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What is collaborative problem solving?

This chapter introduces the PISA 2015 assessment of collaborative problem solving. It provides the rationale for assessing collaborative problem-solving competence in PISA and introduces the innovative features of the 2015 assessment, particularly in contrast to the individual problem-solving assessment of PISA 2012. The framework for the assessment is discussed and sample items are presented.



In the long history of humankind (and animal kind, too) those who learned to collaborate and improvise most effectively have prevailed.

Charles Darwin

Today's workplaces demand people who can solve non-routine problems – that was the rationale for assessing individual problem solving in PISA 2012. However, today's workplaces also demand people who can solve problems in concert and collaboration with others by combining their ideas and efforts. Collaborative problem solving has several advantages over individual problem solving: labour can be divided among team members; a variety of knowledge, perspectives and experiences can be applied to try to solve the problem; and team members can stimulate each other, leading to enhanced creativity and a higher quality of the solution.

However, collaboration also poses potential challenges to team members. Labour might not be divided equitably or efficiently, with team members perhaps working on tasks for which they are unsuited or that they dislike. Some group members may not contribute their fair share to the team, while others may prioritise their own goals over the team's goals. Conflict may arise between team members, hindering the development of creative solutions. Finally, team members might not effectively co-ordinate tasks, resulting in a loss of time and reduced productivity. The potential is rife for poor communication, unhappy and resentful team members, and an inefficient use of resources. Successful collaboration, therefore, requires a concerted and constructive effort from all parties and is a skill in itself.

There is an ever-increasing demand for collaboration skills in modern workplaces. In the 20th century, there was a high and increasing wage premium related to educational attainment: those with university degrees were paid more than those with only a high school diploma, and the difference in wages between these two groups increased over the latter half of the century (Autor, Levy and Murnane, 2003; Murnane, Willett and Levy, 1995). This was attributed to an increase in employer demand for those in service, sales-related, professional and managerial/administrator positions. The skills needed to succeed in these fields were, for much of the twentieth century, the cognitive skills associated with those one obtained through a university degree.

However, Autor, Levy and Murnane (2003) and Deming (2015) further found that the skills for which there was the greatest increase in demand in the last decades of the 20th century were non-routine analytical skills (i.e. those involved in problem solving) and, to an even larger extent, non-cognitive (or social) skills, including collaboration skills. By contrast, those skills for which demand decreased were routine manual and cognitive skills. Increasing automation is expected to further reduce the demand for such routine skills while simultaneously raising the demand for those complex skills that cannot be automated.

Deming (2015) also found that, in the United States, jobs requiring a high level of both mathematics and non-cognitive skills grew by 7.2 percentage points (as a share of the US labour force) between 1990 and 2012. Jobs requiring a low level of mathematics skills but a high level of social skills grew by 4.6 percentage points over the same period. However, jobs requiring a high level of mathematics skills but a low level of social skills – including many jobs in the fields of science, technology, engineering and mathematics (or STEM fields) – fell by 3.3 percentage points between 1990 and 2012.

The increase in the number of jobs requiring a high level of social skills has been accompanied by an increase in the wages for such jobs, suggesting that there is higher demand from employers for such skills instead of simply a surplus of workers who hold such skills. While hourly wages for jobs that require high mathematics proficiency but low social skills have increased by 5.9% between 1980 and 2012, they have increased by 26% for jobs that require both high mathematics proficiency *and* high social skills (Deming, 2015). Moreover, wages have risen by over 20% for jobs that require high social skills but low mathematics skills, suggesting that social skills are increasingly of value to employers.¹

The importance of collaboration extends beyond the workplace. A great number of human activities take place in groups, from a variety of physical and artistic endeavours to living in harmony with one's neighbours. More generally, as John Donne said, "No man is an island": almost every human relies on interactions with other individuals to do what he or she cannot do for him or herself or do alone. These activities range from essential tasks like obtaining food, clothing or shelter, to organising large celebrations, to simply agreeing with one's friends and family as to where to go and what to do while on vacation. Collaboration skills are essential to facilitating such interactions.

Co-operation and collaboration are also important beyond the individual level. A variety of actors must collaborate to propose, pass and implement the laws that govern a country, and groups of interested people must work together to advocate for their ideas on a scale greater than what could be achieved by any individual in the group. For instance,



trade unions have relied on collaboration between its members to achieve higher pay, obtain better working conditions, and ensure more stringent health and safety standards. Likewise, restorative justice requires victims, offenders and society at large to collaborate and compromise in order to determine how an offender can best atone for his or her offense.

Many contemporary issues, such as trade, migration, climate change, intellectual property protection and the fight against tax avoidance and profit shifting, go beyond the local or national level and require co-operation between countries at the international level. For example, 196 countries signed the Paris Agreement regarding greenhouse gas emissions in 2015 as part of a concerted global effort to limit global warming, while the European Union gives its individual member countries a greater united voice in world affairs. Organisations including the OECD (which produces PISA), the G20, and the United Nations provide a space for countries to discuss and attempt to resolve global problems. Although it is ostensibly countries that collaborate in these situations, it is humans who negotiate each of these agreements and deals. “No man is an island” is also figuratively, if not literally, true for countries and other groups of humans.

TEACHING AND ASSESSING COLLABORATIVE PROBLEM-SOLVING SKILLS

Some education systems across the world are beginning to adapt their curricula and instruction to equip their students with collaboration skills (Griffin and Care, 2015; Hesse et al., 2015). One concrete example of such a pedagogical programme is Project Work, introduced for grade 11 students in Singapore in 2000 to “provide students with the opportunity to synthesise knowledge from various areas of learning, and critically and creatively apply it to real-life situations” (MOE, 2017).² Four learning outcomes were identified: knowledge application, communication, independent learning and collaboration. For the latter learning outcome, students “acquire collaborative skills through working in a team to achieve common goals”.

However, in most countries and economies, collaboration is not a skill that is explicitly taught in schools but is rather acquired through the teaching of other subjects. For example, students are often asked to perform group work in traditional academic subjects (such as the three core PISA domains), and are also given chances to interact with one another in a variety of other contexts in other activities and classes, such as physical education class, music class, or extracurricular sports teams.

There have been few attempts to assess how well students collaborate with one another. This may be partly due to the lack of an obvious measure for how well one has collaborated. For example, in Singapore’s Project Work, students are assessed in the learning outcomes of knowledge application (generating, developing and evaluating ideas and information in order to execute project tasks) and communication (presenting ideas clearly and coherently in both written and oral form). Collaboration and independent learning, which are skills developed and used on the way to completing their project tasks, are not assessed (MOE, 2017).

Hence, PISA 2015 decided to assess 15-year-old students’ ability to collaborate in order to solve problems. By doing so, PISA aims to address the lack of internationally comparable data in this field, allowing countries and economies to see, for the first time, where their students stand in relation to students in other education systems in these skills. Within-country analyses will give policy makers the information they need to enable them to develop programmes to improve their students’ collaboration and interpersonal skills. PISA thus seeks to address the lack of knowledge about which factors, policies and practices are related to the development of collaboration skills.

HOW PISA 2015 DEFINES COLLABORATIVE PROBLEM SOLVING

PISA 2015 defines collaborative problem-solving competency as:

the capacity of an individual to effectively engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge, skills and efforts to reach that solution.

The PISA 2015 framework publication (OECD, 2017a) discusses the definition in full. Some of the key elements are discussed immediately below; other elements will be described in the following section on the more detailed framework of the assessment.

... the capacity of an individual ...

Collaboration necessarily requires the presence of at least two agents – after all, one cannot collaborate on his or her own. The success of the collaborative process can be evaluated at the collective level: How well did the group solve the problem? How well did group members work together? How well did the group manage conflict? Indeed, one of the advantages of collaboration is that the end result often exceeds the sum of each group member’s individual contribution (Blaney et al., 1977; Laughlin et al., 2006; Schwartz, 1995), and such synergies can only be evaluated at the group level.



However, PISA measures individual competency and, in the context of collaborative problem solving, measures the ability of individuals to work in collaborative settings. Although the performance of an individual in collaborative problem solving depends on the group in which he/she finds himself/herself, he/she also has a certain baseline ability to collaborate with others. By varying, in a controlled manner, the characteristics of the group members with whom an individual collaborates, an overall assessment of the individual's collaborative problem-solving competency can be made.

... whereby two or more agents ...

As mentioned above, collaboration always involves the interaction of two or more agents working together. These agents must be theoretically capable of performing all of the actions involved in collaborative problem solving, such as communicating, reacting to others' actions and statements, advancing the task at hand, and managing group organisation.

The agents may be humans or computerised simulations of humans. In the PISA assessment, one agent is the student whose performance is being evaluated; all other agents are computerised simulations. This allows the assessment to control the behaviour of the other agents in order to isolate the collaborative problem-solving ability of the student being evaluated (Graesser et al., 2018; Kreijns, Kirschner and Jochems, 2003; Rosen and Rimor, 2009). Had the student been in a group with other students, his or her performance would have depended on the ability of the other students and the pre-existing relationships between the students. The use of computer agents also broadens the range of groups and situations that can be created, hence ensuring that all components of the framework (discussed below) are examined. Logistically, computer agents also allow for rapid scoring of students' results and avoid the need to co-ordinate communication between students in a time-limited situation. As a result, the PISA collaborative problem-solving framework favoured the use of computer-simulated agents. Box V.2.1 discusses the concerns in using computer agents instead of human agents when measuring collaborative problem-solving competence.

Box V.2.1. **The use of computer agents instead of human agents when measuring collaborative problem-solving competence**

In the PISA 2015 collaborative problem-solving assessment, the student test-taker interacts with computer agents instead of other human agents. The use of other human agents is impractical: student performance depends on the agents with whom the student interacts, and as human agents are unpredictable, students would need to interact with a large variety of other humans to be certain to place the students in a variety of collaborative environments. The other students would also need to be comparable across schools and countries.

Computer agents allow the assessment to precisely control and vary the characteristics of the other agents with whom students interact. The assessment can thus test a variety of aspects of students' collaborative problem-solving competency within 30-minute clusters.

However, in the workplace and in society at large, students are generally required to interact with other humans. The question therefore arises: Does the PISA 2015 assessment accurately measure students' ability to collaborate with other humans? Do the computer agents faithfully proxy for humans?

A study investigating these questions was carried out by the University of Luxembourg in classrooms in Germany and in cognitive laboratories at the University of Luxembourg (Herborn, Mustafic and Greiff, forthcoming; Herborn et al., forthcoming). In the classroom studies, four PISA collaborative problem-solving units were re-formatted by replacing one of the computer agents with a human agent partner who could select his or her response from a set of prepared responses, similar to what the human test-taker would see. Only the human test-taker was scored. Prior to starting the unit, students were informed whether they were interacting with a human or a computer agent. A statistically significant yet small difference in scores was observed between students who interacted with a computer agent and students who interacted with a human agent; this difference was deemed too small to be relevant from a practical standpoint.

In the cognitive laboratories, students were instructed to think aloud as they completed one of the original units used in the PISA 2015 assessment (with computer agents) and one re-formatted unit (with a human agent). Each student completed these units individually, i.e. in his or her own space, without direct contact with other humans/human agents. It was found that teachers' opinions of their students' collaboration skills were significantly and moderately well correlated with students' performance in the original and re-formatted collaborative problem-solving units.

...



The re-formatted units included at least two other agents: one human agent and at least one computer agent. Anecdotal evidence from students indicates that they were unable to distinguish which of the agents was the human agent, likely because their responses were all prepared.

Hence, although students collaborated with computer agents instead of real human agents in the PISA 2015 collaborative problem-solving assessment, any differences between the two types of agents were difficult to discern. There are no pertinent differences between the use of human and computer agents in the context of electronic collaboration where students cannot write their own individual responses.

With improvements in technology, more and more collaboration takes place in virtual settings: people find themselves increasingly working with others located on different floors, in different companies and organisations, and in other cities and countries. The PISA 2015 collaborative problem-solving assessment is thus particularly pertinent to the changing face of how humans collaborate in the twenty-first century.

Students also performed a collaborative problem-solving unit face-to-face with another human agent in the cognitive laboratories, where they could freely formulate their responses. This unit was evaluated by independent observers. It was found that students' performance in the original and re-formatted units, both of which took place in a virtual, computer-based setting, was a moderately good predictor of their performance in the face-to-face collaboration units with another human. Hence, the PISA 2015 collaborative problem-solving assessment is informative about students' performance in real-life collaboration scenarios, where they directly collaborate with other humans.

... attempt to solve a problem ...

A student's collaborative problem-solving ability is, as the name implies, assessed in scenarios where he or she must solve a problem. In this context, a problem is not necessarily a cognitive task, such as setting up a sustainable fish farm, planning the construction of a bridge, or writing a persuasive letter. Instead, it may be communicating with other agents, delegating roles to other agents, ensuring that the group remains focussed on the task at hand, or evaluating whether other agents have performed their assigned tasks, among other examples. All of these actions are directed towards the ultimate goal. In the case of the released unit described at the end of this chapter, *Xandar*, the goal is to answer questions in a simulated contest, and the problem-solving process incorporates all of the steps towards the final goal.

Collaborative problem-solving ability is not measured solely by whether the problem was successfully solved; for example, in the case of *Xandar*, it is not measured solely by how well students perform in the contest. Instead, assessment is continuous throughout the unit and incorporates all of the student's interactions with and responses to the computerised agents. Each response is indicative of how the student has chosen to interact and collaborate with the other agents in that particular situation.

THE PISA 2015 FRAMEWORK FOR ASSESSING COLLABORATIVE PROBLEM-SOLVING COMPETENCE

The PISA 2015 framework for assessing collaborative problem-solving competence guided the development of the assessment and sets the parameters for reporting results. The framework identifies two major components to collaborative problem solving: the cognitive and general problem-solving aspects common to individual problem solving (as examined in PISA 2012) and the collaborative aspects unique to collaborative problem solving.

As in PISA 2012, four processes in individual problem solving were identified:

- **exploring and understanding:** exploring the problem situation by observing it, interacting with it, searching for information and finding limitations or obstacles; and demonstrating understanding of the information given and the information discovered while interacting with the problem situation
- **representing and formulating:** using tables, graphs, symbols or words to represent aspects of the problem situation; and formulating hypotheses about the relevant factors in a problem and the relationships between them to build a coherent mental representation of the problem situation
- **planning and executing:** devising a plan or strategy to solve the problem; executing the strategy; and perhaps clarifying the overall goal and setting subgoals
- **monitoring and reflecting:** monitoring progress; reacting to feedback; and reflecting on the solution, the information provided with the problem or the strategy adopted.



Unique to PISA 2015 are three collaborative problem-solving competencies:

- **establishing and maintaining shared understanding:** identifying the knowledge and perspectives that other group members hold and establishing a shared vision of the problem states³ and activities
- **taking appropriate action to solve the problem:** identifying the type of collaborative problem solving-related activities that are needed to solve the problem and carrying out these activities to achieve the solution
- **establishing and maintaining team organisation:** understanding one's own role and the roles of other agents, following the rules of engagement for one's role, monitoring group organisation, and facilitating the changes required to optimise performance or to handle a breakdown in communication or other obstacles to solving the problem.

These three collaborative problem-solving competencies are crossed with the four individual problem-solving processes to form a matrix of twelve specific skills, as illustrated in Figure V.2.1 below.⁴ Each item within the collaborative problem-solving evaluation assesses one (or sometimes more than one) of these specific skills. The assessment as a whole is developed to measure all 12 specific skills over the various tasks.

Figure V.2.1 ■ Skills evaluated in the PISA 2015 collaborative problem-solving assessment

		Collaborative problem-solving competencies		
		(1) Establishing and maintaining shared understanding	(2) Taking appropriate action to solve the problem	(3) Establishing and maintaining team organisation
Problem-solving processes	(A) Exploring and understanding	(A1) Discovering perspectives and abilities of team members	(A2) Discovering the type of collaborative interaction to solve the problem, along with goals	(A3) Understanding roles to solve the problem
	(B) Representing and formulating	(B1) Building a shared representation and negotiating the meaning of the problem (common ground)	(B2) Identifying and describing tasks to be completed	(B3) Describing roles and team organisation (communication protocol/rules of engagement)
	(C) Planning and executing	(C1) Communicating with team members about the actions to be/being performed	(C2) Enacting plans	(C3) Following rules of engagement (e.g. prompting other team members to perform their tasks)
	(D) Monitoring and reflecting	(D1) Monitoring and repairing the shared understanding	(D2) Monitoring results of actions and evaluating success in solving the problem	(D3) Monitoring, providing feedback and adapting the team organisation and roles

No assumption is made that the processes and competencies involved in solving a particular problem are sequential or that all of the processes and competencies listed are involved in solving a particular problem. As individuals confront, represent and solve problems in a collaborative group setting, they may move to a solution in a way that transcends the boundaries of a linear, step-by-step model. Nevertheless, each item in the PISA 2015 collaborative problem-solving assessment is intended to have one of these processes and one of these competencies as its main focus.

Although reasoning skills were not explicitly used to organise the domain, each of the individual problem-solving processes and collaborative problem-solving competencies draws upon one or more of them. In understanding a problem situation, the solvers may need to distinguish between facts and opinion; in formulating a solution, they may need to identify relationships between variables; in selecting a strategy, they may need to consider cause and effect; and, in reflecting on results, they may need to critically evaluate assumptions and alternative solutions.

Likewise, in establishing and maintaining shared understanding, students may need to determine which group member possesses each piece of information and what remains unknown; in taking appropriate action to solve the problem, they may need to analyse various possible ways to proceed towards the solution and determine how best to do so; and in establishing and maintaining team organisation, students may need to evaluate group dynamics and judge whether each group member is correctly following his or her assigned role and tasks. However, the PISA 2015 collaborative problem-solving assessment does not explicitly set out to assess cognitive reasoning skills. Thus, the level of cognitive demand is intended to be lower than that in the three core subjects of science, reading and mathematics.



Similarly, while each item targets one or more of the four individual problem-solving processes, these processes are not the focus of the PISA 2015 collaborative problem-solving assessment. Items were designed so that they required a low or intermediate level of proficiency in individual problem solving, so as to more explicitly measure proficiency in collaborative problem solving.

There are two key dimensions common to both individual and collaborative problems: the problem context and the nature of the problem situation. These two dimensions are described in Box V.2.2.

Box V.2.2. **Dimensions common to both individual and collaborative problems**

The PISA 2012 individual problem-solving assessment defined a problem in part by both the problem context, or how familiar a student is likely to be with the problem, and the problem situation, or the extent of the information to which a student has access at any given moment while solving the problem (OECD, 2013). These concepts are used again in the PISA 2015 collaborative problem-solving assessment (OECD, 2017a).

In the framework developed for the 2012 assessment, the problem context is composed of both its setting and its content (OECD, 2013). The setting of a problem may be either technology-based (e.g. controlling or troubleshooting a technological device) or not technology based (e.g. route planning, scheduling or decision making); private (relating directly to the student and his/her immediate circle, such as planning a party) or public (relating to the student's community or to society at large, such as choosing the best location to build a school); and school or non-school. The content of a problem refers to the topics covered in the problem. These may be one of the other PISA domains (science, reading, mathematics or financial literacy) or other subjects, such as civics, politics or sports.

One aspect of the problem situation is whether all of the information is present at the outset, in what are termed static problems, or whether students must delve into the problem to obtain additional information necessary for solving the problem, in what are known as dynamic or interactive problems. The other aspect of the problem situation is how clearly defined the problem is. Problems where the goals, possible actions, and problem states are clearly specified are known as well-defined problems. By contrast, ill-defined problems may have multiple goals and underspecified problem states and actions.

Problems that are solved collaboratively are, by nature, more likely to be interactive rather than static: team members rely on and learn from other team members during the course of solving the problem. Problems that require collaboration to solve are also more likely to be ill-defined (from the point of view of participants), as team members can neither control nor predict what other team members will do.

The collaborative aspect of the assessment adds several new dimensions to each problem. Perhaps the most obvious change between the individual and collaborative problem-solving assessments is that in 2015, students work in teams, and hence team composition is a new dimension to be considered. The group might be composed of just the student being evaluated and one collaborative agent, or it might be a larger group that includes the student being evaluated and multiple other agents. Team members might have the same or different roles and actions available to them.⁵

A new aspect of the problem situation is the type of collaboration required. PISA uses several different types of collaborative problem-solving tasks, including:

- **jigsaw or hidden-profile tasks**, where each group member is given different information or skills. Groups need to pool each member's information and skills together in order to solve the problem and hence collaboration among group members is required. Moreover, group members are dependent on one another to arrive at the solution; no single member can achieve the solution on his or her own, and a group member who chooses not to participate can jeopardise the achievement of the group's goal
- **consensus-building tasks**, where a group must agree on a decision after considering the views, opinions and arguments of all group members. A successful solution will involve all group members contributing their ideas and the careful yet efficient consideration of all such ideas. However, some group members may dominate the conversation and not allow for all ideas to be aired, while other group members may not be willing to disagree with what has already been said, potentially leading to "group think"
- **negotiation tasks**, where not all group members share the same individual goals. They must negotiate in order to achieve, in the best-case scenario, a win-win situation that satisfies both their individual goals and the goals of the group.



Jigsaw/hidden-profile tasks are primarily group co-ordination tasks, while consensus-building and negotiation problems are both primarily group decision-making tasks. A final type of collaborative problem is group production tasks, where the group must create a deliverable, such as a design for a new product or a written report. However, as the PISA 2015 collaborative problem-solving assessment was completely automated, it did not include any production tasks with open-ended products.

The type of collaboration might change over the course of a unit. For example, a unit may begin as a jigsaw task as team members try to work out what other team members know and can perform. Once this has been established, the unit may become a consensus-building task or a negotiation task as team members work to make some sort of final decision. It is also common for the problem situation (see Box V.2.2) to change over the course of the unit, particularly with jigsaw tasks. Problems may start out as dynamic as team members discover what other members know and may then become static once all of the information has been shared.

THE DESIGN AND DELIVERY OF THE PISA 2015 COMPUTER-BASED ASSESSMENT OF COLLABORATIVE PROBLEM SOLVING

While there has been much research on how to assess individual problem-solving competency and tools have been developed for conducting such assessments, PISA 2015 is the first large-scale, international assessment that tries to evaluate competency in collaborative problem solving.

Science is the major domain of the PISA 2015 assessment, meaning that each student received two 30-minute clusters (also known as booklets) of science tasks. Students also received two more 30-minute clusters chosen from among the other three domains: reading, mathematics and collaborative problem solving. These two additional clusters may have been chosen from the same domain or from different domains. Three collaborative problem-solving clusters were designed for the study.

Each collaborative problem-solving cluster comprises several units, which are interactive scenarios that students must work through while interacting with programmed computer agents. Units in the collaborative problem-solving assessment typically require between 5 and 20 minutes to complete and were time-limited. Each unit may be composed of multiple parts, or large, coherent subdivisions of the unit, and each part includes several items, which are the individual actions taken by students that change the state of the problem.⁶ Most actions in this assessment require the student to select one response out of four possible options while in a conversation with the computer agents; some require students to provide a solution to a problem using information gathered with the other agents, generally by clicking on a region in the visual display area. Each unit consisted of between 10 and 30 individual items.

Each item can be classified as targeting one of the 12 specific skills in the collaborative problem-solving matrix (Table V.2.1), and thus as targeting one of the 3 collaborative problem-solving competencies and one (or more) of the 4 individual problem-solving processes. However, small sample sizes in each country did not allow for the creation of subscales in each of the competencies and processes. Annex A of the *PISA 2015 Technical Report* (OECD, 2017b) identifies the skills, competencies, and processes targeted by each item.

As noted earlier, student performance in collaborative problem solving depends on the other members in the collaborating group. A complete assessment of performance in this domain therefore requires that students interact with different types of agents in different types of group situations. For example, certain units and tasks may require students to supervise the work of other agents, while other units and tasks may require students to follow the direction set by a computer agent. Likewise, some groups may be more collaborative than other groups. The degree to which the other team members collaborate can be precisely controlled as they are computerised agents.

One potential pitfall of an interactive testing environment is that students who select different options may end up in different problem states. For example, students with high collaborative problem-solving proficiency may quickly incorporate information from and the perspectives of other team members, while students with low collaborative problem-solving skills may never obtain the required input from other team members and set off on a tangent that does not lead to a solution. This presents problems when trying to be consistent in measuring students' collaborative problem-solving abilities.

To overcome such problems, a "rescue agent" can intervene when students choose actions that do not represent a step towards solving the problem. The rescue agent, who is one of the computerised agents, can bring the problem back to the desired state by, for example, giving the student another chance to request the missing information, asking for the missing information himself/herself, or providing the missing information himself/herself. In this way, students always end up at the same problem state no matter what actions they take, and thus they are always faced with the same items. This is illustrated in the next section, which presents the released unit, *Xandar*.



SAMPLE COLLABORATIVE PROBLEM-SOLVING ITEMS

One full unit included in the PISA 2015 main survey is described below. A screenshot of the stimulus information is provided, together with a brief description of the context of the unit. This is followed by a screenshot and description of each item from that unit. The unit described below is also available for viewing on line at www.oecd.org/pisa/test/. The interactive nature of the unit *Xandar* can best be appreciated by trying to solve the items oneself.

Sample unit: XANDAR

In the unit *Xandar*, a three-person team consisting of the student test-taker and two computer agents takes part in a contest where it must answer questions about the fictional country of Xandar. The questions are evenly divided between Xandar's geography, people and economy. This unit involves decision-making and coordination tasks, requires consensus-building collaboration, and has an in-school, private, and non-technology-based context.

Figure V.2.2 ■ XANDAR: Introduction

	Four questions will be on its geography. Sample Question: What is Xandar's largest rainforest?
	Four questions will be on its people. Sample Question: What is the average age in Xandar?
	Four questions will be on its economy. Sample Question: What is the employment rate in Xandar?

The unit consists of four independent parts; all parts and all items within each part are independent of one another. No matter which response a student selects for a particular item, the computer agents respond in a way so that the unit converges. All students are hence faced with an identical version of the next item.

Xandar: Part 1 – Agreeing on a Strategy

In Part 1 of *Xandar*, the student is familiarised with how the contest will proceed and in particular, the chat interface and the task space (buttons that students can click and the scorecard that monitors team progress). The teacher has asked teams to put off searching for questions and answers until the contest begins and instead to discuss how to approach the contest. The student has been assigned to work in a team with agents named Alice and Zach.

The first item of Part 1 requires students to click “Join the Chat” instead of clicking any of the buttons in the task space (“Geography”, “People” or “Economy”). This item is classified as (C3) *following the rules of engagement*, requiring students to display the (C) *planning and executing* individual problem-solving process and the (3) *establishing and maintaining team organisation* collaborative problem-solving competency.



Figure V.2.3 ■ XANDAR: Part 1, Item 1

PISA 2015

Xandar - Introduction

Part 1 - Directions

You and your teammates, Alice and Zach, can use the following features:

- **chat** to communicate with one another
- **buttons** labeled by subject to see the contest questions and find the answers on a map of Xandar
- a **scorecard** to track your team's progress. The scorecard will show the number of correct answers your team has found.

The teacher has asked teams not to search for questions and answers until the contest starts. Instead she suggests taking a little time to chat about how best to approach the task. Your teammates Alice and Zach have begun the chat.

To join the chat, click on the button below.

[Join the Chat](#)

Scorecard

Geography	People	Economy

[Geography](#) [People](#) [Economy](#)

Figure V.2.4 ■ XANDAR: Part 1, Item 2

PISA 2018

Xandar - Introduction

Part 1 - Directions

Who's in the Chat

YOU Alice Zach

Alice: Hi, I'm not sure about the best way to do this.

Zach: Let's just get going.

You are continuing the chat. Click on a choice below. Then click on Send.

You:

[Send](#)

Scorecard

Geography	People	Economy

[Geography](#) [People](#) [Economy](#)



The second item in this part requires students to continue the conversation in a chat with Alice and Zach regarding how to proceed. Zach indicates that he wants to go ahead and start answering questions without a strategy, and the credited response from the student states his or her preference for developing a strategy. The skill evaluated in this item is (C1) *communicating with team members about the actions to be/being performed*, which synthesises the (C) *planning and executing* individual problem-solving process and the (1) *establishing and maintaining shared understanding* collaborative problem-solving competency.

Regardless of the student's response to Part 1, Item 2, Alice mentions her desire for a strategy, followed by Zach reminding the team of how the winning team is determined without describing a strategy *per se*. The student must once again choose between four response options. The credited response to this item, Part 1, Item 3, advances the problem-solving situation by focusing the discussion on the development of a strategy. This item requires (B1) *building a shared representation and negotiation the meaning of the problem* skills, involving the (B) *representing and formulating* individual problem-solving process and the (1) *establishing and maintaining shared understanding* collaborative problem-solving competency.

Alice, regardless of the student's response to Part 1, Item 3, continues to press for a collaborative strategy. Zach reiterates an individual strategy for winning the contest that does not take account of the collaborative nature of the contest. The student's credited response to this item, Part 1, Item 4, proposes this collaborative strategy. This is also a (B1) *building a shared representation and negotiation the meaning of the problem* item, which requires the (B) *representing and formulating* individual problem-solving process and the (1) *establishing and maintaining shared understanding* collaborative problem-solving competency.

Figure V.2.5 ■ XANDAR: Part 1, Item 3

The screenshot displays the XANDAR interface for PISA 2015. The interface is divided into two main sections. On the left, a chat window titled "Who's in the Chat" shows a conversation between Alice, Zach, and the user (YOU). Alice asks for help, Zach suggests starting, and the user proposes talking about strategy. Alice wants a plan, and Zach emphasizes speed. Below the chat, the user is prompted to choose a response from four options. On the right, a "Scorecard" section features a table with columns for "Geography", "People", and "Economy". Below the table are three buttons labeled "Geography", "People", and "Economy".

Regardless of how the student responded to Part 1, Item 4, Alice states that it would be self-defeating if they were to look for answers to the same questions at the same time. The credited response to the next item, Part 1, Item 5, identifies the concrete strategy the team should use: each team member will be responsible for one of the subjects. This item is classified as (B3) *describe roles and team organisation (communication protocol/rules of engagement)*, and involves the (B) *representing and formulating* individual problem-solving process and the (3) *establishing and maintaining team organisation* collaborative problem-solving competency. Part 1 ends here.



Figure V.2.6 ■ XANDAR: Part 1, Item 4

PISA 2015

Xandar - Introduction

Part 1 - Directions

Who's in the Chat

YOU Alice Zach

YOU: Maybe we should talk about strategy first.

Alice: I'd really like to have a plan before we start.

Zach: We're supposed to answer the questions as fast as we can.

YOU: True, but what's a good way to do that?

Alice: Guys, we still need to figure out how to work well as a team.

Zach: Each of us has to work at top speed. What's so complicated?

You:

The rules of the contest seem pretty simple. Let's just do our best.

We can each work our fastest, but some of us will still be faster than others.

It doesn't matter whether one of us answers more questions than the others, so long as we win.

We can answer more questions if we divide them among us.

Send

Scorecard

Geography	People	Economy

Geography People Economy

Figure V.2.7 ■ XANDAR: Part 1, Item 5

PISA 2015

Xandar - Introduction

Part 1 - Directions

Who's in the Chat

YOU Alice Zach

Alice: Guys, we still need to figure out how to work well as a team.

Zach: Each of us has to work at top speed. What's so complicated?

YOU: We can answer more questions if we divide them among us.

Alice: You know, we'll just slow ourselves down if we're all looking for the same answers at once.

Zach: Oh yeah ... I finally get it.

You:

We could each take one of the subjects.

If there's a prize for winning, let's divide it equally.

The contest lets us come up with our own team strategy.

OK, then we're ready to begin.

Send

Scorecard

Geography	People	Economy

Geography People Economy



Xandar: Part 2 – Reaching a Consensus Regarding Preferences

At the beginning of Part 2, students are informed that each group member will be responsible for the questions in one subject area, regardless of how they responded to Part 1, Item 5. In Part 2, the team members will apportion the subject areas among themselves.

Figure V.2.8 ■ **XANDAR: Part 2**

The screenshot shows the XANDAR interface for Part 2. The left panel is titled 'PISA 2015' and contains a navigation menu with 'Xandar - Introduction' and 'Part 2 - Directions'. Under 'Part 2 - Directions', there is a text box that reads: 'Your team has agreed that each member will be responsible for answering the questions in one of the subject areas. Alice and Zach have begun a new chat. To join the chat, click on the button below.' Below this text is a 'Join the Chat' button. The right panel is titled 'Scorecard' and contains a table with three columns: 'Geography' (with a globe icon), 'People' (with a group of people icon), and 'Economy' (with a dollar sign icon). The table has four rows, all of which are empty. Below the table are three buttons labeled 'Geography', 'People', and 'Economy'.

Figure V.2.9 ■ **XANDAR: Part 2, Item 1**

The screenshot shows the XANDAR interface for Part 2, Item 1. The left panel is titled 'PISA 2015' and contains a navigation menu with 'Xandar - Introduction' and 'Part 2 - Directions'. Under 'Part 2 - Directions', there is a 'Who's in the Chat' section with a list of names: 'YOU', 'Alice', and 'Zach'. Below this is a chat window with the following messages: 'Alice: I'd like to take People.' and 'Zach: Hey, I wanted that one.' Below the chat window is a 'You:' section with four text boxes containing the following questions: 'Nobody asked me what subject I want. Why should you guys choose first?', 'Can each of you explain why you want that subject?', 'Why are we wasting time arguing about this?', and 'Alice and Zach, are you going to answer questions faster than you choose subjects?'. Below these questions is a 'Send' button. The right panel is titled 'Scorecard' and contains the same table as in Figure V.2.8, with three columns: 'Geography', 'People', and 'Economy', and four empty rows. Below the table are three buttons labeled 'Geography', 'People', and 'Economy'.



At the beginning of Part 2, both Alice and Zach show their preference for taking the subject “People”. The credited response to the first item of this part, Part 2, Item 1, has the student, although not in the role of team leader, helping to resolve this disagreement. This response displays the (A1) *discovering perspectives and abilities of team members* skill, which involves the (A) *exploring and understanding* individual problem-solving process and the (1) *establishing and maintaining shared understanding* collaborative problem-solving competency.

Figure V.2.10 ■ XANDAR: Part 2, Item 2

PISA 2018

Xandar - Introduction
Part 2 - Directions

Who's in the Chat
YOU Alice Zach

Alice: I'd like to take People.
Zach: Hey, I wanted that one.
YOU: Can each of you explain why you want that subject?
Zach: I just thought the questions on People would be easiest.
Alice: I'm really interested in the people and lifestyles of different countries. That's mostly what I read about.

You:
It sounds as though People should be Alice's subject. Zach, are you OK with that?
Alice, maybe you could study abroad in a visiting students program.
Yes, it's good to know what your interests are.
People in Xandar probably aren't very different from people anywhere else.

Send

Scorecard

Geography	People	Economy

Geography People Economy

Figure V.2.11 ■ XANDAR: Part 2, Item 3

PISA 2015

Xandar - Introduction
Part 2 - Directions

Who's in the Chat
YOU Alice Zach

YOU: Can each of you explain why you want that subject?
Zach: I just thought the questions on People would be easiest.
Alice: I'm really interested in the people and lifestyles of different countries. That's mostly what I read about.
YOU: It sounds as though People should be Alice's subject. Zach, are you OK with that?
Zach: I guess Economy would be all right. I like money.

You:
Well, everyone likes money.
Liking money doesn't mean you understand economy.
We need to stop debating and make a decision.
I'll take Geography.

Send

Scorecard

Geography	People	Economy

Geography People Economy



Alice and Zach give reasons as to why they both want to answer questions on “People”, regardless of whether the student explicitly asked for them or not in Part 2, Item 1. The student, continuing to resolve the disagreement, is credited with a correct response to the next item, Part 2, Item 2, if he or she advances the problem and uses the information provided by Alice and Zach to assign the subject “People”. This item is classified as (B3) *describe roles and team organisation (communication protocols/rules of engagement)*, combining the (B) *representing and formulating* individual problem-solving process and the (3) *establishing and maintaining team organisation* collaborative problem-solving competency.

Alice has been assigned a subject area and Zach has now claimed a second subject area. The collaborative response to Part 2, Item 3 requires the student to claim the last subject area for him or herself. Although this might not, at first glance, appear to be collaborative, claiming the last subject area implicitly confirms that the other two subject areas have already been assigned to Alice and Zach. This item tests (B3) *describe roles and team organisation (communication protocol/rules of engagement)* skills, which involve the (B) *representing and formulating* individual problem-solving process and the (3) *establishing and maintaining team organisation* collaborative problem-solving competency. Part 2 ends here.

Xandar: Part 3 – Playing the Game Effectively

At the beginning of Part 3, students know that their assigned subject area is “Geography”, regardless of whether they claimed it for themselves in Part 2, Item 3. In Part 3, they must enter the contest and answer questions regarding Xandar’s geography.

Figure V.2.12 ■ **XANDAR: Part 3, Item 1**

The screenshot displays the PISA 2015 Xandar interface. On the left, under 'Part 3 - Directions', it states: 'Your team has reached the following agreement.' Below this, three items are listed: 'Geography will be your subject.', 'People will be Alice's subject.', and 'Economy will be Zach's subject.'. A message at the bottom says: 'The contest has started! Please click on a subject button to begin.' On the right, a 'Scorecard' table is shown with columns for 'Geography', 'People', and 'Economy', and three rows for scores. Below the table are three buttons labeled 'Geography', 'People', and 'Economy'.

The student is requested to start the contest, with a reminder in the chat interface that he or she has been assigned to answer questions about geography. To begin, the student must click on one of the buttons in the task space; the student is credited with a correct response for Part 3, Item 1 if he or she clicks on the button that says “Geography”. In this item, students can exhibit the (C3) *following rules of engagement* skill, which combines the (C) *planning and executing* individual problem-solving process and the (3) *establishing and maintaining team organisation* collaborative problem-solving competency.

Regardless of which button the student clicked, he or she is next presented with a screen that instructs students how to proceed with the contest: he or she must click on icons in the task space to obtain answers to questions about Xandar’s geography.



Figure V.2.13 ■ XANDAR: Part 3, Item 2, Screen 1

PISA 2015

Xandar - Introduction

Part 3 - Directions

Your team has reached the following agreement.

- Geography will be your subject.
- People will be Alice's subject.
- Economy will be Zach's subject.

Click on the symbols on the map to learn about Xandar and find the answers to the questions on the right.

When you find the answer to a question, click on the answer space next to the question and the answer will display.

When a question is answered correctly, a checkmark will be added to the scorecard.

To continue, click the button below.

[Click Here to Continue](#)

Scorecard		
Geography	People	Economy

Geography People Economy

What is Xandar's longest river?

What is Xandar's tallest mountain?

What is Xandar's rainy season?

What proportion of Xandar is desert?

Figure V.2.14 ■ XANDAR: Part 3, Item 2, Screen 2

PISA 2015

Xandar - Introduction

Part 3 - Directions

Who's in the Chat

YOU Alice Zach

Alice: We got one – let's keep going!

You:

The clock is ticking—let's not waste time on chat messages.

Whoever answered a Geography question, nice work!

Since somebody answered a Geography question, I'm going to switch subjects.

I should answer the Geography questions. Let's work on the subjects we chose.

[Send](#)

Scorecard		
Geography	People	Economy
✓		

Geography People Economy

What is Xandar's longest river?

What is Xandar's tallest mountain?

What is Xandar's rainy season?

What proportion of Xandar is desert?



After clicking the “Click Here to Continue” button but before the student has a chance to click on one of the icons on the map of Xandar, a checkmark is placed on the scoreboard to indicate that one of the questions on Xandar’s geography has been answered. Alice makes a remark to this effect in the chat interface. In Part 3, Item 2, students must then come up with an appropriate response. While one might be tempted to celebrate the progress made in the contest, the item actually tests to see whether the student has observed that the previously-agreed rules of engagement – that the student himself or herself should be the team member to answer the questions related to geography – are not being followed. This item therefore assesses the (D1) *monitoring and repairing the shared understanding* skill, which combines the (D) *monitoring and reflecting* individual problem-solving process and the (1) *establishing and maintaining shared understanding* collaborative problem-solving competency.

The student, regardless of how he or she responded to Part 3, Item 2, now continues with the contest by clicking on icons in the task space. No matter which icon is clicked, the statement “10 percent of Xandar is desert” pops up; students must then click on the blank space next to the question “What proportion of Xandar is desert?” in order for “10 percent” to show up and a checkmark to be recorded on the scoreboard. Students are not required to manually enter in their answers to questions regarding Xandar.

Figure V.2.15 ■ **XANDAR: Part 3**

The screenshot displays the PISA 2015 Xandar interface. At the top, it says "PISA 2015" and "Xandar - Introduction" and "Part 3 - Directions". On the left, a "Who's in the Chat" window shows "YOU", "Alice", and "Zach". The chat history shows Alice saying "We got one -- let's keep going!" and YOU replying "I should answer the Geography questions. Let's work on the subjects we chose." Below the chat is a message: "Continue answering the questions about Xandar by clicking on the symbols of the map and then clicking on the appropriate answer space next to the question." In the center-right, a "Scorecard" table shows a checkmark in the Geography column. Below the scorecard are buttons for "Geography", "People", and "Economy". To the right of these buttons is a list of questions: "What is Xandar's longest river?" (with "Korfu River" as an answer), "What is Xandar's tallest mountain?", "What is Xandar's rainy season?", and "What proportion of Xandar is desert?". At the bottom is a map of Xandar with several globe icons placed on it.

After answering this item, students are interrupted and informed that they have made progress in some, but not in all, subjects, and that Alice has sent another message. This is the end of Part 3.

Xandar: Part 4 – Assessing Progress

Part 4 picks up from Part 3 and requires students to evaluate their progress and fix any problems that have resulted.

Alice asks the team about its progress. In the credited response to Part 4, Item 1, the student provides, as accurately as possible, a response to Alice’s question. This item is classified as (D2) *monitoring the results of actions and evaluating success in solving the problem*, which requires students to display the (D) *monitoring and reflecting* individual problem-solving process and the (2) *taking appropriate action to solve the problem* collaborative problem-solving competency.



Figure V.2.16 ■ XANDAR: Part 4, Item 1

PISA 2015

Xandar - Introduction

Who's in the Chat
YOU Alice Zach

Alice: Is my scorecard right? How are we doing?

You:

I think your scorecard is working--mine is.

Great, we're half way there.

We look fine, except for Economy.

I'm not sure since I don't know the other teams' scores.

Send

Scorecard

Geography	People	Economy
✓	✓	
✓	✓	
✓	✓	

Geography People Economy

What is Xandar's longest river? Korfu River

What is Xandar's tallest mountain? Mount Mojo

What is Xandar's rainy season? Summer

What proportion of Xandar is desert?

Figure V.2.17 ■ XANDAR: Part 4, Item 2

PISA 2015

Xandar - Introduction

Who's in the Chat
YOU Alice Zach

Alice: Is my scorecard right? How are we doing?

YOU: We look fine, except for Economy.

Zach: Economy is hard. I'm having trouble.

You:

Keep trying. When Alice and I are done we'll help you--right Alice?

Zach, aren't you the one who said we all had to work fast?

Do you expect us to stop what we're doing and help you instead?

Are you behind because you were working on my Geography questions?

Send

Scorecard

Geography	People	Economy
✓	✓	
✓	✓	
✓	✓	

Geography People Economy

What is Xandar's longest river? Korfu River

What is Xandar's tallest mountain? Mount Mojo

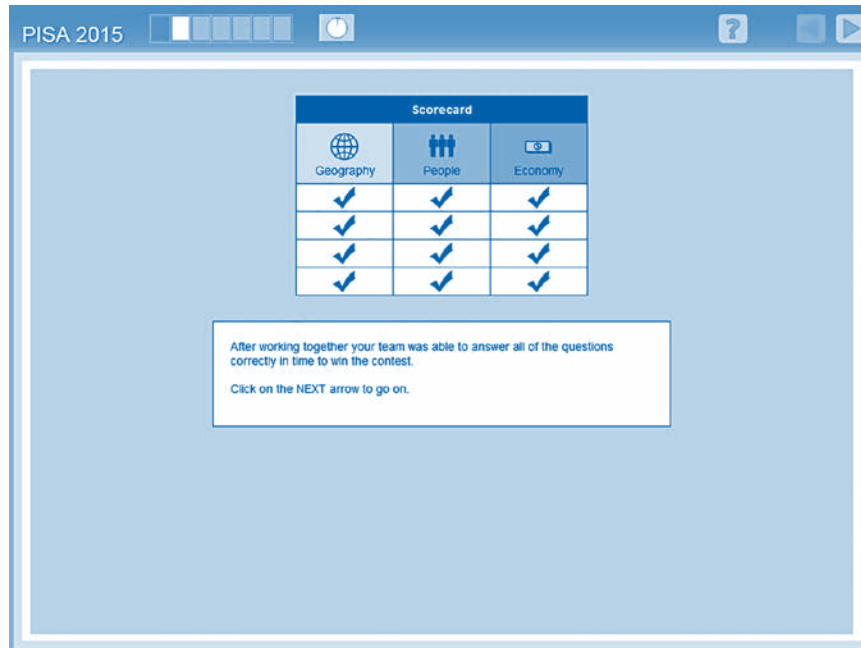
What is Xandar's rainy season? Summer

What proportion of Xandar is desert?



Regardless of the student's answer, Zach responds that he is having trouble with the questions in his assigned subject area, economy. In Part 4, Item 2, the student must choose the best response among the four possible options, which is the only one that encourages Zach and proposes how the student and Alice might help him. It also maintains team organisation by ensuring that the roles previously agreed – that each team member works on his or her assigned subject area first – are still followed. (D3) *Monitoring, providing feedback and adapting the team organisation and roles* skills are evaluated by this item, which thus also evaluates the (D) *monitoring and reflecting* individual problem-solving process and the (3) *establishing and maintaining team organisation* collaborative problem-solving competency.

Figure V.2.18 ■ **XANDAR: Conclusion**



Finally, regardless of how the student responded to Part 4, Item 2, he or she is informed that his or her team won the contest by answering all of the questions correctly. The unit ends here.

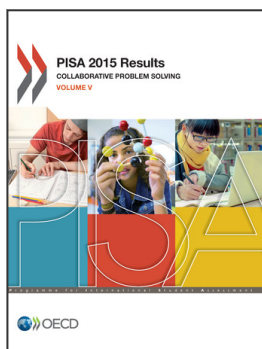
Notes

1. This is not to say that social skills are more valued than mathematics and other cognitive skills. Indeed, the median salary of those who rank in the top 10 percent of cognitive skills in the United States was \$67 000, while that of those who rank in the top 10 percent of non-cognitive skills was \$52 000. These numbers are an average of salaries in 2000, 2002 and 2004 for a sample who were first collected in 1981 and tested between the ages of 35 and 48 (Schanzenbach et al., 2016).
2. Most students in Singapore who sit the PISA assessment will have attended only grades 7 through 10, where project work is infused into the rest of the curriculum.
3. The problem state at any given point during the problem-solving process includes all of the conversation and actions that have already taken place, all of the information and perspectives accumulated up to that point, and all of the possible actions that may be taken in the future.
4. The twelve specific skill cells have been labelled with a letter-number combination referring to the rows (individual problem-solving processes, represented by a letter) and columns (collaborative problem-solving competencies, represented by a number) for ease of cross-referencing later in this report and in related materials.
5. Team members, while sharing the same goals, may have different status levels, which is another new dimension to collaborative problem solving not observed in individual problem solving. However, the PISA 2015 collaborative problem-solving assessment did not include any units where team members had different status levels.
6. In some cases, responses from multiple actions were combined into one unit for statistical reasons, such as high correlation between the actions.



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From:
PISA 2015 Results (Volume V)
Collaborative Problem Solving

Access the complete publication at:
<https://doi.org/10.1787/9789264285521-en>

Please cite this chapter as:

OECD (2017), “What is collaborative problem solving?”, in *PISA 2015 Results (Volume V): Collaborative Problem Solving*, OECD Publishing, Paris.

DOI: <https://doi.org/10.1787/9789264285521-7-en>

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