- data.frame(Variable1 = character(0), Variable2 = character(0),
SpearmanRho = numeric(0), PValue = numeric(0), stringsAsFactors = FALSE)

    for (trans_col in trans_columns) {
      for (strategies_col in strategies_columns) {
        combined_data <- na.omit(data.frame(outcome_trans[[trans_col]],
outcome_strategies[[strategies_col]]))

        # Perform cor.test using Spearman's method
        if (nrow(combined_data) > 2) {  # Ensure there are at least two pairs of non-NA
data points
          test_result <- cor.test(combined_data[[1]], combined_data[[2]], method =
"spearman", exact = FALSE)
          # Store the results in the data frame
          results <- rbind(results, data.frame(Variable1 = trans_col, Variable2 =
strategies_col, SpearmanRho = test_result$estimate, PValue = test_result$p.value,
stringsAsFactors = FALSE))
        } else {
          results <- rbind(results, data.frame(Variable1 = trans_col, Variable2 =
strategies_col, SpearmanRho = NA, PValue = NA, stringsAsFactors = FALSE))
        }
      }
    }
```

```
# Print the results table
print(results)

## Correlations propensities and transactivity
# Convert all columns to numeric, except the 'Participant' column and any other non-numeric columns
# Identify numeric columns for outcome_trans
trans_columns <- c('Externalization', 'Elicitation', 'Information sharing', 'Agreement', 'Dissagreement', 'Quick Consensus', 'Transactive integration', 'Critiquing', 'Transactivity', 'Total')
trans_columns <- trans_columns[trans_columns %in% names(outcome_trans)]

# Identify numeric columns for outcome_propensities, excluding non-numeric
propensities_columns <- setdiff(names(outcome_propensities), "Participant")
propensities_columns <- propensities_columns[sapply(outcome_propensities[propensities_columns], is.numeric)]

# Convert columns to numeric
outcome_trans[trans_columns] <- sapply(outcome_trans[trans_columns], function(x) as.numeric(as.character(x)))
outcome_propensities[propensities_columns] <- sapply(outcome_propensities[propensities_columns], function(x) as.numeric(as.character(x)))

# make a list
results <- data.frame(Variable1 = character(0), Variable2 = character(0), SpearmanRho = numeric(0), PValue = numeric(0), stringsAsFactors = FALSE)

# perform cor.test with Spearman's rho,
for (trans_col in trans_columns) {
  for (propensities_col in propensities_columns) {
    # Create a combined data frame
    combined_data <- na.omit(data.frame(outcome_trans[[trans_col]], outcome_propensities[[propensities_col]]))
```

```
            if (nrow(combined_data) > 2) {  # Ensure there are at least two pairs of non-NA data points
              test_result <- cor.test(combined_data[[1]], combined_data[[2]], method = "spearman", exact = FALSE)
              # Put the results in the data frame
              results <- rbind(results, data.frame(Variable1 = trans_col, Variable2 = propensities_col, SpearmanRho = test_result$estimate, PValue = test_result$p.value, stringsAsFactors = FALSE))
            } else {
              results <- rbind(results, data.frame(Variable1 = trans_col, Variable2 = propensities_col, SpearmanRho = NA, PValue = NA, stringsAsFactors = FALSE))
            }
          }
        }

        print(results)
```