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Students' collaboration dispositions across diverse skills of collaborative problem solving in a computer-based assessment environment

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ABSTRACT

Collaborative problem solving (CPS) has been considered as one of the vital 21st century skills. To be successful in CPS requires not only CPS skills but also positive attitudes towards collaboration (i.e., collaboration dispositions). However, the relationship between CPS skills and collaboration dispositions has not been studied much, especially among early adolescent students. The purpose of this study is to investigate the dimensions of students' collaboration dispositions and their relationship to students' assessed CPS skills (i.e., social and cognitive skills of CPS, see Hesse et al., [2015]). Data were collected from 214 Finnish sixth-grade students ($Mean_{age}$ = 12.44, SD_{age} = 0.32, female = 116, 54.21%) in 2019. Students' CPS skills were assessed based on the log file data collected from student pairs' participation in four tasks in a computer-based assessment environment. Collaboration dispositions were measured through a self-report questionnaire. Exploratory factor analysis was applied to investigate the dimensions of students' collaboration dispositions. In addition, analysis of variance was utilised to examine the dimensions of students' collaboration dispositions across their diverse social and cognitive CPS skills. Three dimensions of students' collaboration dispositions were identified, namely, *negotiation*, *advocate/guide* and *cooperation*. Further, we found that the early adolescent students' CPS social skills, but not cognitive skills of CPS, were associated with their perceived collaboration dispositions. Based on our results, we argue that it is crucial to provide systematic and rigorous interventions and/or models to pay attention not only to integrating CPS skills with subject studies in schools, but also to make students aware of their collaboration dispositions.

1. Introduction

Learning and working successfully in the digital age requires competence of managing rapidly increasing amounts of information, creating new knowledge, and collaborating with others (Häkkinen et al., 2020). This presupposes that learners are competent in generic and transversal 21st century skills such as problem solving, collaboration, critical thinking and the use of information and communication technologies (Binkley et al., 2012). These skills have been defined by various international organisations and projects such as the Organisation for Economic Co-operation and Development (OECD) and the Assessment and Teaching of 21st Century Skills (ATC21S) project (Care et al., 2018). However, such skills are not specific to this century (i.e., these skills have been considered crucial for human beings for several decades), although typical for this century is the way in which these skills impact national and global economies (Rotherham & Willingham, 2009). Rather than memorising facts, 21st century skills are to be learnt together with subject matter to facilitate the individual's ability to apply the acquired knowledge for different purposes (Silva, 2009). Recent research acknowledges the expansion of what students should learn to encompass 21st century skills, for instance, collaborative problem solving (CPS) and other skills that are discussed in international and national reports (Graesser et al., 2022). In the present study, we focus on assessing early adolescents' (i.e., sixth graders') CPS skills with regard to collaboration and problem solving (Hesse et al., 2015) because these aspects are intertwined in the sphere of daily life (Li et al., 2021). In addition, collaboration can facilitate the improvement of learning performance (Aldieri et al., 2018).

On the other hand, 21st century skills are defined to cover not only the actual skills but also the attitudes, knowledge, values and ethics related to these skills (Voogt & Roblin, 2012). In this study, we used collaboration dispositions to represent students' general attitudes towards collaboration. Having positive collaboration dispositions is considered vital for students to have greater creative self-efficacy (Kong

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et al., 2018), to better recognise shared goals and shared benefits when working with others (Johnson & Johnson, 2009), to have higher satisfaction towards online courses (Wengrowicz et al., 2018), and to learn effectively in our global knowledge society (Voogt et al., 2013). For instance, in pairs or small groups, it is crucial for members to possess positive values with respect to collaboration for successful learning outcomes (Barron et al., 2013; Wang et al., 2009). Particularly, it has been found that students' collaboration dispositions are highly associated with their learning outcomes in the context of CPS (Koutrouba et al., 2012; OECD, 2017). Consequently, obtaining a better understanding of the relationship between students' CPS skills and their collaboration dispositions offers grounds for a deeper investigation into how instructions could be better designed to assist in students' developing these skills (Hughes & Jones, 2011).

Previous studies have investigated mid- and late-adolescents' collaboration dispositions (e.g., ninth- and tenth-graders from Germany [Stadler et al., 2020], high school students from the United States [Wang et al., 2009] and first- and second-year pre-service teacher students from Finnish universities [Ahonen et al., 2018; Häkkinen et al., 2020]). In this study, we fill in the research gap to investigate the association between early adolescents' (i.e., sixth graders') assessed CPS skills and their perceived collaboration dispositions.

2. Background

2.1. CPS skills

CPS refers to a shared activity between pairs or small groups to transform a given problem state into a desired goal state (Hesse et al., 2015), combining problem solving, communication and collaboration (Care et al., 2016). Although there are several definitions of CPS in recent research (e.g., Care et al., 2018), all of them emphasise that there is a shared goal to be accomplished through problem solving and that an individual is ill-equipped to or cannot solve the problem alone (Graesser et al., 2020). The present study adopted the CPS framework developed in the ATC21S project, which is based on the distinction between social and cognitive skills and includes a hierarchy of subskills (Hesse et al., 2015). In this framework, the social skills associated with CPS involve managing oneself and other members, while the cognitive skills associated with CPS involve managing the given task. The social skills are articulated through social interactions with other students, including participation, perspective taking and social regulation. "Participation" refers to one's readiness to share knowledge/information and to externalise individuals' ideas; "perspective taking" is often considered a key commutation competence (Weinstein, 1969) and refers to the ability to take into account partners' perspectives; further, "social regulation" denotes one's awareness of the strengths and weaknesses of their partners (i.e., team awareness [Fransen et al., 2011]). On the other hand, cognitive skills refer to the "problem solving" component of CPS, which includes task regulation and knowledge building. "Task regulation" is defined as the planning and monitoring of the skills required for developing strategies for problem solving and shared problem representation (i.e., "joint problem space" [Roschelle & Teasley, 1995]), whereas "knowledge building" (Scardamalia & Bereiter, 1996) refers to the ability to learn and build knowledge through interactions between members. Thus, members in pairs or groups should identify the structure of the problem, collect information for building solutions and engage in solving the problem strategically.

A significant amount of earlier research has investigated the social and cognitive skills related to CPS as separated constructs (e.g., Chung et al., 1999), while more recent work has addressed the complex relationship between these two sub-sets of CPS skills (e.g., Liu et al., 2015). Existing research argues that interactions involving participants with high social skills can facilitate high-quality cognitive engagement because active social interactions enable feedback to be communicated well and can support joint planning and the execution of plans within a pair or small group (Rogat & Linnenbrink-Garcia, 2011). Thus, the social and cognitive skills associated with CPS are inherently interrelated, and they manifest according to situational needs (Hesse et al., 2015). According to Chang et al. (2017), there are three core CPS situations in which social and cognitive CPS skills function interactively: 1) when constructing shared knowledge to understand the problem and its solution (Rummel & Spada, 2005), 2) when negotiating and coordinating (Barron, 2000) (i.e., responding to members' questions or ideas and monitoring the execution of the solution plan) and 3) when maintaining the pair or group function (i.e., ensuring individuals' roles in the pair or small group and taking the initiative to advance CPS processes). In these CPS situations, first, establishing a mutual understanding requires members to socially engage in building and constantly updating a common ground (Clark & Brennan, 1991) of information and knowledge, which calls for certain cognitive CPS skills such as the ability to collect elements of information related to the task. In turn, proficiency in social communication entails taking into consideration partners' perspectives and building and maintaining a shared understanding and knowledge to solve the problem (Graesser et al., 2017). Second, efforts to achieve an agreed-upon solution plan by negotiating and coordinating the content and structure of the interaction between partners also require strong social skills. Pairs or small groups often experience major difficulties in coordinating the collaborative process in general, particularly when establishing common frameworks of references, coming to a joint understanding, resolving variations in understanding and negotiating individual and collective actions (Barron, 2000). Communication involving members with good social skills is the key to resolving these difficulties (Bause et al., 2018). Third, it is important that all members are aware of being a part of the pair or small group and realise that the collective outcomes are affected by individual behaviours. Maintaining an effective pair or small group requires the members to distribute responsibilities among themselves (Care et al., 2016), which often naturally evolves during the CPS process. Sometimes, members may not stay focused on the task and/or may distract other members by talking about issues that are not related to the task. At such times, other members with good social skills could attend to the functioning and organisation of the pair/small group by taking the initiative to advance the required CPS processes (Hesse et al., 2015).

2.2. Students' collaboration dispositions

Although teachers could explicitly instruct students to collaborate (Littleton & Mercer, 2013), an affirmative collaboration disposition plays a crucial role in collaboration due to the importance of students' willingness to participate in the contribution to joint work (Fransen et al., 2013). In collaborative activities, pairs or small groups assume ownership of the procedures and outcomes of the collaboration when individuals are empowered and encouraged to collaborate towards shared goals and collective achievements (Zurita & Nussbaum, 2004). In other words, collective achievements greatly rely on individual members' attitudes towards collaboration, and it is important to examine students' collaboration dispositions and their relationship to students' assessed CPS outcomes.

In this study, we defined students' collaboration dispositions as their general attitudes towards collaboration and working in pairs or groups (e.g., Wang et al., 2009). Collaboration dispositions are considered relatively broad and stable attitudes or habits (Schussler, 2006) beyond specific collaborative learning contexts or learning activities (Ahonen et al., 2018). This is in accordance with the concept of collaboration dispositions used in the work of Wang et al. (2009) that proposed three dimensions of high school students' collaboration dispositions: negotiation, advocate/guide and cooperation. Negotiation is a core element of collaboration, in which students need to have discussions with their partners, take others' perspectives into consideration and attempt to adjust their perspectives and actions accordingly. Advocate/guide refers to dispositions towards guiding partners and spontaneously taking

primary responsibility for the accomplishment of the pairs or small groups. Cooperation focuses on the general attitudes towards collaboration and working in pairs or small groups, such as the students' perceptions regarding the effectiveness and/or preferences of the working mode.

Utilising the same self-report questionnaire to assess students' collaboration dispositions as that used by Wang et al. (2009), Stadler et al. (2020) also found three dimensions of collaboration dispositions (i.e., negotiation, advocate/guide and cooperation) among 483 German mid-adolescents (i.e., ninth- and tenth-graders with a mean age of 15.80 years), which are the same dimensions found in the work of Wang et al. (2009) with 159 high school students (mean age 16.10 years) in the United States. It appears that the three dimensions extracted from the measurements of students' perceived collaboration dispositions by Wang et al. (2009) function adequately for mid-adolescent students. Consequently, the present study applied the instruments of Wang et al. (2009) for the collaboration dispositions among early adolescent students.

Students' collaboration dispositions conceptually reflect the students' general attitudes or perceptions towards collaboration. On the other hand, students' CPS skills are their actual competences in CPS conceptualized into social and cognitive skills with several subskills respectively (Hesse et al., 2015). In the ATC21S computer-based assessment environment that adopted the framework of Hesse et al. (2015), the assessed social and cognitive skills of CPS are the outcomes of students' CPS tasks. In terms of the relationship between students' collaboration dispositions and their learning outcomes in CPS, Stadler et al. (2020) found that the perceived collaboration dispositions (i.e., cooperation, advocate/guide and negotiation) were positively associated with the outcomes of the PISA 2015 CPS tasks at a moderate level among ninth- and tenth-graders from Germany. Moreover, applying a revised version of the self-report questionnaire of Wang et al. (2009) and using the ATC21S computer-based assessment tasks, Ahonen et al. (2018) found that the disposition related to negotiation in CPS was strongly associated with the assessed social CPS skills (but not with the cognitive ones) among second-year pre-service teacher students from a Finnish university. Based on the findings of Stadler et al. (2020) and Ahonen et al. (2018), we assumed that early adolescent students' collaboration dispositions might also be related to their assessed social and cognitive CPS skills.

Therefore, our study addresses the following research questions:

1. What kinds of dimensions of collaboration dispositions can be identified in early adolescent students? How are these related to one another?
2. How do collaboration dispositions vary across different social and cognitive CPS skill levels?

3. Methods

3.1. Participants and procedure

Data were collected from 214 sixth-grade students ($Mean_{age} = 12.44$, $SD_{age} = 0.32$, female = 116, 54.21%) in 12 classes from five primary schools in a Finnish urban area in 2019. All the participants filled in a consent form to participate in the study. We utilised the computer-based assessment environment developed in the ATC21S project at the University of Melbourne. In our study, a bundle of four game-like tasks (i.e., Laughing Clown, Sunflower, Hot Chocolate and Olive Oil) (Care et al., 2015) was administered to the students. The tasks were based on the hypothetico-deductive approach with a focus on generic skills, meaning that the tasks were content-free with no requirement of prior knowledge. Students were randomly assigned to work in pairs and were labelled as "A" or "B" (Student A or Student B). Before the tasks started, the aims of the study and the practical issues of using the assessment environment (e.g., how to log in the computer-based assessment environment) were introduced to the participants. Each student collaborated synchronously in a different room with their paired partners using laptops. The participants were told that they have to solve the problems together with their partners and could communicate to each other by typing texts in the chat window. They could also click buttons and drag objects on their computer screens. Further, they had to go through the assessment tasks in a fixed order (i.e., Laughing Clown, Sunflower, Hot Chocolate and Olive Oil) and could not proceed to the next task before both members of the pair had clicked the "Finish" buttons on their screens. Moreover, once the "Finish" button had been clicked, the tasks would not be available to access again. The participants were allowed to skip a task by not solving the problem. In this case, both of the students in the pair should click the "Finnish" button to reach a consensus to skip the task. No time limit was imposed for any of the tasks. In addition to the four CPS tasks, the participants also responded to a printed questionnaire that assessed their perceived collaborative dispositions.

3.2. CPS tasks

Laughing Clown is a symmetric task (i.e., both participants had the same resources and visuals) that was the simplest of the four tasks. In this task, a clown machine and 12 balls were shown to each student, and they needed to identify how the clown machine functions to determine whether their clown machine worked in the same way as their partner's. The Sunflower task is also a symmetric task, and it required the paired partners to mix two plant foods to maximise the height of a plant. The goal of Hot Chocolate was to maximise profits and sales in Europe by utilising information related to the given recipe and market. The Hot Chocolate task is asymmetric, for which students in a pair had different resources and visuals. To address the enhancement of inductive and deductive reasoning skills, the Olive Oil task follows the reasoning procedures that are required for the Tower of Hanoi problem popularised by mathematician Eduard Lucas in 1883 (Newell & Simon, 1972). In the Olive Oil task, Student A had a 3-L jar, an olive oil tank, a transfer pipe and a bucket, while Student B had a 5-L jar, a transfer pipe and a bucket. The objective of the task was to fill Student B's jar with 4 L of olive oil. Both students could type texts in the chat window to talk to each other. Fig. 1 displays the resources provided in the problem space on the two screens for the Olive Oil task. For the details of the tasks, see Griffin and Care (2015).

3.3. Social and cognitive CPS skills

The social and cognitive CPS skill levels of the participants were identified and automatically assessed based on the data collected from the four tasks mentioned above. Log file data consisted of mouse events (e.g., clicking a button or dragging to move an object) and chat discussions (i.e., typing texts in the chat window) in the task environment. All the actions were recorded in sequence and time-stamped.

The focus of the ATC21S assessment tasks is on "the process and quality of problem solving" (Adams et al., 2015, p. 116) rather than the conventional design that relies on the attainment of a solution as the sole criterion using dichotomous scores. Adopting various rubrics and partial credit approaches, the students' social and cognitive CPS skill levels were measured through automation procedures based on their actions from the log file during the four CPS tasks. The automation procedure began with the identification of task features that matched the elements of the framework of Hesse et al. (2015) (i.e., participation, perspective taking and social regulation represent social skills, while task regulation and knowledge building represent cognitive skills) from all the tasks administered. This was followed by the generation of simple rules (see below) to collect data points to represent these elements. The data points were extracted from the log files generated by students' actions (i.e., clicking buttons, moving objects, typing) during the assessment tasks and consisted of the documentation of each event (i.e., every action

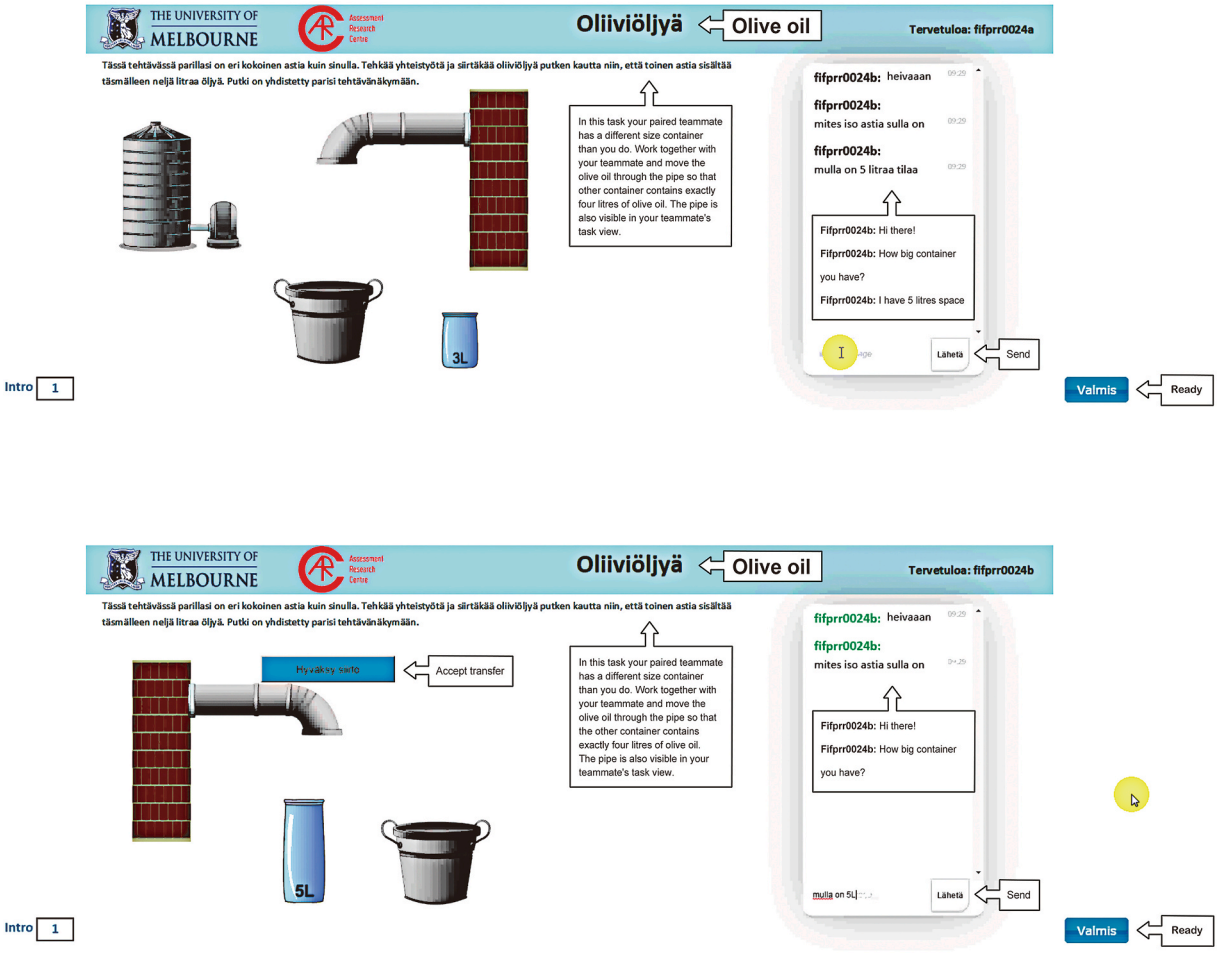

Fig. 1. Asymmetrical screen views of Student A (top) and Student B (bottom) for the Olive Oil task (originally in Finnish with English translation).

Table 1
Indicators and their corresponding levels of social regulation and knowledge building (adapted from Hesse et al., [2015]).

Element	Indicator	Low	Middle	High
Social regulation				
Negotiation	Achieving a resolution or reaching compromise	Comments on differences	Attempts to read a common understanding	Achieves resolution of differences
Self evaluation (Metamemory)	Recognising own strengths and weaknesses	Notes own performance	Comments on own performance in terms of appropriateness or adequacy	Infers a level of capability based on own performance
Transactive memory	Recognising strengths and weaknesses of others	Notes performance of others	Comments on performance of others in terms of appropriateness or adequacy	Comments on expertise available based on performance history
Responsibility initiative	Assuming responsibility for ensuring parts of task are completed by the group	Undertakes activities largely independently of others	Completes activities and reports to others	Assumes group responsibility as indicated by use of first person plural
Knowledge building				
Relationships (Represents and formulates)	Identities connections and patterns between and among elements of knowledge	Focused on isolated pieces of information	Links elements of information	Formulated patterns among multiple pieces of information
Rules: "If … then"	Uses understanding of cause and effect to develop a plan	Activity is undertaken with little or no understanding of consequence of action	Identifies short sequences of cause and effect	Uses understanding of cause and effect to plan or execute a sequence of actions Plan a strategy based on a generalized understanding of cause and effect
Hypothesis "what if …" (Reflects and monitors)	Adapts reasoning or course of action as information or circumstances change	Maintains a single line of approach	Tries additional options in light of new information or lack of progress	Reconstructs and reorganises understanding of the problem in search of new solutions

performed by the participants). In particular, these actions were used as indicators of social and cognitive skills as defined by Hesse et al. (2015). Table 1 shows the indicators of social regulation and knowledge building (see the indicators for all the elements in the framework in Hesse et al., [2015]). Such indicative behaviours were then coded into rule-based indicators that could be extracted from the process log file data through an algorithmic procedure that is similar to the description provided by Zoanetti (2010), which reported how process data (e.g., action counts) can be interpreted as an indicator of a behavioural variable (e.g., learning from a mistake). These coded indicators were considered the primary data source for the scoring procedure. Each of the scoring algorithms took such coded dichotomous or polytomous indicators as inputs and created corresponding outputs defined by the rule established for the relevant indicator. For instance, the algorithm would count the occurrences of the event "chat" (i.e., the action of typing) in the log file data when capturing the amount of interaction that occurred during a task, and the output for this indicator would be a numerical value that represents the frequency of the interaction between the partners (for more details about the algorithms used, see Adams et al., 2015). It is notable that the actual contents that participants typed in the chat window for communication were not included in the automated scoring process. Next, the indicators were analysed by Rasch modelling (Rasch, 1960) with two dimensions (i.e., social and cognitive skill levels). The modelling procedure set the average task indicator difficulty to 0, and the difficulty of an indicator was presented as an estimate that described students' skill levels based on their implementation of the bundle of four tasks. Consequently, students' skill levels were identified to be higher if they conducted more actions for which the corresponding theoretical indicators were more difficult to conduct. Students' social and cognitive skill levels were identified through a weighted likelihood estimate (WLE) score (i.e., the estimates on an item's range of difficulty shown by the participant, which provides a measure of the item's difficulty). In practice, the scoring engine, managed by the University of Melbourne, automatically coded and scored the log file data with Rasch modelling, as well as produced WLE scores and skill levels for further analysis and the production of reports for teacher and student use.

Table 2 depicts the WLE distribution for six CPS skill levels and their corresponding threshold values of WLE, which derived from the computer-based assessment environment administered by ATCS21 project. In this study, we categorised CPS skill levels 1 and 2 as low, levels 3 and 4 as medium and levels 5 and 6 as high for social and cognitive CPS skills for the better interpretability of further analysis. Most of the participants (71.96%) demonstrated a high level of social CPS skills, while a medium level of cognitive CPS skills was demonstrated by a majority of the participants (59.81%). Table 3 shows the distributions of these three levels for social and cognitive CPS skills.

Table 2
Range of WLE scores defined in the ATC21S portal corresponding to the social and cognitive skill levels of a bundle of four CPS tasks.

Skill levels generated from ATC21S	Skill levels we categorised in this study	Social WLE range	Cognitive WLE range
1	Low	Below 1.3	Below −3.5
2	Low	Between −1.3 and −0.7	Between −3.5 and −0.8
3	Medium	Between −0.7 and −0.5	Between −0.8 and 0.5
4	Medium	Between −0.5 and 0.3	Between 0.5 and 1.7
5	High	Between 0.3 and 1.5	Between 1.7 and 2.1
6	High	Between 1.5 and 7	Above 2.1

Table 3
Distributions for three levels of social and cognitive CPS skills.

Levels	Social skills of CPS (%)	Cognitive skills of CPS (%)
Low	12 (5.61%)	68 (31.78%)
Medium	48 (22.43%)	128 (59.81%)
High	154 (71.96%)	18 (8.41%)

3.4. Collaboration dispositions

To assess students' perceived collaboration dispositions, we administered a self-report questionnaire to the same participants who conducted the four CPS tasks. Measurements of collaboration dispositions (Wang et al., 2009) were applied through 16 items with a 5-point Likert-type scale that ranged from 1 (*completely disagree*) to 5 (*completely agree*), such as "I like to lead groups or projects", "I am a good listener", and "I would rather work in a group than alone". Cronbach's α for these 16 items was 0.89.

3.5. Analytic strategy

The data analysis was conducted in R 4.1.0 (R Core Team, 2021). As mentioned in previous sections of this article, there is no existing study investigating the association between early adolescents' (i.e., sixth graders') assessed CPS skills and their perceived collaboration dispositions. Therefore, rather than confirmatory factor analysis, exploratory factor analysis was conducted for the collaboration dispositions. Pearson correlations and descriptive statistics were also examined. Univariate analysis of variance (ANOVA) was conducted to compare the factors extracted from the items of collaboration dispositions across three levels (i.e., low, medium and high) of social and cognitive CPS skills. To control for Type I error when conducting multiple tests, Holm correction (Holm, 1979), instead of Bonferroni correction, was applied to compute the adjusted target p-value because Holm correction makes the Bonferroni correction less conservative. This means that it is better to detect differences that actually exist (Field et al., 2012), and hence, it is more powerful than Bonferroni correction (Aickin & Gensler, 1996; Simes, 1986). Post-hoc tests (Tukey and Bonferroni) were applied after ANOVAs.

Table 4
Descriptive statistics of self-reported items for students' collaboration dispositions.

Items	Mean	SD	Rank of mean
I enjoy seeing my classmates to succeed.	4.26	0.79	1
I find it nice that my classmates support my thoughts or suggestions.	4.23	0.87	2
I take into account what others are interested in.	4.22	0.72	3
I enjoy cooperating with other students.	4.06	0.94	4
I am open for all kind of opinions.	4.02	0.89	5
I am flexible when working with a group.	4.01	0.89	6
I am a good listener.	3.98	0.75	7
I would rather work in a group than alone.	3.95	1.15	8
I find it pleasant to bring a group together.	3.94	0.99	9
I think that groups make better decisions than individuals.	3.92	0.92	10
I find it pleasant to tell about my thoughts to others and hear what do the others think about the topic.	3.77	0.99	11
I think that teamwork increases my efficiency.	3.73	1.09	12
I find it pleasant to tell about my ideas to others.	3.65	1.11	13
I enjoy reflecting on different perspectives.	3.62	0.91	14
I like to lead groups or projects.	3.24	1.21	15
I am able to convince the others and make them see the things in my way.	3.17	0.90	16
Overall	3.86	1.00	

Note: Responses ranged from 1 (completely disagree) to 5 (completely agree).

4. Results

4.1. Factors of self-report collaboration dispositions

The internal consistency (Cronbach's α) within the 16 items related to collaboration dispositions was 0.89, which was a good level. Descriptive statistics of these 16 items is shown in Table 4. An exploratory factor analysis was conducted on the 16 items with oblique rotation (promax) because we expected the factors to be correlated. The Kaiser-Meyer-Olkin measure verified the adequacy of sample size for the analysis, KMO = 0.87 (the value is great according to Field et al. (2012)) and all KMO values for individual items were >0.75, which is well above the acceptable limit of 0.5 (Field et al., 2012). Bartlett's test of sphericity χ^2 (120) = 1575.77, $p < 0.0001$, revealed that correlations between items were sufficiently large for EFA. An initial analysis was applied to obtain eigenvalues for each factor in the data. Three factors had eigenvalues over Kaiser's criterion of 1. The scree plot clearly showed the inflexion that would justify retaining 3 factors. Given the convergence of the scree plot and Kaiser's criterion on three factors, this is the number of factors that were retained. A three-factor solution explained 51.10% of the variance in students' self-reported collaboration dispositions. The accepted minimum loading per factor for each item was over 0.45 (Tabachnick et al., 2001). Table 5 shows the factor loadings after rotation. The three factors for collaboration dispositions were named according to the work of Wang et al. (2009) from which the items in the present study derived. The first factor, entitled *advocate/-guide,* consisted of items that measured students' perceptions of leading teamwork, convincing other members, as well as offering opinions and advice. The second factor, *negotiation,* comprised items that examined the perceptions of listening to partners, taking others' perspectives into account and adjusting their actions according to other members. The third factor, cooperation, included items that measured students' perceptions of working together with others, for example in terms of how effective or preferable mode of working it was perceived to be.

The correlations between the three factors of collaboration dispositions were significantly positive and were all over 0.40 at a moderate level. This result revealed that the three dimensions of collaboration dispositions are positively related to one another. Table 6 shows the correlations between the three factors and the corresponding descriptive statistics.

Table 5
Factor loadings of the exploratory factor analysis for collaboration dispositions.

Items	Factors		
	1	2	3
1. I like to lead groups or projects.	**0.82**	−0.19	
2. I find it pleasant to tell about my ideas to others.	**0.89**		
3. I am able to convince others and make them see things my way.	**0.67**	−0.14	
4. I find it pleasant to tell about my thoughts to others and hear what the others think about the topic.	**0.74**	0.15	
5. I find it nice that my classmates support my thoughts and suggestions.	**0.54**	0.21	
6. I am a good listener.	0.20	**0.53**	
7. I enjoy seeing my classmates to succeed.		**0.61**	
8. I take into account what others are interested in.		**0.66**	
9. I enjoy reflecting on different perspectives.	−0.18	**0.78**	
10. I am open for all kinds of opinions.	−0.18	**0.74**	0.17
11. I am flexible when working with a group.	0.29	**0.46**	
12. I would rather work in a group than alone.	−0.12	−0.19	**0.85**
13. I think that groups make better decisions than individuals.		0.11	**0.52**
14. I find it pleasant to collect a group together.	0.26		**0.60**
15. I think that teamwork increases my efficiency.		0.19	**0.74**
16. I enjoy cooperating with other students.		0.15	**0.73**
Eigenvalues	6.16	1.88	1.68
% of variance explained	18.80	16.80	15.40
Cronbach's α	0.85	0.81	0.85

Note: Factor 1 = Advocate/guide; Factor 2 = Negotiation; Factor 3 = Cooperation.
Factor loadings over 0.45 appear in bold.

Table 6
Correlations and descriptive statistics between the three factors of collaboration dispositions.

	Advocate/guide	Negotiation	Cooperation
Advocate/guide	–		
Negotiation	0.49***	–	
Cooperation	0.44***	0.47***	–
Mean	3.61	4.02	3.94
SD	0.81	0.59	0.80
n	207	203	204

Note: *** = correlation is significant at the <0.001 level.

4.2. Comparisons of collaboration dispositions across social and cognitive CPS skills

To compare students' collaboration dispositions across social and cognitive skill levels respectively, three composite variables were created to represent three factors of collaboration dispositions by calculating the means of the items in each construct. Results of univariate ANOVAs showed that students who perceived the highest level of negotiation in their collaboration dispositions showed the highest social skills of CPS in the ATC21S computer-based assessment environment (see Table 7). Those who perceived the lowest level of negotiation demonstrated the lowest social skills of CPS. This implies that the students' assessed social skills of CPS were positively related to their perceived negotiation of collaboration dispositions. In terms of perceived advocate/guide, students whose social skills of CPS were assessed to be of the highest level perceived the most advocate/guide. Interestingly, students perceiving the highest level of cooperation exhibited the lowest level of social skills in the CPS assessment tasks.

Table 7 shows the results for collaboration dispositions across different social skills of CPS. Post-hoc tests (Tukey and Bonferroni) indicated that significant differences existed between medium and high social skills of CPS for negotiation, advocate/guide and cooperation. In addition, low and high social skills of CPS also presented a statistically significant difference in negotiation.

In terms of cognitive skills of CPS, there was no significant difference in the six-graders' perceptions on negotiation, advocate/guide and cooperation across the different assessed levels (see Table 8). It implied that students' assessed cognitive skills of CPS were not related to their self-report collaboration dispositions.

5. Discussion

In the present study, three factors of collaboration dispositions were found among sixth-graders in Finland, namely, advocate/guide, negotiation and cooperation. The three-factor solution in the present study is in line with the results of Häkkinen et al. (2020) except for the item "I find it pleasant to bring a group together". This item is under the cooperation category in our study but under advocate/guide in the work of Häkkinen et al. (2020), which involved 872 first-year students from three Finnish universities. However, focusing on high school students with a mean age of 16, Wang et al. (2009) found that the item "I find it pleasant to bring a group together" is one of the sub-items of cooperation, which is also under the cooperation category in our results. The participants in our sample are sixth-graders, with an average age of 12, from five Finnish primary schools. The age difference between the participants might be related to the loading of the item of "I find it pleasant to bring a group together" into different factors of collaboration dispositions. This item might reflect one of the dimensions of cooperation for early and mid-adolescents and it might represent one of the sub-items of advocate/guide in late adolescents.

Table 7
Results of univariate ANOVAs for collaboration dispositions across social skills of CPS levels.

Social skill levels of CPS	Low ($n = 12$)	Medium ($n = 45$)	High ($n = 150$)	F (df)	Significant level before Holm correction	Significant level after Holm correction
Negotiation (M/SD)	3.70/0.52	3.85/0.56	4.09/0.59	4.70 (2, 200)	$p < 0.05$	$p < 0.050$
Advocate/guide (M/SD)	3.43/0.90	3.11/0.84	3.78/0.72	13.49 (2, 204)	$p < 0.001$	$p < 0.017$
Cooperation (M/SD)	4.07/0.67	3.57/0.86	4.04/0.76	6.40 (2, 201)	$p < 0.01$	$p < 0.025$

Table 8
Results of univariate ANOVAs for collaboration dispositions across cognitive skills of CPS (three levels).

cognitive skill levels of CPS	Low ($n = 63$)	Medium ($n = 126$)	High ($n = 18$)	F (df)	Significant level before Holm correction	Significant level after Holm correction
Negotiation (M/SD)	3.84/0.61	4.07/0.57	4.20/0.61	4.11 (2, 200)	$p < 0.05$	$p > 0.017$
Advocate/guide (M/SD)	3.40/0.87	3.69/0.76	3.80/0.76	3.31 (2, 204)	$p < 0.05$	$p > 0.025$
Cooperation (M/SD)	3.94/0.86	3.94/0.76	3.84/0.88	0.13 (2, 201)	$p > 0.05$	$p > 0.050$

There were six items in the negotiation dimension of the collaboration dispositions, and five items for both the advocate/guide and the cooperation dimensions for the 12-year-old students included in our study (see Table 5). Naturally, negotiation had the highest factor loadings. This is in accordance with Stadler et al. (2020), who utilised 30 extended items from the study by Wang et al. (2009) for 483 German ninth- and tenth-graders (mean age = 15 years). It appears that negotiation is the key dimension in students' perceived collaboration dispositions (Valtonen et al., 2017) because, during collaboration, individuals need to discuss their perspectives with their partners (Häkkinen et al., 2020), adjust their actions during conflicts and resolve conflicts (Wang et al., 2009).

Regarding comparisons of students' collaboration dispositions across their social skills of CPS, we found out that students who perceived the highest level of negotiation in their collaboration dispositions showed the highest social skills of CPS, whereas those who perceived the lowest level of negotiation demonstrated the lowest social skills of CPS. This finding is in alignment with that of Ahonen et al. (2018), which reported that second-year Finnish pre-service teacher students' measured social skills and self-reported negotiation dispositions are strongly associated in the ATC21S computer-based CPS assessment tasks. Because individuals need to negotiate with their partners and adjust their actions to solve a problem, the negotiation factor is strongly related to individuals' tendency to listen to their partners, their flexibility and openness to change if there are conflicts and their competence to resolve the conflicts (Wang et al., 2009).

Interestingly, students perceiving the highest level of cooperation showed the lowest level of social skills in our CPS assessment tasks. Thus, merely preferring cooperation or enjoying it does not guarantee students to be active in social aspects of CPS. For low levels of social skills of CPS, students commence the task "independently with limited interaction from partner, mainly prompted by instructions. They may acknowledge communication cues by their partner but have not started to work collaboratively. Most communication occurs at the beginning of tasks and only in those tasks where the instructions are clear" (Griffin et al., 2015, p. 171). In other cases of low social skills of CPS, a student "actively participates in the task when it is scaffolded but works largely independently. Communication between partners occurs more frequently but is limited to significant events and information necessary to commence the task" (Griffin et al., 2015, p. 171). One possible explanation for the result of the students with low social skills of CPS perceiving a high level of cooperation is that these students are likely to avoid conflicts in collaboration activities (Tehrani & Yamini, 2020), which in turn, lead them to be somehow less expressive so as to prioritize harmony in CPS settings. In perceived advocate/guide, sixth-graders whose social skills of CPS were assessed to be of the highest level perceived the most advocate/guide. This finding is not surprising because successful advocate/guide involves a considerable amount of social interaction, which requires a high level of social skills (Stadler et al., 2020).

Collaboration provides rich opportunities for students to develop social skills; in turn, social interaction is the key to collaboration (Kreijns et al., 2003). However, based on our results, perceived advocate/guide and perceived cooperation are not positively associated with the students' assessed social skills of CPS in a computer-based assessment environment (i.e., students with medium-level of assessed social CPS skills demonstrated the lowest dispositions towards advocate/guide and cooperation; see Table 7). Hence, when designing instructions, teachers should pay attention to providing additional support to enhance students' dispositions towards advocate/guide and cooperation for those who exhibit medium levels social CPS skills. For instance, students could be encouraged to take responsibility for collaborative activities and to develop cooperation.

On the other hand, we found out that students' collaboration dispositions were not significantly different across various levels of their assessed cognitive skills of CPS. This is in line with that of Ahonen et al. (2018), who reported that cognitive skills of CPS were not associated with collaboration dispositions among 24 second-year Finnish pre-service teacher students. In the framework of Hesse et al. (2015), on which both the present study and the study of Ahonen et al. (2018) lean on, the cognitive skills of CPS "refer to the ways in which problem solvers manage the task and hand and the reasoning skills employed" (Hesse et al., 2015, p. 46). Accordingly, cognitive skills of CPS are greatly similar to those skills that are conductive to individual students' problem solving. Consequently, cognitive skills of CPS are not closely related to students' collaboration dispositions.

Applying the extended version (30 items) of collaboration dispositions (Zhuang et al., 2008), Stadler et al. (2020) found that German ninth- and tenth-graders' perceived collaboration dispositions were also positively associated with their PISA 2015 CPS performance. Similarly, utilising 16 items to measure collaboration dispositions adopted from Wang et al. (2009) which were based on the work of Zhuang et al. (2008), we found that Finnish sixth-graders' perceived collaboration dispositions are related to social skills of CPS in the ATC21S assessment environment. As Dishon and Gilead (2021, p. 407) argued, "education must not neglect the past" when seeking to develop 21st century skills, such as CPS skills. The association between students' collaboration dispositions and their assessed CPS skills could provide grounds for designing adequate interventions related to collaboration (Scalise et al., 2016), as high-level collaboration in pairs or in small groups is necessary

in almost all contexts (e.g., from families to public organisations and government agencies [OECD, 2017]). In the Finnish context, students identify collaboration as their most vital learned skills (Ahonen & Kinnunen, 2015). Although collaboration activities are a part of daily instruction in Finnish schools, there are no large-scale systematic intervention studies to assist teachers to assess or teach collaboration and CPS skills in Finland. Therefore, students appear to learn these skills more through natural maturation than through particular instructional interventions (Ahonen & Kankaanranta, 2015). We call for rigorous and systematic intervention research on a large scale (e.g., nation-wide) to provide sophisticated knowledge to schools and teachers to enable them to teach and assess students' collaboration, especially to cope with the challenges raised by today's increasingly heterogenous student population (Valtonen et al., 2017). In particular, digital technologies can be applied in such large-scale interventions due to the capabilities of digital technologies to track learning data in a detailed and reliable manner (Graesser et al., 2022).

Three dimensions of collaboration dispositions that were found in our study and in previous studies (e.g., Häkkinen et al., 2020; Stadler et al., 2020; Wang et al., 2009), and their association with the assessed CPS skills offer empirical grounds to design adequate interventions to improve students' collaboration outcomes and enhance affirmative collaboration dispositions in different age cohorts. In particular, the questionnaire dimensions of negotiation, advocate/guide and cooperation are useful starting points for designing such interventions. It might also be useful to consider how students are disposed towards collaboration together with their inclinations regarding advocate/guide and their beliefs in the value or efficacy of collaboration (Scalise et al., 2016).

There are several limitations of our study. First, self-report methods are traditionally utilised for assessing collaboration dispositions (O'Neil et al., 2003). However, self-reports might produce response bias, meaning that students might either under- or over-estimate their dispositions. Because collaboration is socially favourable, students can tend to report themselves to be more collaborative than they truly are (Scalise et al., 2016). Consequently, the sixth-graders in the present study might have over-estimated their collaboration disposition. Such social desirability bias has been widely neglected in constructing, evaluating and conducting self-report scales (King & Bruner, 2000). Future studies could apply teacher-reported and/or peer-reported methods in addition to self-report measures to gauge students' collaboration dispositions. Second, the present study merely investigated perceived collaboration dispositions and assessed CPS skills within early adolescents (i.e., sixth-graders). Future research could also involve students in early, mid- and late adolescence simultaneously so that the possible differences across age cohorts in terms of perceived collaboration dispositions and assessed CPS skills could be uncovered. Third, in our study, students collaborated synchronously in different physical locations using laptops and communicated only through written communication online. Thus, students who communicated more easily through oral expression than in a written form might have been partly restricted to exhibit their capacities in CPS. Future studies could apply both remote and face-to-face CPS settings for the same sample in order to avoid the limitation for students who prefer either written or oral communication.

6. Conclusions

Collaboration and CPS have received increasing attention since much of the work in the knowledge society is conducted by pairs or small groups. Our study investigated dimensions of students' perceived collaboration dispositions and shed light on the relationship between perceived collaboration dispositions and assessed CPS skills. We found that there were three dimensions in the sixth-graders' perceived collaboration dispositions, namely, negotiation, advocate/guide and cooperation. Moreover, students' perceived collaboration dispositions were related to their social skills of CPS, but not to cognitive skills in the ATC21S computer-based assessment environment. The results uncovered the variety of associations between perceived collaboration dispositions and assessed CPS skills among early adolescent students.

Finnish students appreciate 21st century skills, especially collaboration, and recognise their importance for their future (Ahonen & Kinnunen, 2015). Employing 21st century skills, such as CPS skills, more widely as a part of pedagogical practices should take into account students' perceived collaboration dispositions simultaneously. It is important to offer systematic and rigorous interventions and/or models for how CPS skills could be integrated with the context of subject studies (Virtanen & Tynjälä, 2018). For instance, interventions and/or models adopting a game-based learning approach have been found to be effective at facilitating students' development of 21st century skills (for a review, see Qian & Clark, 2016). On the other hand, when we aim at cultivating students' 21st century skills that allows students to adapt to a rapidly evolving social and technological landscape, the role of students' attitudes (e.g., collaboration dispositions) should not be marginalised (Timmis et al., 2016); otherwise, it would undermine the cultivation of 21st century skills (Dishon & Gilead, 2021).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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