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VYTAUTO DIDŽIOJO UNIVERSITETO ŠVIETIMO AKADEMIJA

Educational System for the Development of Collaborative Ill-Structured Problem-Solving Skills

Evelina Jaleniauskienė[1], **Palmira Jucevičienė**[2]

[1] Kaunas University of Technology, Faculty of Social Sciences, Arts and Humanities, A. Mickevičiaus g. 37, LT-44240 Kaunas, evelina.jaleniauskiene@ktu.edu
[2] Kaunas University of Technology, Faculty of Social Sciences, Arts and Humanities, A. Mickevičiaus g. 37, LT-44240 Kaunas, palmira.juceviciene@ktu.edu

Abstract. Problem solving is indicated among the most important 21st century skills and therefore many educational practitioners and researchers suggest to include the development of this skill in diverse subjects across university studies. However, practice of this skill development is usually limited to the application of problem-based learning, which leaves it only among many other goals. The fact also remains that this popular curricular invention is most commonly considered as a content-based method, which puts greater emphasis on subject-related knowledge acquisition in the context of solving problems.

Indeed, solving ill-structured problems is not an easy activity and what higher education needs is a more explicit focus on the development of this skill in students. The article seeks to scientifically and practically explain the system on how this educational aim can be attained. Based on literature review, we design a tripartite system for enabling students to learn collaborative problem solving. It comprises three main parts: preparation for solving ill-structured problems in collaboration, inclusion into the processes of solving such problems and evaluation of the processes as well as outcomes achieved. The designed system is universal and can be implemented across various disciplines and subjects in higher education.

Keywords: *problem solving, collaboration, 21st century skills, ill-structured problems, higher education.*

Introduction

An important trend that is gaining grip nowadays is the decreasing value of knowledge over the importance of soft skills. Soft skills include problem solving, collaboration, conflict resolution and communication, among others. Knowledge is no longer the main success factor making learners to be workforce-ready. For instance, Hatherley-Greene (2018) discusses the findings from Google research which confirm the fact that STEM expertise is far less important than such soft skills as being a good communicator, listener and coach, being empathetic and able to understand different points of views as well as being a good problem solver, which is usually accompanied by being a good critical thinker. The recommendations that follow are that learners should be equipped with a wide set of skills instead of acquiring a narrow occupation-specific knowledge. Problem solving is a skill that holds top positions among most valued skills both on the list of employers and in the major educational frameworks.

Another trend is the increasing value of collective intelligence and collaboration. For instance, the findings from researchers at Massachusetts Institute of Technology confirm that collective intelligence of a group is higher than the intelligence of its smartest member (Malone, 2018). When students work in groups, they create shared understanding and learn from each other not only because some of them are smarter but also because they think differently. Collaborative problem solving differs from individual one because it is based not just on narrow individual knowledge and understanding (inferential process) but on what we see, talk, think and create as a group, which merges a number of opinions and understandings (Griffin & Care, 2016). Indubitably, collaborative problem solving is more advantageous and may lead to better problem solutions and therefore students should be prepared to solve problems in groups.

Although problem solving and collaboration are commonly agreed as crucial skills nowadays and the need to develop them is highlighted by a number of researchers and practitioners (Cho et al., 2015; Csapó & Funke, 2017; Greiff at al., 2013; Halpern, 2014; Jonassen, 2011; Luckin et al., 2017; Siddiq & Scherer, 2017; Tawfik & Jonassen, 2013), the findings reveal that the practice to address them is insufficient. For example, after reviewing eighty cases indicated to be developing collaborative skills in higher education, Lai et al. (2017) conclude that there were only few examples addressing this skill more explicitly. Higher education students leave studies while staying not good enough at problem solving (Csapó & Funke, 2017; Keeling & Hersh, 2011; Luckin et al., 2017; Sellingo, 2017). In addition, educational researchers (Lai et al., 2017; Jonassen, 2011; Csapó & Funke, 2017; Siddiq & Scherer, 2017; Cho et al., 2015) observe that a research gap remains in how both problem solving and collaboration can be developed in practice.

In educational practice, four main ways to develop problem-solving skills have been described: content-based methods, direct development of problem-solving skills, enhanced instruction and, finally, various global approaches that take into consideration improvement of learner motivation, interest and the overall quality of learning (Csapó & Funke, 2017). The listed approaches contribute to the development of problem-solving skills to varying degrees. As explained, problem-based learning belongs to content-based methods and is often criticized for lacking ways to enhance problem-solving skills adequately. For example, Hung (2013) observes that when applying this method learners do not know proper ill-structured problem-solving processes and usually skip problem representation processes, which are essential when solving ill-structured problems. Researchers (e.g., Arts et al., 2006; Hassan et al., 2012; Hung, 2011; Yaqinuddin, 2013) conclude that there is not enough evidence that problem-based learning contributes sufficiently to the enhancement of problem-solving skills. Direct teaching is when learners are taught problem solving directly. For example, they might be presented with well-known information-processing or general problem-solving methods, which are considered to be applicable to all types of problems. However, this practice has major drawbacks. Ill-structured problem solving is highly contextualized and therefore it cannot be taught as a content-free skill. Jonassen (2011) highlights that ill-structured problem solving cannot be seen as a uniform process with a simple application of typical steps of how to solve a problem. Ill-structured problems are complex without any possibilities to apply a single formula, as in the case of some well-structured problems (e.g., mathematics problems). Usually, various other approaches aim for the development of problem-solving skills by simple inclusion of learners into ill-structured problem solving and expecting that learners will naturally develop this skill. Among such, Csapó and Funke (2017) list "powerful learning environments" (enhanced with ICT), "innovative learning environment" (OECD initiative), different forms of group work, collaborative problem solving and inquiry-based science education.

Finally, enhanced instruction integrates some specific improvements and measures to address collaborative problem solving. For example, such measures could include question prompts to regulate problem-solving processes by directing to the most important aspects of the problem, encourage a more effective argumentation and make the process easier (e.g., Ge & Land, 2003; Ge et al. 2010; Jonassen, 2011; Papadopoulos et al., 2011), integrate explicit teaching of collaboration (e.g., Lai et al., 2017), include visualizations for problem representation (Halpern, 2014; Hung, 2013; Jonassen, 2011; Simone et al., 2001), invite peer tutors and use peer review (e.g. Ge et al., 2010; Zou & Mickleborough, 2015) or use any other helpful measures. The listed researchers conclude that helping learners with some additional aids contribute significantly to the refinement of problem-solving performance. However, most of the research done on the application of the enhanced instruction usually describes separate single measures and their effect on learning to solve problems. What is lacking is a more systematic approach to how develop problem-solving skills across various subjects.

To address the discussed gaps, the research problem of the article is how to enable students to develop collaborative problem-solving skills. More specifically, what stages should be undergone and what set of measures should be applied so that students enhance all aspects included into collaborative problem solving. We theorize what should be done during the time students prepare for ill-structured problem solving in collaboration, what is necessary during the process of inclusion into realistic ill-structured problem solving and finally what forms of evaluations should be incorporated. For this purpose, we design an overarching tripartite system that could be suitable to attain such a goal and allow educators to create modern educational environments. It is aimed at the development of collaborative problem-solving skills rather than individual ones.

Based on literature review, first, we explain most common types of problems and problem solving. Second, we discuss what is necessary for learners to be prepared for collaborative problem solving. Third, we explain the processes of inclusion in collaborative problem solving. Fourth, we analyze the assessment part of the system. Finally, we present conclusions.

Types of problems and problem solving

A problem exists when "an individual has a particular goal, but doesn't know how to achieve it" (Duncker, 1945, as cited in Csapó & Funke, 2017, p. 62). Simply speaking, a person faces a problem when there is lack of knowledge and understanding of how currently to solve it. In addition, problem understanding cannot be limited to something negative.

In educational literature, the most common classification of problems is according to their structure by dividing them into well-structured and ill-structured problems. Well-structured problems "present all of the information needed to solve the problems in the problem representation; they require the application of a limited number of regular and circumscribed rules and principles that are organized in a predictive and prescriptive way; possess correct, convergent answers; and have a preferred, prescribed solution process" (Wood, 1983, as cited in Jonassen, 2011, p. 6). For example, well-structured problems are most mathematical problems that require the application of a formula and have one single correct answer. Such problems can also be answering questions provided at the end of a coursebook material just for memory checking. On the other hand, ill-structured problems are "those that we encounter in everyday life, in which one or several aspects of the situation is not well specified, the goals are unclear, and there is insufficient information to solve them" (Ge & Land, 2004, p. 5, as cited in Ertmer et al., 2008). They are multidisciplinary in nature, may have multiple solutions or no solution at all (Jonassen, 2011). For example, the design of a system for the development of collaborative problem-solving skills is an ill-structured problem because it has many unknown elements and variables, no single solution paths and solution itself. Obviously, the process of solving well-structured problems cannot be equated to solving ill-structured problems and learners cannot become better at ill-structured or real-life problem solving while just solving well-structured problems. However, well-structured problems are still frequent in formal education despite the stressed need to teach learners to solve real life resembling ill-structured problems (e.g., Walker et al., 2015; Jonassen, 2011; Jonassen & Hung, 2008; Hung, 2011).

Problem solving can be approached as either an activity or a skill, competence or knowledge. Considering problem solving as an activity, Mayer and Wittrock (1996) define it as "cognitive processing directed at achieving a goal when no solution method is obvious to the problem solver" (p. 47). Thus, problem solving is the search through the problem space from its current state to the goal state that requires a set of skills, abilities and knowledge (Funke et al., 2018). They can be grouped into three broad categories: cognitive aspects, non-cognitive aspects and knowledge required.

Seeing problem solving as a skill/competence and knowledge, it depends whether it is collaborative or individual. If a learner is involved in an ill-structured problem solving, it requires cognitive skills necessary for solving such types of problems or, simply speaking, capabilities to manage the task of problem solving at hand. As summarized by Sinott (1989), Voss and Poss (1988) and Voss et al. (1991) (as cited in Ge & Land, 2004) it usually comprises four major processes: problem representation (creation of its understanding), development of solutions, making justifications and selecting from the generated solutions as well as monitoring and evaluating problem-solving process. What matters for each we discuss in the subsequent chapter.

Apart from cognitive skills, whenever individuals solve ill-structured problems in collaboration, this additionally requires non-cognitive skills, such as social skills (collaborative aspect of problem solving) or managing oneself and other participants in a group. According to Hesse et al. 2015, this comprises three broad groups of capabilities: participation, perspective taking and social regulation. Again, what performance each of these require we discuss in the subsequent chapter.

Among non-cognitive aspects, researchers and practitioners also list such non-cognitive aspects as motivational and attitudinal. For instance, Kirkley (2003) stresses the idea that learners have to want to solve the problem, which influences problem solving greatly. Attitudinal aspects, such as confidence, anxiety, effort, persistence and knowledge about self, also matter for how a problem solver approaches a problem and determines his/her performance. Similarly, Jonassen (2011) distinguishes between internal factors of problems (related to an individual) and external ones (related to a problem itself). Internal factors, such as reasoning abilities, various cognitive styles, level of prior domain knowledge to solve similar problems, breadth of knowledge required to solve the problem, interest, problem solver's personality traits, his/her motivation and creativity (individual cognitive, social and personality differences) are indicated among the factors influencing problem solvers' performance and outcomes of problem solving (Jonassen, 2011).

A number of researchers (e.g., Csapó & Funke, 2017; Gagne, 1985, as cited in Kirkley, 2003; Mayer & Wittrock, 2006; Shin & Song, 2016) have discussed various types of knowledge required for the process of problem solving. Usually, it is divided into two main types of knowledge: declarative (what, that, why – knowledge of concepts) and procedural (how, when – knowledge of procedures). More specifically, declarative knowledge comprises factual or conceptual knowledge (knowing content-specific or factual knowledge within a discipline). For instance, a learner should know when water freezes. On the other hand, procedural knowledge comprises knowledge on operations how to do something and metacognitive knowledge or awareness and control of one's own cognitive processing. For instance, knowing how to break a problem into parts is a procedural knowledge, while knowing that you still lack knowledge of a proper problem-solving strategy is an example of metacognitive knowledge.

Preparation for solving ill-structured problems

Introduction to the task

In order to be prepared for problem solving, learners first need to be clearly informed about the purpose of the task. Part of the introductory stage should be also allocated for group formation. Educators should carefully think of a group size, its formation principle and criteria according to which students could be assigned or organize themselves into groups. After reviewing a number of research concerning such issues, Lai et al. (2017) conclude that likely there is no best group size. We consider an optimal number of group members to be from 3 to 5. Consistent with the conclusions that groups formed by instructors usually show lower levels of satisfaction (Oakley et al., 2007, as cited in Lai et al., 2017), we suggest that self-selected group formation method is a better choice since students are given freedom of choice and may come into groups according to mutual trust that they already have towards each other. Finally, as it concerns the choice of criteria, it depends on the situation, subject where problem-solving activities are integrated and all educational goals.

Preparation for the collaborative aspects of ill-structured problem solving

Second, learners need to be prepared additionally for collaborative aspects of collaborative problem solving. The fact that has been concluded by a number of researchers (e.g., Juceviciene & Vizgirdaite, 2012; Ge & Land, 2003; Hesse et al., 2015; Lai et al., 2017; Targamadzė, 2014) is that learners still have deficiencies in collaborative abilities. For instance, Ge and Land (2003) observe that group members tend to cooperate and divide their work depending on each student's expertise. Among most typical characteristics of Generation Z, Targamadzė (2014) lists students' individualism and unwillingness to be working in groups. Hesse et al. (2015) note that insufficient quantity of participation, externalization of thoughts and sharing information are common in groups that are expected to collaborate.

Educational researchers (e.g., Juceviciene & Vizgirdaite, 2012; Lai et al., 2017; Prichard et al., 2006) agree that simple involvement in group work is not a sufficient practice and any deliberate attempts to teach collaboration may increase the effectiveness of students' collaboration. Lai et al. (2017) suggest applying explicit teaching of collaboration, such as explaining to students how to disagree appropriately, teaching them to resolve conflicts, involving them in analyzing some worked up examples or offering checklists of good behaviors. In their comprehensive research on collaborative learning, Juceviciene & Vizgirdaite (2012) design a model which allows to achieve collaboration rather than just cooperation.

What we propose for the system during the stage of preparation is explaining to students what aspects matter for real collaboration among group members to occur. Namely, it is a kind of explicit pre-teaching of this aspect during which students are explained why collaborative problem solving is important nowadays and how it is advantageous over individual one, what the differences between cooperation and collaboration are, how group members are expected to behave and what consensus seeking means. Additionally, students can be asked to reflect on their available experience of collaboration by comparing how their previous understanding is different from what they discuss during the introductory stage. For proper consensus seeking, students should be explained that "consensus-seeking does NOT mean caving in to majority opinion, and it does not mean forcing others to agree with you" (Halpern, 2017, p. 24). It is a process during which group members discuss and accept what is true or good about alternative positions and in this way gain support for their own positions (Halpern, 2014).

Drawn on the ideas suggested by Hesse et al. (2015), students should be explained that real collaboration occurs whenever they participate equally and effectively, coordinate their actions with the efforts of the rest group members, interact with each other and show continued efforts and determination towards the completion of the task. Efficient perspective taking occurs when group members are empathetic and try to understand others emotionally, view a situation from the perspectives of other group members and are willing to integrate contributions from the rest members into their own thinking as well as try to adapt their behavior so it suits for all group members (Hesse et al., 2015). The aspect of social regulation requires that learners find ways to use the diversity of knowledge, expertise, strategies and opinions of each group member by negotiating, avoiding conflicts and controlling biased information (Hesse et al., 2015). In addition, learners should be reminded that each of them should be responsible for the progress of the group.

Checklists of "good behaviors" could be provided in the rubrics prepared in advance or using the practice of formulating ground rules together with the students. For example, such rubrics might include Likert-type scales with detailed indicators of proper collaborative behavior, which might be later used for the assessment purposes.

Development of students' understanding about ill-structured problems and their solving

During preparation stage to problem solving, time could be also allocated to inform students about the peculiarities and processes of solving ill-structured problems. Among such peculiarities, they could be reminded that such problems are not self-contained and therefore require additional information search and time for understanding deepening; they may have multiple solutions and paths to reach them. Among important aspects there is also guidance that learners cannot jump right into the solution offering processes without first trying to interpret the problem; sufficient ill-structured problem representation is the key to their solution; ill-structured problems might have multiple criteria for selecting solutions; the best solutions are those that are most viable and for which a group can provide the most cogent arguments.

Regarding the processes necessary for solving ill-structured problems, the first and most important one is the process of devising its representation or understanding of the situation described in the problem. During it, learners clarify what is known and what information should be additionally searched for. The process requires that group members identify all elements of the problem, its contextual factors, causes and constraints. Learners should be explained that this stage should be based on collaborative work and creation of shared understanding. Later, the group should continue by jointly planning how to reach the goal state or intermediate states towards the solution or solutions of the problem. Learners should be explained that only after a thorough representation of the problem, can they start developing solutions and making justifications for them. Group members should aim at reaching consensus on the best solution or solutions. Collaborative monitoring and then evaluating of a group's activities and progress made should be present throughout all the problem-solving process. Learners should participate in self-regulation of the whole process. In this way, they consider the effectiveness of their social and cognitive processing. It might lead to modifications if necessary and allow to boost efficiency of the group's work. Again, checklists of proper behavior could be provided in rubrics. In addition, these aspects could be agreed in ground rules or provided in procedural guidelines given for the completion of the task.

Introduction to the tools facilating collaborative ill-structured problem solving

During the preparatory stages, students can be additionally provided with some knowledge, understanding and experience of how to use various tools/scaffolds that might enhance and facilitate problem solving. For instance, we propose integrating the usage of visual thinking for problem representation. For this, students could be pre-taught how to draw both individual and collective problem schemas which "include semantic information and situational information about the problem associated with the procedures for solving that type of problem" (Jonassen, 2011, p. 242). As most useful advantages, a number of researchers (e.g., Halpern, 2014; Eseryel et al., 2013; Jonassen,

2013) agree that visual drawings of structural and situational characteristics of problems as well as structural relationships among them may facilitate problem understanding and the whole process of its solution.

Summing up, the introductory stage should include a thorough introduction to the task, measures to increase students' understanding of collaborative aspects, ill-structured problems and cognitive skills related to their solving as well as introduction to the tools that might facilitate problem solving. Figure 1 illustrates these steps.

Introduction to the task	**Preparation for the collaborative aspects of ill-structured problem solving**	**Development of students‘ understanding about ill-structured problems and their solving**	**Introduction to the tools facilating collaborative ill-structured problem solving**
▪ Introduction to the task, its aims, process and assessment system. ▪ Students form groups according to the self-selection principle.	▪ Provision of additional knowledge of collaborative aspects of problem solving, discussion on differences between individual and collaborative problem solving and discussion on learners‘ previous experience. ▪ Agreements on ground rules.	▪ Provision of knowledge of ill-structured problems and the process of solving them.	▪ Introduction to various tools that might facilitate ill-structured problem solving.

Figure 1. Educational measures to prepare students for collaborative ill-structured problem solving

Inclusion into collaborative ill-structured problem solving

After being prepared to solve problems, students should be included into realistic ill-structured problem solving. Educators should choose or give learners freedom to choose the problem that most of the students approve and demonstrate motivation to solve, at least initially. The task might be quite difficult because most ill-structured problems are complex and have a tendency to be dynamic (Jonassen, 2011). This means that relationships among problem variables may change over time, which no doubt may influence problem solver's understanding of the problem and his or her attitude towards it. Jonassen and Hung (2008) advise that problems should be complex and to a degree that remains motivating and engaging students' interests, as well as adapted to their prior knowledge, cognitive development and readiness. Problems could be related to students' major and future career. We suggest that when seeking a more focused development of problem-solving skills and procedural knowledge for doing that, it is more relevant to choose problems that demand less discipline-related factual knowledge, which are termed as knowledge-lean problems (e.g., Funke et al., 2018). If educational goals are both subject-related content acquisition and development of problem-solving skills, then this advice is less relevant.

Problem representation: creation of individual and shared understanding of the problem

Ill-structured problems are usually complex because of having a number of unknown elements and many solutions and paths to them or sometimes no solution at all. As a result, their solution processes are difficult and include many implicit processes. Therefore, such tasks require that students are additionally scaffolded and guided through them. A number of researchers (e.g., Hung, 2013; Jonassen, 2011) agree that additional scaffolding is necessary because students lack understanding of right ill-structured problem solving processes. For example, after reviewing a considerable body of research, Kirschner et al. (2006) come to conclusion that whenever learners face complex learning situations, they should be explicitly provided with some guidance for what to do and how to do. They argue in favor of guided instruction and note that minimally guided or unguided approaches, such as constructivist, problem-based, discovery, experiential and inquiry-based, are ineffective or detrimental to learning because of the too heavy cognitive loads on the learners' working memory. Similarly, Hesse et al. (2015) propose coordinating steps of collaborative problem-solving by using verbal or non-verbal observable signals or by externalizing such processes. After analysing different types of interventions and their impact on students' achievement, Hattie (2009, as cited in Luckin et al., 2017) concluded that making teaching and learning processes clear and visible was the key feature influencing learning outcomes. Thus, we consider guided learning more suitable for such complex tasks as collaborative ill-structured problem solving.

For guidance implementation in practice, educators could be using detailed procedural guidelines to explain all the necessary processes included in collaborative ill-structured problem solving. The guidelines could also contain important reminders of what matters for the right processes. For example, they could include reminders not to start offering solutions without firstly representing the available problem thoroughly. Learners may be offered question prompts to ensure a more effective problem-solving process (e.g., Ge & Land, 2003; Ge et al. 2010; Jonassen, 2011; Papadopoulos et al., 2011). As an example, for the problem representation process, students' reasoning and discussions could be led by a set of the following questions:

- What do we already know about the problem?
- What are its elements, context, constraints, causes, stakeholders involved, etc.?
- How are their interrelated with each other?
- Is there any missing information? What information is missing?
- What could be relevant sources for gathering additional information?
- How could we present facts, context, constraints and causes structurally and situationally as interrelated with each other?

- Have we collected enough evidence/information for understanding of the problem?
- Do we need additional evidence?
- What type of additional evidence/information do we need?

As already mentioned, we consider the construction of problem schemas suitable for problem representation process. First, learners might be asked to construct their individual problem schemas which are then merged into the collective ones. Such schemas might be useful for problem understanding, development of solutions and facilitation of the whole problem-solving process. In this way, learners create shared understanding and it might be helpful for retaining working memory of a group.

Development of solutions

Similarly, during the development of solutions learners might be first asked to bring their individual solutions and later discuss all available solutions as a group. For the best solution or solutions, learners should seek consensus, as defined by Halpern (2014).

Furthermore, we argue that regulation of talk among group members is necessary for problem-solving learning environments. Educational researchers suggest using implicit ground rules to improve the quality of talk and behavior among group members. For instance, Fernández et al. (2001) propose to include reminders that group members are expected to share information, take joint responsibility, give clear reasons for opinions expressed, not to be afraid to accept challenges, discuss alternatives, encourage each other to talk and reach agreements. After analyzing a number of discourse transcripts when students were following these rules, Fernández et al. (2001) concluded that this allows to achieve the best type of talk – exploratory talk. It is the kind of talk during which group members exposition ideas and arguments, explore different options and give reasons for suggestions, try to collaborate and understand each other's points of view instead of just adding discrete facts to an existing store of knowledge and contrapositioning of ideas without arguments, proposing options, challenging others without providing reasons for individual choices of answers and imposing group members' viewpoints (Mercer, 2002; Fer-nández et al., 2001).

Evaluation of solutions, making justifications and construction of arguments

Moreover, during the process of inclusion, a very important aspect is that problem solvers constantly monitor and evaluate problem-solving processes. We discuss ill-structured problem-solving assessment in the subsequent chapter.

To conclude, during the inclusion into ill-structured problem solving, students are expected to increase their personal experience in solving such problems, develop all subskills necessary for that and master tools that might facilitate the process. Figure 2 illustrates all the necessary ill-structured problem-solving aspects for which we conclude that students need guidance and support.

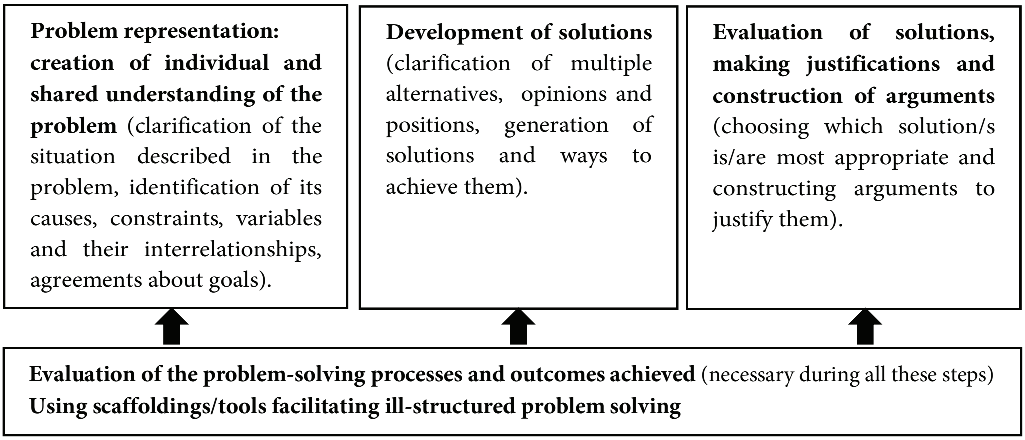

Figure 2. Processes of solving ill-structured problems requiring guidance and support

Assessment of learning processes and outcomes achieved

Presentations of solutions reached in each group and their evaluation

Both design of problem-solving learning environments and assessment of collaborative ill-structured problem solving might be equally complicated. Difficulties with assessment may arise because of peculiarities related to ill-structured problems (it is an open-ended activity, no single correct answer). Also, collaborative ill-structured problem solving is a mix of abilities and skills requiring various types of knowledge. The assessment can be based both on individual and collaborative problem-solving performance or utilize a hybrid system. Furthermore, it can take individual or collaborative outcomes and artefacts created as the object to be assessed, without exclusion of a hybrid form for considering both individual and collaborative outcomes. Comprehensive rubrics describing the desired performance could be beneficial not just for the initial stages for explaining students the ways they are expected to perform but also for marking the performance that was observed (by educators themselves or their peers). Overall, researchers (Funke et al., 2018; Jonassen, 2011; Siddiq & Scherer, 2017; Wang et al., 2016) conclude that assessment methods and systems for the evaluation of the progress of learners solving ill-structured problems in collaboration are at their initial stage.

In the cases when educators opt for performance-based (also called behavioral observation) assessment, the aspects that should be assessed are both cognitive (related to the task of solving the problem) and social (related to collaboration among group members), which both make learners' collaborative problem-solving performance. Regarding the form it can be implemented in practice, we suggest that students could be provided with a list of questions that encourage them to reflect on their learning. For example, such questions could be: "How can we evaluate our group actions and results achieved during this stage? Were we deep enough? Are we satisfied with the results I/our group achieved? What could be done better?" Such questions could be given both for the whole group or each individual separately. Most importantly, students' performance should be assessed both during the time they solve problems and at the end of problem-solving sessions. Ongoing assessment or formative assessment (as reflected in Figure 2) matters because it gives learners opportunities to refine their behavior during the process of problem-solving. The assessment at the end of problem solving sessions might help students to realize their changed competencies and pitfalls to be avoided during future collaborative problem-solving scenarios.

Utilizing outcome-oriented assessment, educators or/and peers might be assessing problem solving reports that include either their individual and collective reflections on the processes of problem-solving as well as outcomes (e.g. explanations of solutions, their implementation plans). As already mentioned, in case students create problem schemas individually and then collectively, they can be also taken for assessment as valuable artefacts created.

Obviously, the instrument for assessing all collaborative problem-solving aspects is not that easily possible to be created and therefore we suggest that educators select only one part of aspects that they consider to be most important. For example, they might be developing a hybrid assessment system to assess each learner's individual performance in a group (e.g., social/collaborative aspects) plus assess the artefacts created by a group.

Identification and reflections on new/improved skills and subskills related to collaborative ill-structured problem solving

Apart from educators that might be observing students‘ learning and change of their capabilities, learners themselves could be included into self-assesment and/or be assessed by their peers at the end of the course. Hesse et al. (2015) created a comprehensive framework for teachable collaborative problem-solving skills which is divided into two main parts of social skills and cognitive skills necessary for collaborative problem solving. These skills are divided into smaller elements which all have three levels of achievements described. We suggest that the part of framework explaining social skills (see Hesse et al., 2015, p. 43) could be taken for self-assessment and/or peer-to-peer assessment of collaborative aspects of problem solving. In addition, students could be invited to answer open-ended questions to identify their changed competences.

The table below summarizes what could be evaluated at the end of problem-solving sessions.

Presentations of solutions reached in each group and their evaluation	Identification and reflections on new/ improved skills and subskills related to collaborative ill-structured problem solving
▪ Presentations of problem solutions reached by each group and their discussion. ▪ The assessment of presentations and problem-solving reports.	▪ Participation in self-assessment and assessment of others by using rubrics defining three levels of social aspects (participation, perspective taking and social regulation).

Figure 3. Final assessment of collaborative ill-structured problem-solving

Conclusion

To conclude, if higher education truly seeks long-term outcomes and preparation of students for an unpredictable job market, development of problem-solving skills should be set as a major goal of it. Students should be prepared for real-life scenarios ready to collaborate in solving increasingly complex problems and creating collective intelligence, which, no doubt, will not be that easily replaced by artificial intelligence significantly redefining the ways people work.

Such educational goals can be attained whenever educators design complex and overarching systems for: 1) the preparation to solve problems where learners should deepen understanding about collaborative and ill-structured problem-solving aspects, 2) realistic inclusion into solving ill-structured problems with proper guidance and scaffolding present so that learners gain experience of collaborative ill-structured problem solving and the use of tools facilitating the process, and 3) evaluation of processes and outcomes of such activities with learners' contribution to this process. Notably, such a system makes learning to solve ill-structured problems visible and clearer for students. It also contributes to altering old mind-sets towards a more appreciated collaborative working culture nowadays and meaningful forms of learning – it can occur not only intentionally but also while acting purposefully while solving real-life problems in formal education.

Although we do not touch upon educators' competencies, it is obvious that such complex learning environments require additional efforts and time to be invested. We suggest that groups of educators could be collaborating on such important educational goals. Finally, continuous practice of creating these educational environments and reflections on them could help to refine them.

The tripartite system we design does not put emphasis on mastering declarative knowledge (factual or content-specific knowledge within the discipline). Instead, the system is designed for gaining procedural ("how") knowledge and experience necessary for solving ill-structured problems in collaboration and in this way enhancing problem-solving skills. Therefore, we believe in its wider application across a wide array of subjects with some refinements for focus on different aspects, if necessary.

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Neaiškios struktūros problemų sprendimo bendradarbiaujant gebėjimų plėtojimo edukacinė sistema

Evelina Jaleniauskienė[1], Palmira Jucevičiennė[2]

[1] Kauno technologijos universitetas, Socialinių, humanitarinių mokslų ir menų fakultetas, A. Mickevičiaus g. 37, 44240 Kaunas, evelina.jaleniauskiene@ktu.edu
[2] Kauno technologijos universitetas, Socialinių, humanitarinių mokslų ir menų fakultetas, A. Mickevičiaus g. 37, 44240 Kaunas, palmira.juceviciene@ktu.edu

Santrauka

Problemų sprendimas yra įvardijamas kaip vienas iš svarbiausių XXI amžiaus gebėjimų, ir todėl daugybė edukologijos mokslo atstovų ir praktikų nurodo, kad šio gebėjimo ugdymas turėtų būti integruojamas į įvairius universitetinius dalykus. Tačiau ši praktika dažniausiai apsiriboja probleminio mokymosi taikymu, problemų sprendimo gebėjimo ugdymas čia yra nurodomas tik kaip vienas iš daugelio tikslų. Taip pat svarbu pažymėti, kad šis populiarus metodas yra priskiriamas prie padedančių perprasti dalyko turinį metodų, jį taikant tam ir skiriama daugiau dėmesio.

Iš tikrųjų neaiškios struktūros problemų sprendimas yra sudėtingas procesas, todėl aukštajame moksle turėtų būti skiriama daugiau dėmesio šio gebėjimo ugdymui. Šiame straipsnyje siekiama pagrįsti mokymo / mokymosi sistemą, kuri ir padėtų įgyvendinti tokį edukacinį tikslą. Pasitelkiant literatūros analizę, yra kuriama sistema, kuri leistų plėtoti problemų sprendimo bendradarbiaujant gebėjimą. Ji susideda iš trijų dalių: pasirengimo spręsti neaiškios struktūros problemas bendradarbiaujant, įsitraukimo į tokių problemų sprendimą ir šių procesų bei pasiektų rezultatų vertinimo. Sukurta sistema yra universali ir gali būti pritaikyta dėstant įvairias mokslo disciplinas ar tarpdalykinius kursus aukštojoje mokykloje.

Esminiai žodžiai: *problemų sprendimas, bendradarbiavimas, XXI amžiaus gebėjimai, neaiškios struktūros problemos, aukštasis mokslas.*

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