International Round Table Phase I for Advancing Skills in STEM Education

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Dr. Eli Eisenberg
Prof. Arnon Bentur
Dr. Avigdor Zonnenshain
Tamar Dayan

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1.Introduction

There has been a significant body of research, including numerous documents, articles, and programs, that have examined the necessity for reform in the education system with a focus on developing skills and competencies. The proposed approaches to reform, which have been well-established in theory since the 1970s, have been widely studied. The importance of 21st century skills in various studies, the labor market, and everyday life cannot be overstated and has been a consistent theme in research, papers, reports and surveys.

The promotion of competencies and skills within the education process is an important element in preparing the students to integrate, prosper and achieve themselves in the society and economy of the modern world. The competencies and skills identified and prioritized in the round table are of generic nature, and they are relevant to all fields of activity, as well as personal development and preparation for the future employment world. Skill such as critical thinking is of importance for personal achievement, for employment as well as for integration in the academic world, whether in STEM areas or social and liberal art domains.

During the pilot project which dealt with the integration of excellence promotional skills in STEM through the school-academy interface, led by the Samuel Neaman Institute, it was identified that there are significant challenges in implementing the strategies discussed in academic literature. Despite the abundance of publications on the subject, the actual implementation in practice has been limited and slow. The main factors contributing to this state of affairs include:

- The existence of numerous theoretical and often impractical definitions that are difficult to apply in real-world settings.
- The lack of accessible and effective teaching, learning, and experiential methodologies for various teaching levels.
- The absence of well-developed and universally agreed upon assessment and measurement methods and tools that can be applied in the field.

In order to overcome these obstacles, there is a need for a process that will make it possible to formulate a common, agreed upon and coherent language for characterizing the skills required to promote STEM as well as resolve ways to develop teaching/learning/experiential methods and measurement tools for their evaluation. The availability of such a system and practical tools will facilitate the promotion of skills required for excellence in STEM within the education process for both, students at school and in higher education of science and engineering.

For this purpose, a round table forum for skills and competencies was established, consisting of central bodies and institutions in Israel and the world, which have proven professional expertise and experience in the field of skills and competencies.

The objective is to develop a common language, agreed upon and coherent, with respect to characterization of the components which make up the skills required for excellence in STEM, as well as analysis of teaching/learning/experiencing methodologies and assessment and evaluation tools, for high school students and higher education students.

2.Methodology

Mode of operation

To accomplish this objective, a method of operation was implemented that utilized roundtable meetings as the primary mechanism for discussion and collaboration. Prior to each meeting, background materials were prepared to provide context and facilitate informed discussion. Following each meeting, a summary was prepared to document the key points discussed and the decisions made. This process was designed to lead to the development of a common language and understanding of the terminology, definitions, as well as accepted and user-friendly methods of application and assimilation in the field of STEM education. This would serve as the foundation for developing a practical and applied guide for teachers and lecturers to implement in their classrooms. The guide will provide a clear and consistent framework for developing skills and qualifications in STEM education, at both the school and university level (Phase 2 of the Skills' Round Table).

The round table partners

The partners of the round table consist of central bodies and institutions that possess demonstrated professional expertise and experience in the field under discussion.

Samuel Neaman Institute

Beit Berl College

The National Institute for Testing and Evaluation ("NITE")

Ministry of Education (The Pedagogical Secretariat, the Administration for Technological Education and the Senior Division for Strategy)

National Authority for Measurement and Evaluation in Education (RAMA)

Technion Israel Institute of technology

The Afeka Academic College of Engineering

Jewish Federaion of Cleveland

Social Finance Israel (SFI)

Joint Israel

IDF Department of Behavioral Sciences

TIES Teaching Institute for Excellence in STEM

The European Training Foundation (ETF)

OECD

Partnerships in Education and Resilience (PEAR)

The list of participants is presented in Appendix 1.

The roundtable methodology was based on several principles:

- Six meetings were held every six weeks over a ten-month period from May 2022 to February 2023. The meetings were held online, with representatives from each organization.
- The Samuel Neaman Institute led the professional and organizational process of the proceedings and roundtable meetings.
- A SharePoint for the "proceedings" was established to manage relevant information collected from various sources.
- The participating organizations and institutions agreed to disclose materials and tools they have developed and are developing in the field of discussion with appropriate transparency.
- The outcome of the Round Table will be a final report that addresses the three main topics: characterization of key competencies that promote excellence in STEM, appropriate methods for teaching/learning/experiencing and measurement and assessment tools for evaluating mastery of competencies. The final report will be agreed upon and approved by all partners in the process (any points of disagreement will be noted in the report).
- The participating organizations and institutions agree that the results of the process will be exposed and accessible to policymakers, decision-makers, and the general public.

- Starting from the third meeting, representatives from partner organizations and institutions presented their expertise and experience in the field of skills during the meetings.
- The possibility of a dedicated conference was examined during the roundtable, to create an impact for the results of the proceedings and hopefully will be carried out in phase 2 of the Round Table.

Description of the meetings

Six Round Table meetings were held with each devoted to a specific topic, as outlined in table 1.

Table 1: Round Table meetings

Meeting No.	Content	Accompanying document	Date	Advance document
1	Goals, methodologies, modes of actions, case study presentation	Abstract report: Acquisition of skills, knowledge, competencies, values, and attitudes in the education chain	30.05.2022	
2	Self-study, Lifelong learning	Relevant material on Self-study and Lifelong learning	05.07.2022	Report and questionnaire for the Round Table participants
3	Teamwork, cooperation and collaboration, interpersonal communication	Relevant background material on teamwork, cooperation and collaboration, Interpersonal communication	23.08.2022	Report and questionnaire for the Round Table participants

Meeting No.	Content	Accompanying document	Date	Advance document
4	Complex problem solving, critical thinking	Relevant background material on complex problem solving, critical thinking	[1]08.11.2022	Report and questionnaire for the Round Table participants
5	Additional skill or supplements	Suggested options for phase 2 of the Skills Round Table	20.12.2022	Skills International Round table – Phase 2: Suggested Options
6	Concluding meeting	Draft summary report of the Skills' Round Table	07.02.2023	Draft Summary Report

Before each meeting, an agenda of the meeting and background documents were sent to all participants.

The first meeting was dedicated to establishing the methods of operation for the roundtable, including the selection of the three main skills on which the meetings will focus, and the guidelines of the meetings as outlined above. The three skills chosen for focus were:

- Self-study and Lifelong learning.
- Teamwork, cooperation and collaboration, interpersonal communication.
- Complex problem solving and critical thinking.

In preparation for the second, third and fourth meetings, background documents were prepared for each skill/competency that included review of definitions, a description of methodologies for developing the skills, and evaluation and measurement methods. In addition, a survey was prepared and conducted among the participants in which they selected the relevant elements they considered most important for the skill being discussed, their preferred methodologies, and preferred assessment and measurement methods. This information was used to guide the discussions and focus of each meeting.

The survey sent to the participants consisted of a Likert-type questionnaire with 5 levels from 1 (Totally Disagree) to 5 (Fully Agree). The results of the survey were processed statistically using SPSS software, including the calculation of the percentage of respondents in each level

[1] The date was postponed by a week due to the election day in Israel

on the Likert scale for each item, as well as the average, median, and standard deviation of each item. Participants were also given the opportunity to provide comments or clarifications and any missing items. The findings were presented in a table which included a graphical presentation of the survey results and sent to the participants before each meeting. During the meeting, the results of the survey were presented, highlighting the items on which there was agreement, and discussing points of clarification or comments that were noted.

As mentioned, additional information and details can be found in Appendices 2, 3 and 4, which are supplementary materials to this main document; they provide additional information and support for the information provided in the main text.

As per the instruction given, all meetings were accompanied by simultaneous translation in order to allow the participants to express themselves in the language they are comfortable with. The meeting was supported by the IT Manager of the Neaman Institute.

All the materials for the meetings and the meeting summaries were written in the English language.

In addition, after each meeting, a summary of the meeting was sent to all participants, for feedback and corrections and a link to the recording of the meeting.

3.Self-study and Lifelong Learning (LLL) Competencies: Definitions, Methodologies and Evaluation

3.1 Components and Definitions

Self-study and Lifelong Learning (LLL) competencies are derivatives of (specific and broad) knowledge combined with skills, such as the ability to search and acquire relevant content and the ability to apply new learning strategies. It includes the encouragement of the development of self-study competencies, the building of motivation to complete relevant knowledge on one's own initiative, as well as the instilling of self-resilience to meet challenges and complexities that will all become an integral part of the future world of work. In addition, the 21st Century worker will need to think flexibly as well as be able to take initiative and consider the changing and dynamic environment.

OECD (Drake et al. 2018) defined self-study, self-directed learning and LLL as meta-learning skills, which can be described as "the process by which learners become aware of and increasingly in control of habits of perception, inquiry, learning and growth (Maudsley, 1979), which implies as "being aware and taking control of one’s own learning" (John Biggs 1985). It includes developing dispositions that support motivation, self-regulation, perseverance, adaptability and resilience. It also calls for a growth mindset – a belief in one’s ability to learn – combined with the use of strategies for planning, reflecting on and monitoring progress towards one’s goals and reviewing potential next steps, strategies and results.

According to the Israeli Ministry of Education, self-study is the ability to make appropriate decisions, identify required actions, set personal targets for personal development and learning as well as to take action to achieve them independently. It is not dependent only on acquiring of the skills but also on their implementation. Taking responsibility over the process of self-development, which involves active partnership in the design of the learning process, will also significantly enhance the motivation and commitment, which in turn will assist in achieving the educational goals (the profile of the adult independent self-learner).

In the background report for the Competencies Round Table Project fourteen components of self-study competencies were proposed:

In conclusion of the survey, the literature and discussion in the roundtable, several components were identified which seem to be emerging as being important for consideration:

Table 2: Components of definitions

No.	components
1	Ability to search and locate relevant information
2	Development of motivation to self-acquire knowledge
3	Self-management of the learning process
4	Constant developments of self-learning habits
5	Self-growth attitude and self-efficacy
6	Effective planning and management of time and information
7	Setting achievable goals and striving to attain them
8	Ability to cope with failures and move forward to achieve the task
9	Taking initiative
10	Persistence over time
11	Implementing new learning strategies such as consulting
12	Ability to adopt to changes
13	Identifying possible barriers and taking the appropriate steps
14	Setting appropriate priorities

In the round table discussions, it was agreed upon that the first seven are of the highest relevance and priorities.

3.2 Methodologies for learning, teaching and experiencing

Self-learning implies the engagement of the students in their own education and in their own formation of understanding of their own learning. There's a difference between active learning, between the acquisition of learning and being a receptacle of information.

In the background report for the Competencies Round Table Project six methodologies for self-study acquisition in the framework of education were proposed:

Table 3: components of methodologies

No.	Components
1	Project-inquiry based learning
2	Experiment laboratory
3	Flipped classroom - practicing information and knowledge acquired at home in the classroom
4	Minimal guidance instruction
5	Presentations
6	Posters

In the round table discussions, it was agreed upon that the first three are of the highest relevance and priorities.

The various aspects and characteristics of these methodologies are addressed below.

It is essential that students have the opportunity to exercise this skill or capability, but it should not lead to untutored direction. Here there is a tension between allowing autonomy and having guidance. It is a discourse issue and not a question of whether a student prepared a presentation or not, but what happens around that. The task has features that allow the student autonomy for inquiry and a possibility of dialogue where the teachers enable and support the process via the feedback and frames the task in supportive ways.

Sometimes, a minimally guided instructional approaches is proposed suggesting that people learn best in an unguided or minimally guided environment. Popular formats for minimally guided instruction include problem-based learning (PBL) or inquiry-based learning (IBL). Because of the minimal guidance provided, this type of instruction may foster self-directed learning. Within these frames, research assignments and projects are central, and they include the writing of papers, presentation of posters, planning of activities within the subject learning, presentations.

The "flipped classroom" can be described as a learning model in which students obtain some foundational material on their own, prior to class, and then class time is used to help apply that learned information. An example of a highly structured flipped classroom is team-based learning (TBL). Flipped classrooms have the potential to move students towards self-directed learning. First, students prepare prior to class with faculty-provided materials. This preparation allows students to develop confidence in self-regulation skills (e.g., what to focus their time on, selecting appropriate study strategies, self-assessment) and self-paced learning (e.g. "I need to get this done before class, but I am free to study when I want and for as long as I want"). With the help of the instructor, the targeted content acquired outside the class can be applied, expanded upon and worked with such a way as to reinforce and deepen learning. This may serve to model and assist the student in the development of the skills needed for future self-direction.

The implementation of these methodologies requires quality teachers/instructors, which implies designing proper training of current teachers, in the context outlined below. The teachers need to first understand what Self-Directed Learning (SDL) is and what the key components of the SDL process are. Self-directed learning can be described as a six-step process (Robinson and Perski 2020):

- Developing goals for study.
- Outlining assessment with respect to how the learner will know when they have achieved those goals.
- Identifying the structure and sequence of activities.
- Laying out a timeline to complete activities.
- Identifying resources to achieve each goal.
- Locating a mentor/faculty member to provide feedback on the plan.

It is further suggested that developing self-directed learners requires a scaffolded approach in which more self-paced- or teacher-directed activities are introduced early on, during didactic instruction, to help students become more self-regulated in their "self-directedness." Over time, as the student moves from the classroom to the experiential setting, control of the learning environment can be shifted from the instructor to the student. This scaffolding may include starting with more self-paced activities and providing guidance to the learner on how to be more self-regulated.

3.3 Evaluation and measurement tools for self-study and lifelong learning

Self-Directed Learning (SDL) evaluation often includes methods that are more qualitative in nature, since the focus is on the building of meaning and self-development of skills, many of which emotional in nature, based on experience.

In the background report for the Competencies Round Table Project six evaluation and measurement tools for self-study acquisition in the framework of education were proposed:

Table 4: components of evaluations

No.	Components
1	Self-feedback questionnaires
2	Observation indicators
3	Interviews

No.	Components
4	Peer feedback questionnaire
5	LEQ-H questionnaires
6	Using technologies such as Cascade and eVIVA

In the round table discussions, it was agreed upon that the first five are of the highest relevance and priorities.

Some of the approaches can be subjective in nature and thy include:

- Reflections
- Interviews
- Observations of behaviors
- Feedbacks from students
- Self-reporting questionaries

Additional considerations in implementing these modes of evaluation:

- Skill assessment must be a continuous event and cannot be assessed with a single tool. It is an ongoing event that is measured at several different points. If we address the explicit acquisition of skills, assessment can be done during the learning/acquisition process itself (self-report).
- There are high stakes in the evaluation process, namely, do these tests hinder the development of these skills? Assessment might steer ones behavior and thus the question comes up whether assessment could hinder the development of these skills.

The tools often involve the application of a rubric methodology, and an example is given below, in the form of a Standards-Based Report Cards, shown in the table below.

Table 5: a rubric methodology

Skills	**Behaviors / products**	**0** **Below Expectations**	**1** **Emerging Expectations**	**2** **Meets Expectations**	**3** **Exceeds Expectations**
Self-learning/ Lifelong learning	Students learn to think about their own thinking and learning (metacognition) and to believe in their ability to learn and grow (growth mindset). They develop their ability to set goals, stay motivated and work independently.				
	Students reflect on their thinking, experiences and values, and respond to critical feedback, to enhance their learning. They also monitor the progress of their learning.				
	Students develop a sense of identity in the context of various and diverse communities				
	Students cultivate emotional intelligence to better understand themselves and others and build healthy relationship				
	Students learn to take the past into account in order to understand the present and approach the future in a more informed way				

4.Teamwork, collaboration and cooperation Competencies: Definitions, Methodologies & Evaluation

4.1 Components and Definitions

Eizenberg and Raveh (2020) define **teamwork, collaboration, and cooperation** as the ability of the individual to collaborate and cooperate as part of a team to meet the challenges of complex missions, and the ability to continue the teamwork when difficulties arise. Effective teamwork requires social as well as cognitive abilities, such as project management and task focusing. The website of the Ministry of Education of Ontario, Canada, defines **collaboration** as involving the interplay of the cognitive (thinking and reasoning), interpersonal, and intrapersonal competencies needed to work with others effectively and ethically. These skills are improved as they are applied and practiced, with increasing versatility, to co-construct knowledge, meaning and content with others in diverse situations, both physical and virtual, that involve a variety of roles, groups, and perspectives.

In the background report for the Competencies Round Table Project there are more definitions for the teamwork, collaboration & cooperation competencies on the different perspectives of these competencies, like: Collaboration with others, effective teamwork, interpersonal communication skills, social conduct, management of conflicts, management of interpersonal relations. In this background report, twelve components of teamwork competencies were proposed:

Table 6: Components of definitions

No.	components
1	Acting resiliently as a team despite difficulties and challenges
2	A team's quality of project management (assignment of tasks, time management' etc.)
3	Maximum utilization of the team members' knowledge and cognitive resources
4	Ability to make decisions collaboratively
5	Effective work with other members of the team
6	Flexibility and adaptability as a team member

No.	components
7	Collaborative responsibility of the team
8	Understanding the attitudes and points of view of fellow team members
9	Providing help and support to team members
10	Verbal communication: active listening and speaking
11	Accepting and giving effective feedback
12	Utilizing advanced technologies to support teamwork

The first eight components were supported as more important components during the survey that was conducted with the roundtable participants and partners.

During the discussion there were several remarks made:

- Empowerment of the team vs. empowerment of the individual
- Supporting a team leader
- It is proposed that the low rank for using advanced technologies is due to our relatively low experience in practicing advanced technologies to support teamwork. It should be considered more thoroughly.

4.2 Methodologies for learning, teaching and experiencing

There are a variety of methodologies and ways for effective learning, teaching, and practicing teamwork and collaboration. Some of these methodologies are described in the above-mentioned background report for the Competencies Round Table Project. One important principle is to teach and learn teamwork in its relevant context. Finnelli et al, describe four stages for this mission- construct teams carefully, design good and appropriate team assignments, teach team skills, assess team performances (assessment of teamwork will elaborate in the next paragraph).

Construct teams carefully:

- Construct the right size of team-not too big, not too small
- Form heterogeneous teams with diverse members (gender, age, discipline experience, Character etc.) so that the team can involve diverse points of view
- Consider practical issues when creating teams (like availability)

Design good and appropriate team assignments:

- Begin with simple, well-defined tasks, then increase their difficulty

- Define individual versus team accountability
- Develop assignments that require interdependence
- Present assignments that require holistic views
- Present challenges that are interesting for the team members

Teach team skills:

- Observe and guide teams – In some cases, teams need a great deal of support while individuals learn to interact with diverse peers. Observing the teams is fundamental to detecting and correcting problematic dynamics in a timely way.
- Have members talk about important team behaviors
- Have teams develop contracts, rules, and code of conduct
- Exercise problems solving through teamwork
- Cooperative learning is essentially a learning model that focuses on developing knowledge and competencies in the social-cultural context, within the framework of a challenge jointly responded to by team members with short- or long- term tasks.

In the background report, nine components of methodologies for effective learning and practicing teamwork & collaboration competencies were proposed for feedback survey:

Table 7: Components of methodologies

No.	components
1	Team-based learning
2	Problem-/project-/product-based learning
3	Group discussion
4	Collaborative inquiry learning
5	Detailed planning of the team members' roles, work methods, behavioral rules, etc.
6	Teamwork in a variety of environments: nature, jobs, communities.
7	Creating a heterogeneous team of team members with different abilities and strengths.
8	Using peer instruction of teachers to demonstrate teamwork
9	Creating a heterogeneous team of team members with different abilities and strengths.

The first seven components were supported as more important components for effective teaching teamwork competencies during the survey that was conducted with the roundtable participants.

During the discussion session there was an emphasis on the importance of teaching it in the relevant context.

4.3 Evaluation and measurement tools for teamwork, cooperation and collaboration, and interpersonal communication

Evaluating teamwork means that you assess the quality of the whole team as working together, and you assess the quality and contribution of each member of the team.

When faced with a collaborative task, the most important question is how to assign credit to each member of the group, as well as how to account for differences across groups that may bias a given member's performance. This issue arises whether members are asked to work in pre-assigned complementary roles or whether they are also being assessed on their skills in inventing ways to collaborate in an undefined situation. Questions on assigning individual performance as well as group ratings become even more salient for international assessments where cultural boundaries are crossed (Kechagias 2011).

Several ways to evaluate teamwork, collaboration and cooperation, and interpersonal communication are presented in the background report for the Competencies Round Table Project. These are: Peer assessment, direct assessment, behavioral observation and more. Also, it includes Standards-Based Report Cards which are useful for evaluating competencies. In this background report, five components of methodologies for effective assessing teamwork & collaboration competencies were proposed for feedback survey by the roundtable participants:

Table 8: Components of evaluations

No.	components
1	Peer assessment
2	Behavioral observation
3	Self-feedback questionnaire
4	Utilization of advanced technologies such as simulations and AI
5	Direct assessment

The participants supported the first four components as being of higher relevance and priority.

5.Complex problem solving and critical thinking: Definitions, Methodologies & Evaluation

5.1 Components and Definitions

Critical thinking and problem solving involve locating, processing, analyzing and interpreting relevant and reliable information to address complex issues and problems, make informed judgements and decisions and take effective action. With critical thinking skills comes an awareness that solving problems can have a positive impact on the world, and this contributes to achieving one's potential as a constructive and reflective citizen. Learning is deepened when it occurs in the context of authentic and meaningful real-world experiences.

Problem-solving skills refer to an individual's capacity to engage in cognitive processing to understand and resolve situations where a method or solution is not immediately obvious. Problem solving takes time and includes several stages that presume different sub-skills and can include a variety of forms starting from "interpersonal problem solving" (problems are solved alone) to different forms of collaborative problem solving (Drake et al., 2018).

Problem solving according to UNICEF MENA is a higher-order thinking process interrelated with other important life skills, such as critical thinking, analytical thinking, decision-making and creativity. More specifically, being able to solve problems implies a process of planning,i.e., the formulation of a method to attain the desired goal. Problem solving begins with recognizing that a problematic situation exists and establishing an understanding of the nature of the situation. It requires the solver to identify the specific problem(s) to be solved, plan and carry out a solution, and monitor and evaluate progress throughout the activity.

According to the OECD (Drake et al., 2018) **Critical thinking** can be defined as questioning and evaluating ideas and solutions. This definition of critical thinking skills embodies components of metacognition, social and emotional skills (reflection and evaluation within a cultural context), and even attitudes and values (moral judgment and integration with one's own goals and values), depending on the context.

In many cases, definitions of **critical thinking** emphasize logical or rational thinking, i.e., the ability to reason, assess arguments and evidence, and argue in a sound way to reach a relevant and appropriate solution to a problem. However, critical thinking also includes a dimension of "critique" and "perspective-taking." In addition to rational or logical thinking, critical thinking includes two additional dimensions: the recognition of multiple perspectives (or the possibility of challenging a given one) and the recognition of the assumptions (and limitations) of any perspective, even when it appears superior to all other available ones (Vincent-Lancrin et al., 2019 p.24).

Pearson (n.d.) has defined **critical thinking** as consisting of four core skills: 1. systems analysis: the ability to determine the relationship between variables in a system; 2. argument analysis: the ability to draw logical conclusions based on data or claims; 3. creation: the ability to construct a strategy, theory, method or argument based on a synthesis of evidence (the artifact that is created goes beyond the information at hand); 4. evaluation: the ability to judge the quality of procedures or solutions. Evaluation involves criticism of a work product using a set of standards or specific framework.

Critical thinking according to the Israeli Ministry of Education is the ability to review and evaluate information, opinions and ideas intelligently; form an opinion and formulate a position independently; choose between alternatives and make reasoned decisions. It includes four core capabilities: **evaluation of information and data sources, argumentation, decision-making and doubting**.

In the materials prepared for the Skill' Round Table ten definitions-components of complex problem solving and critical thinking, seen below, were described and analyzed.

Table 9: Components of definitions

No.	components
1	Locating, processing, analyzing, and interpreting relevant and reliable information to address complex issues and problems
2	Questioning and evaluating ideas and solutions
3	Understanding and resolving situations where a method or solution is not immediately obvious
4	Three types of thinking: reasoning, making judgements, and problem solving
5	Learners learn that for every issue there are multiple perspectives that they can explore
6	Evaluating future consequences of present actions for self and others
7	Ability to find solutions to both simple and complex issues in uncertain situations.
8	Thinking involves higher-order executive functioning: This is a "meta-skill" through which one learns to think about thinking and develop purposeful thinking processes, such as being able to discern and evaluate whether an argument makes sense or not

No.	components
9	Being able to solve problems implies a process of planning, i.e., the formulation of a method to attain the desired goal. Problem solving begins with recognizing that a problematic situation exists and establishing an understanding of the nature of the situation. It requires the solver to identify the specific problem(s) to be solved, plan and carry out a solution, and monitor and evaluate progress throughout the activity
10	Using digital tools in the process of problem solving and identifying the relevant digital resources for the required solutions

The first five components were highly ranked and mostly agreed by the participants of the Skill's Round Table for complex problem solving and critical thinking skill. Some interesting issues were raised in the written remarks and the discussion taken place in the meeting, such as follows:

1. EntreComp and the DigComp, initiatives of the European Training Foundation, are relevant examples for the components of complex problem solving and critical thinking (presentation attached).
2. The components/definitions of the skills/competencies should be stated in terms of behavioral objectives – what the student needs to do to demonstrate his/her mastery of the skill.
3. There is an important and meaningful connection between the STEM subject matter and the components/definition of the complex problem solving and critical thinking skills/competencies. The content domain affects the use of skills and their development.
4. One of the reasons for different definitions/components is that the different components refer to different contexts, different ages and complexity levels.

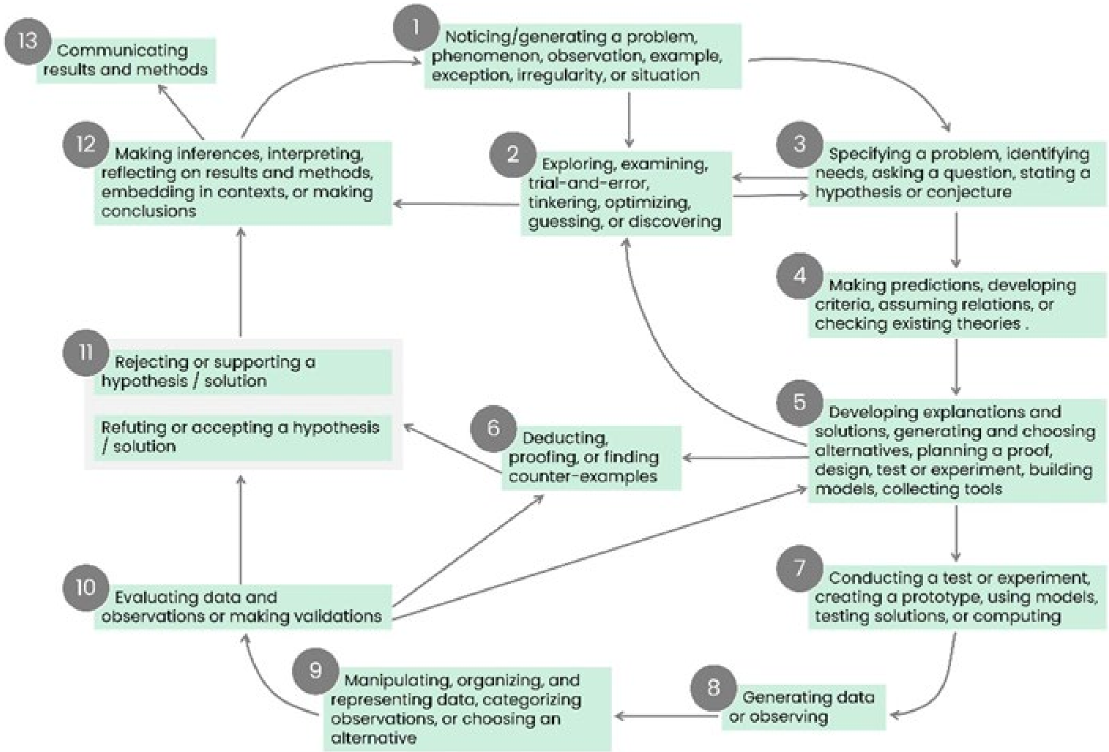
5.2 Methodologies for learning, teaching and experiencing

Integrated framework of problem solving (Burkhard et al., 2019)

The framework can support both practice and research by providing a common background that relates the means, steps, processes and activities to solve problems in the different domains to a single common reference. In doing so, it can support teachers in explaining the multiple ways in which scientific problems can be solved and in constructing problems that reflect these numerous ways. STEM and computer science educational research can use the framework to develop competences of problem solving at a fine-grained level, to construct corresponding assessment tools and to investigate under what conditions learning progressions can be achieved.

Figure 1 shows the multiple processes consisting of 13 steps, through which problems can be solved.

Figure 1: Visual representation of an integrated framework of problem solving.



Source: Burkhard et al., 2019

The framework is visualized with arrows between the different steps, which are represented by boxes. Each step/box contains different but comparable activities that belong to the step, for example, specifying a problem, identifying needs, asking a question or stating a hypothesis or conjecture. These activities can be alternatives, or more than one activity can be relevant for solving a certain problem. The step involving the communication of results and methods is not necessarily a problem-solving step because it is a common practice to share the results derived from this process, and is an activity of high importance in education.

The benefit of the framework is that it offers a variety of different activities that help to solve a problem. However, the framework does not solve the specific problem for the students. Nonetheless, given that the students understand the steps, the framework can serve as a toolbox that offers options and helps them not to forget important processes.

The framework can be used for teaching purposes in a way that is acutely linked to meaningful problems and is applied to content. In this way, the framework can help students gain a comprehensive view of problem-solving methods and techniques used in STEM domains.

The framework can help to reflect problem-solving processes after a problem is solved or after students have given up. All steps taken can be identified, retraced and made visible in a representation such as Figure 1. This helps to focus on scientific strategies of problem solving, putting the solution into a larger context, and to relate the solution to the students' prior knowledge, which is a prerequisite to achieving competences in solving problems.

Explicit instruction

Many researchers have noted that critical thinking skills are unlikely to develop in the absence of explicit instruction (Ventura, Lai, & DiCerbo, 2017).

What form should this instruction take? An infusion approach, specifically teaching critical thinking skills in the context of a particular topic.

Ennis (1989) introduced an illustration that suggests three models: a general model, an infusion model and a mixed model for critical-thinking instruction. The general approach is taken to mean teaching generalized critical thinking skills in a critical-thinking course. The infusion approach is suggestive of self-consciously teaching critical-thinking skills as part of a subject course. Finally, the mixed-model approach is introduced as a general course in combination with either the infusion or immersion approach.

According to Halpern (1998) a depositional or attitudinal component that consists of modeling critical-thinking and actively inspiring thoughtful responses is obligatory. In this regard, the explicit instruction of critical-thinking skills, including structured training activities designed to facilitate the transfer of critical thinking techniques across innumerable contexts, in addition to nurturing metacognitive strategies that include having students discuss the thinking process, is called for. (Fahim & Eslamdoost, 2014).

There appears to be a consensus that the explicit teaching of problem solving is better, not only because it recognizes problem solving as an explicit skill to be taught, but also because it provides guidance in the form of specific problem-solving methods and the problem situations to which these apply (Matthee & Turpin, 2019).

Simulations

Processes, systems, or functions of real-life phenomena are simulated in an authentic manner to enable understanding of a system or device. Studies have found that practice on computer simulations resulted in learning that was comparable to that achieved from traditional lectures. And higher learning gains are achieved when simulations demonstrate high fidelity, or a high degree of similarity, to the physical systems they are designed to represent. For example, an animated simulator teaching electronics troubleshooting resulted in shorter learning times and fewer trials than a static simulator.

Discussion and reflection

These tools are especially relevant for the encouragement of critical thinking, as they make it possible to expose the students to positions that they will not be comfortable with, thus motivating them to respond. The discussion revolves around the materials learned in class and their interpretation, and the ability to associate them with the knowledge gained in class and their personal experience. The discussions can be part of the curriculum and involve even short discussions between the teacher and students during breaks. The discussions can also be enriched with supporting items such as documentary videos. In the discussions to support the development of critical thinking, the teaching team will refrain from presenting their own preferences for one position or another, and help the students raise doubts about their own positions and not merely attack rivals' positions.

The first five components in the table below were highly ranked and mostly agreed by the participants of the Skill's Round Table for complex problem solving and critical thinking skill. Mainly there is broad agreement with regard to simulations and learning to solve problems with computer simulations. 'Discussion and reflection' are also ranked quite high but they are relevant methodologies of teaching/learning/experiencing, nurturing to the students with other cognitive skills.

Table 10: Components of methodologies

No.	components
1	Instructional model
2	Explicit instruction
3	Case Libraries
4	Worked Examples
5	Concept Maps
6	Simulations
7	Computer-supported collaboration scripts.
8	Rubric methodology
9	The Stanford d.school Design Thinking approach
10	Problem-Based Learning Combined with Computer Simulation
11	Integrated framework for problem solving
12	Discussion and reflection
13	Game learning
14	Signature pedagogies

The following issues were raised in the written comments and the discussion in the Skills' Round table:

1. Design thinking methodologies including the engineering design process are relevant to the methodologies of complex problem solving and the decision and critical thinking skill.
2. Design structured tasks that challenge and support students to critically apply disciplinary ideas and practices.
3. One of the first stages in solving problems is searching for data and evaluating the data. But when little data or no data is available you have to cope with uncertainty, which today is the reality in many cases.
4. The meaning of the instructional model provides flexibility, depending on the nature of the skill and the instructor's or teacher's competency.
5. The rubric is a methodology as well as serving an effective formative assessment tool, stressing again the necessity of combining learning and assessment.

5.3 Evaluation and measurement tools for complex problem solving and critical thinking

The current prevailing concept in research is that critical thinking is not a general skill, but is dependent on context. The general cognitive skills required for critical thinking are interpretation, analysis and evaluation of claims, conclusions in view of the information and self-management (i.e., re-evaluation of previous concepts in view of new information and data). Yet, for each field of knowledge, the characteristic data, research methodologies and their suitability for evaluation of the basic assumptions (axioms and norms) are context specific (Leitmanovich 2021).

The evaluation of critical thinking is an important challenge for assessing the evolution of creativity over time, but it should be done in cooperation with the students through dialogue.

Considering the challenges posed by evaluation, it is widely believed that pre-test and post-test results in evaluating critical thinking skill do not reveal retention. Cognitive skills improve with practice and real effects of critical thinking will be apparent sometime later, while long term retention is difficult to assess. As a result, teaching-testing approaches in classroom can be changed in different ways to improve critical thinking abilities in students (Fahim & Eslamdoost, 2014).

In order to assess all skills in critical thinking, educators should aggregate a mix of evidence from critical-thinking activities. Evidence can come from first-hand observations, work products from artifacts (e.g., writing samples, concept maps) or real-time performance data from simulations. Recent advances in technology can supplement observations by enabling real-time capturing and automated scoring of these aspects of writing and systems analysis. When possible, feedback around performance should be provided at both the skill level (e.g., argument analysis) as well as around the task (e.g., does the student make logical conclusions in the argument?). Providing both these types of feedback can ensure the student knows how they are progressing in critical-thinking instruction (Pearson).

Unit model in scientific problem solving (Examples from PISA tests)

The PISA assessment examines students' capacities to generate diverse and original ideas, and to evaluate and improve ideas across a range of contexts or "domains." The assessment includes four domains: written expression, visual expression, social problem-solving and scientific problem-solving. In each of these domains, students engage with open tasks that have no single correct response. They are asked either to provide multiple, distinct responses, or to generate a response that is not conventional. These responses can take the form of a solution to a problem, a creative text or a visual artifact.

The first task of the unit asks students to describe three innovative ways that bicycles might change in the future. This task generates evidence for the facet "generate diverse ideas" of the competency model. Ideas are "appropriate" in this task if they represent a coherent suggestion for a way that bicycles might change, and if the suggested solution, if properly implemented, still maintains the essence of a bicycle (i.e., a transportation device for a single individual).

In the second task of the unit, students are presented with a friend's suggestion for an anti-theft device and asked to come up with an original way to improve the suggestion. This task generates information for the facet "evaluate and improve ideas" of the competency model.

The third and final task of the unit asks students to suggest a creative way that the pedals on the bicycle can be used for a different purpose, now that bicycles can be automatically powered. This item generates information for the facet "generate creative ideas" of the competency model.

Rubric - Indicators methodology

Researchers share an overall common understanding on the key dimensions of creativity and critical thinking. However, transferring the concepts to an educational application requires further translation. This is where rubrics come in (Vincent-Lancrin et al., 2019). The OECD rubrics (Vincent-Lancrin et al., 2019) can serve the teachers as a methodology of teaching and learning as well as evaluation.

Rubrics are a way to simplify, translate and construct a social representation of what creativity and critical thinking look like in the teaching, learning and assessing process. They aim to create a shared understanding of what creativity means in the classroom, and share expectations among teachers and students. The function of rubrics is to simplify the big concepts of creativity and critical thinking so that they become relevant to teachers and learners in their actual educational activities. They also allow teachers to monitor and formatively assess whether their students develop those skills. Rubrics are a metacognitive tool that helps make learning visible and tangible and teaching intentional.

The OECD rubrics capture different dimensions of critical thinking through four high-level and easily memorable descriptors: imagining, inquiring, doing, reflecting. Each of these active words is then associated with a descriptor of critical thinking.

The first two assessment and measurement tools in the table below were highly ranked and mostly agreed by the participants of the Skill's Round Table for complex problem solving and critical thinking skill.

Table 11: Components of evaluations

No.	components
1	Indicators
2	Assessment Task Models (WRITING TASKS, SIMULATION TASKS, CONCEPT MAP TASKS)
3	Domain-General Measures (CAAP, CCTST, WGCTA, EPP, HCTA, and CLA+
4	Unit model in scientific problem-solving tasks (PISA)
5	Problem Types for Critical Thinking
6	Evidence-Centered Design
7	Evidence Models (student-model feedback, evidence-model feedback)
8	Open questions in tests

In the discussion of the Round Table regarding assessment and measurement some issues and comments were raised as follows:

1. Self-reflection questionnaire could serve as an effective tool for evaluation, asking the student reflect on: how did you analyze the problem? How did you come up with different solutions? How did you decide which solution is the best?
2. It is recommended to use rubrics – indicators to support the evaluation of the assessor.
3. Using cost effective assessment and measurement tools, especially in large numbers of students we should investigate Ed-Tech assessment tools and methodologies such as the use of simulations in Messer Institute in Israel.
4. Here again the context and the domain of each STEM discipline is significant and relevant to the different applications used for assessment and measurement.

6.Insights

During the discussions several insights were highlighted which are relevant across the three competencies and they are presented in this section.

- It would be a mistake not to include the personality/attitude as a second priority – the development of optimism and persistence as part of the study, and the development of strategy, interest and curiosity.
- We relate to the subject of growth mindset but also to grit. For example, self-learning and LLL are made up of cognitive aspects (metacognition, planning, breaking things down into information...), practical strategies and skills (searching for information, screening information, using the information effectively) additional factors are related to motivation (initiative, proactiveness, management), and factors related to the reflective aspect of the learning process, such as using feedback, assessment of knowledge, etc.
- The EdTech community has provided excellent e-portfolios and digital portfolios. If the learning is a journey across the education system, where is it captured in the way in which the student presents? Can the student (and not just the teacher) document the process? Where does the culture change when the students pass through the various interface points as they shift from one part of the system to another, from k-12 to the IDF/civil service to higher education? How can these capabilities be demonstrated? What we've seen is that the EdTech world not only provides the simulations and some of the tools but the gathering of it too.
- Skills and competencies should be educated and assessed in different context for three main reasons:
    - The teaching/learning/experiencing methodologies and the assessment and measurement tools need to be adapted to the discipline and domain of learning.
    - The retention rate and the implementation of the skills and competencies is much higher.
    - There is little evidence of transforming and implementing skills from one context to the other.
- There are overlaps among the components/definitions of different skills and competencies which should be defined. However, there are basic, generic components which are inescapable in each of the skills and competencies, and we should start with them.
- The process of research-planning-implementation-evaluating of the 21’st century skills and competencies should start now! (We are already at the end of the first

quarter of the century). The effective connection between research conclusions and field implementation insights, will significantly contribute to relevant education of the graduates of the school system and higher education.

- The developing of skills and competencies of the students empower them to take part and being responsible for the process of learning.
- The education of skills and competencies should be implemented gradually and adapted to the different ages from early childhood, kindergarten, primary and high school, higher education and lifelong learning.
- There are a variety of clear definitions for those competencies, which are supporting the practicing of these competencies in real life environment. These competencies can be effectively develped, by using the methodologies presented in this project. Also, the evaluation methodologies are discussed and presented. It is worth mentioning that there are emerging advanced and digital technologies, like VR, AR, AI, simulations and other (EDTECH) for the development and the assessment of those competencies.
- As these competencies are essential also for the marketplace and the real-life ecosystem, it is recommended to develop and nurture skills and competencies as Lifelong Learning (LLL).
- This project with its background reports, the discussions in the roundtable's meetings and its summary reports, are valuable resources for effective and practical advancement of these competencies.

Appendices

Appendix 1 - The List of Participants

Table 12: Participants

Name	Institute	eMail	Remark
Dr. Eli Eisenberg	Samuel Neaman Institute	elieizenberg@gmail.com	
Prof. Arnon Bentur	Samuel Neaman Institute	bentur@technion.ac.il	
Dr. Avigdor Zonnenshain	Samuel Neaman Institute	avigdorz100@gmail.com	
Inna Zertser	Samuel Neaman Institute	innazertser75@gmail.com	
Tamar Dayan	Samuel Neaman Institute	tamar@sni.technion.ac.il	
Golan Tamir	Samuel Neaman Institute	golan@sni.technion.ac.il	
Dr. Aharon Shahar	Ministry of Education	ahronsh@education.gov.il	
Dr. Gilmor Keshet-Maor	Ministry of Education	gilmorke@education.gov.il	
Naama Moshinsky	Ministry of Education	naamamoshi@gmail.com	
Meirav Zarbiv	Ministry of Education	meiravza@education.gov.il	
Efrat Zangen	Ministry of Education	efratzan@education.gov.il	
Shlomi Achnin	Ministry of Education	shlomied@education.gov.il	
Muhana Fares	Ministry of Education	muhana@education.gov.il	for information
Dr. Hadas Gelbart	National Authority for Measurement and Evaluation in Education (RAMA)	Hgelbart.rama@education.gov.il	

Name	Institute	eMail	Remark
Dr. Inbal Ron Kaplan	National Authority for Measurement and Evaluation in Education (RAMA)	Iron.rama@education.gov.il	for information
Prof. Linor Hadar	Beit Berl College	linor.hadar@beitberl.ac.il	
Prof. Aviva Klieger	Beit Berl College	aviva.klieger@beitberl.ac.il	
Dr. Noa Ragonis	Beit Berl College	noarag@beitberl.ac.il	for information
Prof. Ido Roll	Technion	roll@technion.ac.il	for information
Dr. Olga Chuntonov	Technion	OlgaC@Technion.ac.il	
Dr. Keren Sagi	Technion	keren.sa@technion.ac.il	
Prof. Ami Moyal	Afeka Academic College of Engineering	amim@afeka.ac.il	
Dr. Anat Ratnovsky	Afeka Academic College of Engineering	ratnovskya@afeka.ac.il	
Dr. Irma Jan	Afeka Academic College of Engineering	irmaj@afeka.ac.il	
Ori Carmi-Shachar	Joint-TEVET Israel	OriC@jdc.org	
Sharon Fischer	Joint-TEVET Israel	sharonfi@jdc.org	
Shani Kochva	Joint-TEVET Israel	ShaniKo@jdc.org	
Yair Noam	IDF Behavioral Sciences Department	yairnoam2@gmail.com	
Brigadier General Dr. Hadas Minka	IDF Behavioral Sciences Department	hadas.minka@mail.huji.ac.il	for information

Name	Institute	eMail	Remark
Dr. Edith Manny-Ikan	Henrietta Szold Institute	edithmi@szold.org.il	for information
Dr. Amali Shahaf	Henrietta Szold Institute	amali@szold.org.il	
Jolien van Uden	European Training Institute (ETF)	Jolien.van-Uden@etf.europa.eu	
Prof. Russell Tytler	OECD, Deakin University	russell.tytler@deakin.edu.au	
Jan Morrison	TIES Teaching Institute for Excellence in STEM	Janmorrison@tiesteach.org	
Oren Baratz	Jewish Federation of Cleveland	obaratz@jewishcleveland.org	
Ofer Ben-Shabbat	Bet Shean Ecosystem	Ofer2011@gmail.com	
Orly Rauch	Social finance Israel (SFI)	orly@socialfinance.org.il	
Dr. Tzur Karelitz	National Institute for Testing and Evaluation (NITE)	tzur@nite.org.il	
Prof. Noam Gil	Harvard Medical School and PEAR center	gil_noam@hms.harvard.edu shoots@mclean.Harvard.edu	
Dr. Maya Lugassi-Ben Hamo	Rashi Foundation – Campus Gustave Leven – Beit Yatziv	lugassim@gmail.com	
Ruchie Avital	Interpreter	ruchieavital@gmail.com	

Appendix 2 - Background Materials

Self-study and Life-Long Learning (LLL) Competencies Definitions, Methodologies, Evaluation and Survey

Definitions

Self-study and Life-Long Learning (LLL) competencies are derivatives of (specific and broad) knowledge combined with skills such as the ability to search and acquire relevant content and the ability to apply new learning strategies. The encouragement of the development of self-study competencies, the building of motivation to complete relevant knowledge on one's own initiative, as well as the instilling of self-resilience to meet challenges and complexities will all become an integral part of the future world of work (Eisenberg and Raveh, 2020). In addition, the 21st Century worker will need to think flexibly as well as be able to take initiative and consider the changing and dynamic environment (Eisenberg and Selivansky 2019).

OECD (Drake et al. 2018) defined self-study and LLL as meta-learning skills. Meta-learning skills (including learning to learn skills) can be described as "the process by which learners become aware of and increasingly in control of habits of perception, inquiry, learning and growth that they have internalized (Maudsley, 1979). The idea of meta-learning is used by John Biggs (1985) to describe the state of "being aware and taking control of one's own learning" (p.124).

The Ministry of Education of Ontario[2] suggests that self-directed learning involves becoming aware of and managing one's own process of learning. It includes developing dispositions that support motivation, self-regulation, perseverance, adaptability and resilience. It also calls for a growth mindset – a belief in one's ability to learn – combined with the use of strategies for planning, reflecting on and monitoring progress towards one's goals and reviewing potential next steps, strategies and results. Self-reflection and thinking about thinking (metacognition) support life-long learning, adaptive capacity, well-being and the ability to transfer learning in an ever-changing world.

[2] https://www.dcp.edu.gov.on.ca/en/program-planning/transferable-skills/self-directed-learning

According to the Israeli Ministry of Education, self-study is the ability to make appropriate decisions, identify required actions, set personal targets for personal development and learning as well as to take action to achieve them independently. It is not dependent only on acquiring of the skills but also on their implementation. Taking responsibility over the process of self-development, which involves active partnership in the design of the learning process, will also significantly enforce the motivation and commitment, which in turn assist in achieving the educational goals (the profile of the adult independent self-learner[3]).

The Israeli Ministry of Education defines self-motivation under self-regulation[4], setting targets, planning achievements and taking actions to make things happen. The targets set should be specific, realistic and accurate, matching the abilities and personal preferences. The actions should be effective and efficient and for that, it is necessary, for example, to set priorities, plan time and identify obstacles.

According to the OECD, self-awareness, self-regulation and self-control can be seen as the conscious, deliberate and proactive self-directive processes and self-beliefs that enable learners to transform their mental abilities, such as verbal aptitude, into an academic performance skill, such as writing (Zimmerman & Schunk, 2007).

Learning to learn is the ability to pursue and persist in learning, to organize one's own learning, including through effective management of time and information, both individually and in groups. This competency includes awareness of one's learning process and needs, identifying available opportunities and the ability to overcome obstacles in order to learn successfully. This competence means gaining, processing and assimilating new knowledge and skills as well as seeking and making use of guidance. Learning to learn engages learners to build on prior learning and life experiences in order to use and apply knowledge and skills in a variety of contexts: at home, at work, in education and training. Motivation and confidence are crucial to an individual's competence (Kechagias, 2011).

The Ministry of Ontario defines the components of self-study and LLL as:[2]

- Students learn to think about their own thinking and learning (metacognition) and to believe in their ability to learn and grow (growth mindset). They develop their ability to set goals, stay motivated and work independently.
- Students who regulate their own learning are better prepared to become life-long learners. They reflect on their thinking, experiences and values and respond to critical feedback to enhance their learning. They also monitor the progress of their learning.

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[3] מיומנויות:הלומד העצמאי – דמות הבוגרת והבוגר: המדיניות הפדגוגית הלאומית(openfox.io)

[4] מיומנויות:הכוונה עצמית – דמות הבוגרת והבוגר: המדיניות הפדגוגית הלאומית(openfox.io)

- Students develop a sense of identity in the context of Canada’s various and diverse communities.
- Students cultivate emotional intelligence to better understand themselves and others and build healthy relationships.
- Students learn to take the past into account in order to understand the present and approach the future in a more informed way.
- Students develop personal, educational and career goals and persevere to overcome challenges in order to reach those goals. They learn to adapt to change and become resilient in the face of adversity.
- Students become managers of the various – cognitive, emotional, social, physical and spiritual – aspects of their lives to enhance their mental health and overall well-being.

Question for the survey – Components of self-learning

Kindly rank your acceptance of each of the relevant components of the skill of self-learning/Life-long learning in the table.

Description of the component	Totally Disagree (1)	2	3	4	Fully Agree (5)
Ability to search and locate relevant information					
Implement new learning strategies such as: consulting and interviewing experts and professional stakeholders, intelligent use of relevant websites for assistance and guidance					
Ability to cope with failures and move forward to achieve the task					
Ability to adapt and change					
Development of motivation to self-acquire knowledge					
Constant developments of self-learning habits					
Self-management of the learning process					
Persistence over time					
Taking initiative					
Self-growth attitude and self-efficacy					
Setting achievable goals and striving to attain them					
Setting appropriate priorities					
Effective planning and management of time and information					
Identifying possible barriers and taking the appropriate steps to deal with them					

Please add any missing components of self-learning not included in the above table:

____

Any comments or remarks: ________________________________

Methodologies for learning, teaching and experiencing

(Based on Robinson & Persky, 2020)

The teacher/instructor must first understand the nature of self-directed learning (SDL) and the key elements in the process of self-learning. Robinson and Perski (2020) addressed these issues as follows:

Before creating educational activities to develop SDL, the instructor must first understand what SDL is and what the key components of the SDL process are. Self-directed learning can be described as a six-step process:

- Developing goals for study.
- Outlining assessment with respect to how the learner will know when they have achieved those goals.
- Identifying the structure and sequence of activities.
- Laying out a timeline to complete activities.
- Identifying resources to achieve each goal.
- Locating a mentor/faculty member to provide feedback on the plan.

They further suggest that developing self-directed learners requires a scaffolded approach in which more self-paced- or teacher-directed activities are introduced early on, during didactic instruction, to help students become more self-regulated in their "self-directedness." Over time, as the student moves from the classroom to the experiential setting, control of the learning environment can be shifted from the instructor to the student. This scaffolding may include starting with more self-paced activities and providing guidance to the learner on how to be more self-regulated.

Methodologies of development of self-learning

- Flipped classrooms

A "flipped classroom" can be described as a learning model in which students obtain some foundational material on their own, prior to class, and then class time is used to help apply that learned information. An example of a highly structured flipped classroom is team-based learning (TBL). Flipped classrooms have the potential to move students towards self-directed learning. First, students prepare prior to class with faculty-provided materials. This preparation allows students to develop confidence in self-regulation skills (e.g,. what to focus their time on, selecting appropriate study strategies, self-assessment) and self-paced learning (e.g,. "I need to get this done before class, but I am free to study when I want and for as long as I want"). With the help of the instructor, the targeted content acquired outside the class can be applied, expanded upon and worked with in such a way as to reinforce and deepen learning. This may serve to model and assist the student in the development of the skills needed for future self-direction.

- Learning contracts

A learning contract is an agreement between the instructor and student that specifies the work the learner will complete in a given time period. Learning contracts can be used to keep individuals organized, normalize expectations and increase communication between the learner and instructor. These contracts consist of five components, similar to that of the SDL process: learning objectives, learning resources and strategies, target date for completion, evidence of accomplishment and criteria for evaluation. These can be used within courses, as independent study, or even to help guide extra- or co-curricular activities.

- Minimally guided instruction

Minimally guided instructional approaches suggest that people learn best in an unguided or minimally guided environment. Popular formats for minimally guided instruction include problem-based learning (PBL) or inquiry-based learning (IBL). Because of the minimal guidance provided, this type of instruction may foster self-directed learning.

- Experiment laboratory

LabXchange[5] – an online community for learning, sharing and collaboration.

- LabXchange brings together high-quality content from a variety of sources in the form of online learning assets, including videos, assessments and simulations. An open edX platform gives users the flexibility to search, select and insert these assets into their own customized learning pathways.
- Users can add material to link the learning assets they select to create their own storylines, clarify new learning objectives and adapt existing pathways to better meet their needs.
- Users will be able to share their pathways privately or with a small group to spark discussion and receive feedback.

[5] https://www.labxchange.org/explore

SIT Alemira[6] – a complete digital ecosystem for education and learning.

Active Learning technology to deliver hands-on learning experiences and real results; an integrated platform for learning, education and science management for businesses and higher education.

- Research assignments and projects

This includes the writing of papers, presentation of posters, planning of activities within the subject learning, presentations.

Table 13: Operative settings for teacher

Knowledge	Skills	Attitudes/Values/Ethics
Knowledge and understanding of one's preferred learning methods, the strengths and weaknesses of one's skills and qualifications Knowledge of available education and training opportunities and how different decisions during the course of education and training lead to different careers	Effective self-management of learning and careers in general. Ability to dedicate time to learning, autonomy, discipline, perseverance and information management in the learning process Ability to concentrate for extended as well as short periods of time Ability to reflect critically on the object and purpose of learning Ability to communicate as part of the learning process by using appropriate means (intonation, gestures, mimicry, etc.) to support oral communication as well as by understanding and producing various multimedia messages (written or spoken language, sound, music etc.)	A self-concept that supports a willingness to change and further develop competencies as well as motivation and confidence in one's capability to succeed Positive appreciation of learning as a life-enriching activity and a sense of initiative to learn Adaptability and flexibility Identification of personal biases

Source : Binkley M. et al (2012)

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[6] https://alemira.com/

Additional examples relevant to pedagogical methods can be found on the website of the Ministry of Education, Teachers' portal – Pedagogical space.

https://pop.education.gov.il/teaching-tools/teaching-practices/search-teaching-practices/?categories=76931&skills=219102,219103&page=1

Questions for the survey – Learning, teaching and experiencing methodologies

Kindly rank your acceptance of each of the relevant learning/teaching/experiencing methodologies of the skill: Self-learning/life-long learning in the table.

Name of the Component	Totally Disagree (1)	2	3	4	Fully Agree (5)
Flipped classrooms.					
Minimal guidance instruction					
Experiment laboratories					
Posters					
Project-/Inquiry-based learning					
presentations					

Please add any missing learning/teaching/experiencing methodologies of the skill self-learning/life-long learning not included in the above table:

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Any comments or remarks:

____

Evaluation and measurement tools for self-learning/lifelong learning

Self-Directed Learning (SDL) evaluation often includes methods that are more qualitative in nature, since the focus is on the building of meaning and self-development of skills, many of which emotional in nature, based on experience.

The approaches can be subjective in nature and include:

- Reflections
- Interviews
- Observations of behaviors
- Feedbacks from students
- Self-reporting questionaries

The LEQ-H questionnaire addresses self-perception of "Life Effectiveness" factors, with 24 questions (Richards, Ellis, & Neill, 2002). Initial assessment serves as a basis for measuring students' progress toward soft-skills awareness.

Table 14: Factors addressed by LEQ-H questionnaire (Kechagias, 2011 p.148)

LEQ Dimensions	Description
Achievement Motivation	The extent to which the individual is motivated to achieve excellence and put the required effort into action to attain it.
Active Initiative	The extent to which the individual likes to initiate action in new situations.
Emotional Control	The extent to which the individual perceives s/he maintains emotional control when faced with potentially stressful situations.
Intellectual Flexibility	The extent to which the individual perceives he/she can adapt his/her thinking and accommodate new information from changing conditions and different perspectives.
Self-Confidence	The degree of confidence the individual has in his/her abilities and the success of their actions
Social Competence	The degree of personal confidence and self-perceived ability in social interactions

LEQ Dimensions	Description
Task Leadership	The extent to which the individual perceives s/he can lead other people effectively when a task needs to be done and productivity is the primary requirement.
Time Management	The extent to which an individual perceives that s/he makes optimum use of time.

An example of an **evaluations system** is the eVIVA project developed at Ultralab in the UK. The purpose of eVIVA was to develop a more flexible evaluation system, taking advantage of the option provided by modern technologies such as mobile phone- and Internet-based evaluation methods. By applying these methods, the Ultralab project advanced evaluation methods, self- and colleague-based, as well as dialogues between teachers and students (Binkley et al., 2011).

Cascade – A method that enables large scale evaluations and short evaluation time is under development at the University of Luxemburg and at the Henri Tudor Center for Public Research.

Cascade's test details are designed so that the respondents answer a group of questions and are thereafter asked to rate their response depending on the level of confidence in the reliability of their answer. Afterwards, the respondent is allowed to approach a multimedia source to review the correctness of the answers. At this stage, the respondent answers again on the same set of questions and again rates their reliability. The score is based on comparison of the first and second groups of responses and evaluation of the information routes the respondent took to acquire the additional information.

An additional evaluation method is based on **Standards-Based Report Cards**. An example demonstrating this approach is outlined below:

Table 15: Standards-Based Report Cards

Skills	Behaviors / products	0 Below Expectations	1 Emerging Expectations	2 Meets Expectations	3 Exceeds Expectations
Self-learning / Lifelong learning	Students learn to think about their own thinking and learning (metacognition) and to believe in their ability to learn and grow (growth mindset). They develop their ability to set goals, stay motivated and work independently				
	Students reflect on their thinking, experiences and values, and respond to critical feedback, to enhance their learning. They also monitor the progress of their learning.				
	Students develop a sense of identity in the context of various and diverse communities				
	Students cultivate emotional intelligence to better understand themselves and others and build healthy relationship				
	Students learn to take the past into account in order to understand the present and approach the future in a more informed way				

Question for the survey – Evaluation and measurement tools

Kindly rank your acceptance of each of the relevant evaluation and measurement tools of the skill self-learning/Life-long learning in the table.

Component	Totally Disagree (1)	2	3	4	Fully Agree (5)
Interviews					
Observation indicators					
Self-feedback questionnaires					
Peer feedback questionnaires					
LEQ-H questionnaires					
Using technologies such as Cascade and eVIVA					

Please add any missing learning/teaching/experiencing methodologies of the skill self-learning/Life-long learning not included in the above table:

____

Any comments or remarks:

____

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Teamwork, collaboration and cooperation Competencies: Definitions, Methodologies, Evaluation and Survey

Definitions

Eizenberg and Raveh (2020) define **teamwork, collaboration and cooperation** as the ability of the individual to collaborate and cooperate as part of a team in order to meet the challenges of complex missions, and the ability to continue the teamwork when difficulties arise. Effective teamwork requires social as well as cognitive abilities, such as project management and task focusing. The website of the Ministry of Education of Ontario, Canada[7] defines **collaboration** as involving the interplay of the cognitive (thinking and reasoning), interpersonal, and intrapersonal competencies needed to work with others effectively and ethically. These skills deepen as they are applied, with increasing versatility, to co-construct knowledge, meaning, and content with others in diverse situations, both physical and virtual, that involve a variety of roles, groups, and perspectives.

According to the OECD (Drake et al., 2018), **Collaboration** is a social process of knowledge building in which people work as an interdependent team towards a clear objective, resulting in a well-defined final product, consensus, or decision.

21st Century Learning[8] (Explore SEL[9]) defines **collaboration with others** as demonstrating the ability to work effectively and respectfully with diverse teams; exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal; assume shared responsibility for collaborative work, and value the individual contributions made by each team member.

Effective teamwork requires the development of cognitive and social abilities. The cognitive abilities include a high level of verbal communication; the ability to manage projects, task focusing and integrative learning based on the optimal use of the team's knowledge and cognitive resources. The social abilities include various modes of communication, not only verbal; an active approach; the ability to express oneself in the

[7] https://www.dcp.edu.gov.on.ca/en/program-planning/transferable-skills/collaboration

[8] **Battelle for Kids: P21 Framework for 21st Century Skills** is a framework designed to help practitioners integrate 21st century skills into the teaching of core academic subjects. It was created by the Partnership for 21st Century Learning (P21), a network of Battelle for Kids, with input from teachers, education experts, and business leaders. It focuses on the skills and knowledge needed to succeed in work, life, and citizenship in today's world.

[9] Explore SEL (harvard.edu)

context of teamwork, a holistic view of the teamwork and an understanding of the meaning of proper social conduct (Eizenberg and Zelivansky-Eden, 2019).

Teamwork, according to the PRACTICE Model[10], refers broadly to a set of skills involved getting along with others, understanding their feelings and points of view, communicating effectively, being helpful and agreeable, and not engaging in aggressive or bullying behaviors[11].

The WHO Skills for Health[12] combine several parameters in **interpersonal communication skills**: verbal/nonverbal communication; active listening; expressing feelings; giving feedback (without blaming) and receiving feedback[13].

Learners are able to communicate and get along well with others in a variety of settings and for a range of purposes. One-on-one and in groups, they can speak and listen actively and appropriately. They are able to give presentations at work and write professional emails. They are able to cooperate and work effectively within a group. They are able to provide good customer service and handle difficult customers (EDC Work Ready Now! Framework).[14]

Social conduct, according to the Israel Ministry of Education, implies the ability to manage positive and rewarding relationships, both personal as well as professional[15]. Positive social conduct enables individual self-expression, expression of feelings and obtainment of social support. It includes three core competencies: **conflict-resolution management, teamwork and communication, and management of interpersonal relations.** The table below outlines the components which make up each of these core competencies.

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[10] **The PRACTICE Model** is a social-emotional skills for employability skills framework developed by Dr. Wendy Cunningham and co-authors published in the Policy Research Working Paper at the World Bank Group, a multilateral financial institution committed to reducing poverty, increasing shared prosperity, and promoting sustainable development around the world.

[11] http://exploresel.gse.harvard.edu/terms/532

[12] **The Word Health Organization (WHO)'s Skills for Health outline life skills important for skills-based health and life skills education.**

[13] http://exploresel.gse.harvard.edu/terms/615/

[14] http://exploresel.gse.harvard.edu/terms/655

[15] מיומנויות: מיומנויות חברתיות – דמות הבוגרת והבוגר: המדיניות הפדגוגית הלאומית. משרד בחינוך (openfox.io) (2022)

Core competencies	Components
Management of conflicts	▪ Listening and conducting a respectful dialogue during a conflict situation ▪ Keeping a positive approach and refraining from defensive and offensive behavior (such as jumping to conclusions and interrupting the interlocutor) ▪ Accepting situations of disagreement and knowing how to handle them • Finding adequate solutions through agreement and cooperation – understanding the wishes and interests of all the parties, taking in the entire scene, striving for positive results and being ready to compromise, especially on issues of lesser importance
Teamwork and communication	▪ Receiving and sharing information ▪ Making decisions and performing tasks in a cooperative manner ▪ Being able to express and accept opposing opinions and reservations – being prepared to express opinions that are not in consensus within the group, showing tolerance for opinions that are not accepted by the group and that challenge the group hegemony
Management of interpersonal relations	▪ Active and respectful listening to others – listening without interrupting and paying attention, asking questions to enhance understanding, repeating the message and the reflective emotions emerging from it ▪ Expressing thoughts and feelings clearly, verbally and non-verbally. ▪ Expressing yourself with sensitivity, openness and sincerity ▪ Expressing empathy – acknowledging the feelings of others, which may be different than your own, placing yourself in the other person's shoes and showing interest in his/her feelings and thoughts ▪ Initiating and participating in a variety of interactions, both one-on-one as well as group interactions, effectively and respectfully, with a wide range of participants ▪ Developing and maintaining healthy and fulfilling relationships – relationships that include positive components such as reciprocity, support, sincerity, intimacy, and respect.

Behaviors/outcomes reflecting teamwork, cooperation & collaboration and interpersonal communication[1]

- Students participate successfully in teams by building positive and respectful relationships, developing trust, and acting cooperatively and with integrity.
- Students learn from others and contribute to their learning as they co-construct knowledge, meaning, and content.
- Students assume various roles in the team, respect a diversity of perspectives, and recognize different sources of knowledge, including indigenous ways of knowing.
- Students address disagreements and manage conflict sensitively and constructively.
- Students interact with a variety of communities and/or groups and use various technologies appropriately to facilitate working with others.

Question for the survey – Components of Teamwork, cooperation and collaboration, and interpersonal communication

Kindly rank your acceptance of each of the relevant components of the skill of teamwork, cooperation and collaboration, and interpersonal communication in the table.

Description of the component	Totally Disagree (1)	2	3	4	Fully Agree (5)
Acting resiliently as a team in spite of difficulties and challenges					
A team’s quality of project management (assignment of tasks, time management’ etc.)					
Maximum utilization of the team members' knowledge and cognitive resources					
Ability to make decisions collaboratively					
Effective work with other members of the team					
Flexibility and adaptability as a team member					
Collaborative responsibility of the team					
Understanding the attitudes and points of view of fellow team members					
Providing help and support to team members					
Verbal communication: active listening and speaking					
Accepting and giving effective feedback					
Utilizing advanced technologies to support teamwork					

Please add any missing components of "Teamwork" not included in the above table:

____

Comments or remarks:

____

Methodologies for learning, teaching and experiencing

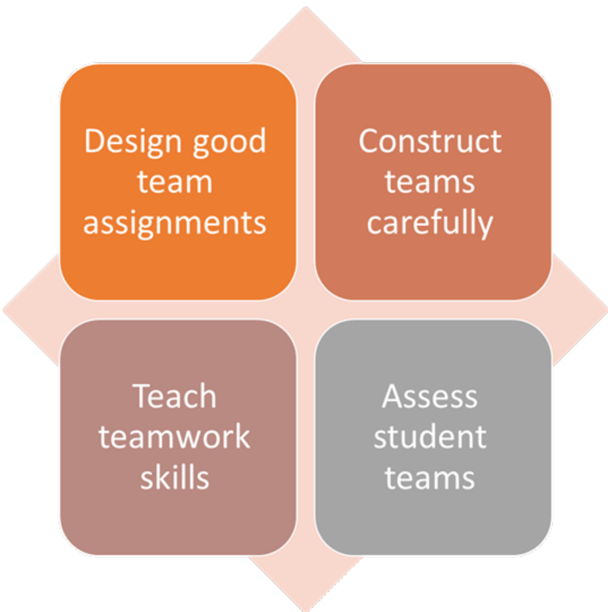
In order to help students develop effective collaboration, teamwork, and communication skills, instructors must go beyond simply creating assignments that require students to work in teams.

There are a variety of research-based practices that support the effective implementation of teams in university classrooms, including:

- Having teams develop contracts defining team roles and expectations
- Using video-conferencing or other computer-mediated communication to accomplish project tasks or conduct team meetings
- Using course wikis or course forums to encourage collaborative group discussion
- Using co-teaching as a method for modeling and teaching teamwork
- Asking students to engage in peer assessment of collaborative work
- Setting up hackathons to solve challenging tasks

The educational context, including the students' academic level, desired learning outcomes, and the complexity of the project, will determine which of these practices is most appropriate (Kusano et al., 2016)

Figure 2: Four components of using student teams successfully (Finelli et al.)



Source: Neaman Institute processing from Finnelli et al.

Designing good team assignments:

- Begin with simple, well-defined tasks, then increase their difficulty
- Define individual versus team accountability
- Develop assignments that require interdependence

Designing good team assignments:

- Form teams of three to five members
- Form heterogeneous teams
- Use instructor-assigned teams
- Consider practical issues when creating teams

Teaching teamwork skills:

- Have students talk about important team behaviors.
- Have teams develop contracts.
- Observe and guide teams – In some cases, teams need a great deal of support while individuals learn to interact with diverse peers. Observing the teams is fundamental to detecting and correcting problematic dynamics in a timely way.

Assess student teams (details to follow):

- Encourage and allow time for team processing – It is important to provide time and guidance for teams to examine how they are working together.
- Use peer evaluations – Because students have the most knowledge about individual contributions to the team, peer evaluations are an important method for team assessment. Peer evaluation can be useful both to provide feedback to improve team interactions while the teamwork is in progress and to measure individual accountability in students' course grades. To accomplish the first objective, instructors should distribute peer evaluations at multiple points during the term so students can learn how to score their teammates and get used to sharing their (anonymous) ratings with teammates. And at the end of the term, the instructor can factor the students' ratings into the overall grade or adjust each student's team score by a multiplier based on the ratings to reflect their team contributions.

Regardless of the chosen approach to creating collaborative assignments and spaces for students, they most effectively succeed in collaborative and team experiences when instructors carefully design and guide the process. This is particularly important for the communication aspect of collaborative work.

- Ask students to explicitly define team roles early in the project by identifying students' strengths.
- Allow a few minutes of class time for teams to do a quick "check-in" meeting with the instructor.
- An available resource to help prime students for effective communication between team members is a "group work plan".

Many studies indicate that explicit design of the various aspects of teamwork lead to improved implementation of competencies compared to groups that did not receive structured guidance. Development of teamwork competencies requires combining explicitly designed teaching and opportunities for receiving peer teacher's feedback (from the presentation of the Beit Berl Academic College).

Team-based learning, **problem-based learning**, **group discussion**, and **peer instruction** are other examples of educational practices that have been shown to foster collaboration and teamwork skills (Kusano et al. 2016).

In team-based learning the students must work within the same team for a significant period of time in order to learn how to develop the dynamics of a functional team (Remington et al.).

Product Based Learning (PBL) is a holistic name for a complex and wide scope multi-stage and continuing process. The product could be a project, a solution to a problem, or an enterprise. Although the products may be different in nature, they share common characteristics with regard to pedagogical aspects. In all of them the student is at the center of the learning processes, which are based on principles of developing in-depth knowledge and critical thinking. The process of PBL can be individual or can be conducted in a team framework, so that in addition to the characteristic features of PBL, it will also be based on the same principles of cooperative learning, including reference to the interpersonal aspects of the 21st century competencies (teamwork and leadership, interpersonal communication, collaboration, responsibility and conflict resolution). PBL processes that take place in a digital environment rich in data sources and the use of applications can assist in achieving pedagogical objectives to develop in-depth learning processes, improve the learning projects and enrich the students' experiences.

Cooperative learning is essentially a learning model that focuses on developing knowledge and competencies in the social-cultural context, within the framework of a challenge jointly responded to by students with short- or long- term tasks. The level of cooperation can be full – all stages of the tasks and its products are common to all members of the team, or partial – some of the parts of the task items are shared while others are individual. The individual parts can be successive (each member carries out a different part and bases it on its predecessor) or simultaneous (each member carries out a part which fits his/her abilities or desire). Each team member has a defined role, which requires him/her to take an active part in the performance of the task and its products, including the shared tasks. The process includes meticulous attention to pre-defined behavioral rules, which are known in advance and are based on the values of the culture of debate, advancing dialogue, empathy, mutual respect and acceptance of the other.

Research-based learning – like in PBL, the research process can be individual or group, and can be held in a digital environment, thus adding value to the learning objectives.

Virtual learning outside the classroom – a model aimed at building up knowledge in a setting that is not part of the formal learning routine, using digital means: lectures by visitors, cooperative learning with students from other schools in the same country or abroad, or participation in endeavors or international research projects. An example is the Science Citizen endeavors on the Zooniverse site or the Society for the Protection of Nature in Israel.

Peer instruction – a teaching model to build up knowledge and develop thinking skills as part of the learning process-teaching-reflective evaluation. It is based on the rationale whereby verbalization, organization design and presentation of information require a deep understanding of the content, which advances development of knowledge and thinking; teachers present a holistic topic or a learning module; students are required to formulate question that are the result of their curiosity, and a class debate is held, which is concluded by the definition of several sub-topics.

1. Every student and group of students choose a topic and with the aid of the teacher, who are then required to search for reliable and updated information sources.
2. The students need to read and learn about the topic by themselves.
3. The students are required to prepare it for presentation before the class.

Innovation-Labs (iLabs) is practice based in a virtual reality whereby the space of cooperative ideas are independent of location, and it thus offers a variety of experiences, depending on the way the student wishes to connect with the world (Callaghane et al.).

For example, whether the world is viewed from a first- or third-person perspective can significantly alter the relative experiences of individual users, especially when working with others in team-based exercises. Furthermore, technologies such as VR headsets, (e.g., the Oculus Rift, or HTC Vive) can be used to generate a more immersive experience in the minds of users, allowing them to move around "Our HEX," with the impression of actually being transported inside the artificial world. Mixed reality interfaces, such as Metavision’s Meta-2 or Microsoft’s HoloLens system, could also potentially be used to superimpose fragments of the space station onto the real world, effectively turning a physical room or other location into an extension of the ‘Our HEX’ environment. Such an arrangement could facilitate interaction between groups of people where several are sharing the same physical space but wish to interact with other remote users present elsewhere in 'Our HEX' (Callaghane et al.)

Operative settings for teacher

Knowledge	Skills	Attitudes/Values/Ethics
Interacting effectively with others • Knowing when it is appropriate to listen and when to speak *Working effectively in diverse teams* • Knowing and recognizing the individual roles of a successful team and knowing one's own strengths and weaknesses, and recognizing and accepting them in others *Manage projects* • Knowing how to plan, set, and meet goals and monitor and re-plan in the light of unforeseen developments	*Interacting effectively with others* • Speaking with clarity and awareness of audience and purpose. Listening with care, patience, and honesty • Conducting oneself in a respectful, professional manner *Working effectively in diverse teams* • Leveraging social and cultural differences to create new ideas and increase both innovation and work quality *Managing projects* • Prioritizing, planning, and managing work to achieve the intended group result *Guiding and leading others* • Using interpersonal and problem-solving skills to influence and guide others toward a goal • Leveraging strengths of others to accomplish a common goal • Inspiring others to reach their very best via example and selflessness • Demonstrating integrity and ethical behavior in using influence and power	*Interacting effectively with others* • Knowing when it is appropriate to listen and when to speak • Conducting oneself in a respectful, professional manner *Working effectively in diverse teams* • Showing respect for cultural differences and being prepared to work effectively with people from a range of social and cultural backgrounds • Responding open-mindedly to different ideas and values *Managing projects* • Persevering to achieve goals, even in the face of obstacles and competing pressures *Being responsible to others* • Acting responsibly with the interests of the larger community in mind

Source : Binkley M. et al (2012), Table 2.6

Additional examples for practices that can be applied to cooperative learning can be found on the website of the Israeli Ministry of Education, teachers' portal-pedagogical space (in Hebrew):

https://pop.education.gov.il/teaching-practices/search-teaching-practices/cooperative-learning/

Questions for the survey – teamwork, cooperation and collaboration, and interpersonal communication methodologies

Kindly rank your acceptance of each of the relevant learning/teaching/experiencing methodologies of the skill teamwork, cooperation and collaboration, and interpersonal communication in the table.

Name of the Component	Totally Disagree(1)	2	3	4	Fully Agree(5)
Team-based learning					
Problem-/project-/product-based learning					
Using peer instruction of teachers to demonstrate teamwork					
Group discussion					
Collaborative inquiry learning					
Detailed planning of the team members' roles, work methods, behavioral rules, etc.					
Innovation-Labs (iLabs)					
Teamwork in a variety of environments: nature, jobs, communities.					
Creating a heterogeneous team of students with different abilities and strengths.					

Please add any missing components of "Teamwork" not included in the above table:

____

Comments or remarks:

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Modes and tools to evaluate and measure teamwork, cooperation and collaboration, and interpersonal communication

When faced with a collaborative task, the most important question is how to assign credit to each member of the group, as well as how to account for differences across groups that may bias a given student's performance. This issue arises whether students are asked to work in pre-assigned complementary roles or whether they are also being assessed on their skills in inventing ways to collaborate in an undefined situation. Questions on assigning individual performance as well as group ratings become even more salient for international assessments where cultural boundaries are crossed (Kechagias 2011).

Several ways to evaluate teamwork, collaboration and cooperation, and interpersonal communication are presented below:

Peer assessment

Peer assessment is one of the most commonly discussed approaches to assessment of collaboration and teamwork. First, peer judgment has been shown to be a significant motivator for students as compared to a single instructor-led assessment. Second, in order for students to adequately assess their peers, they are required to be more thoughtful and to have a more comprehensive understanding of the relevant process or activity (Kusano et al.).

When using peer assessment, it can be helpful to involve students early in the process of negotiating the criteria that will be used. This will enhance the assessment validity, as well as offer students familiarity with and ownership of (i.e., student buy-in) the criteria by which they will be assessed.

One of the most commonly used instruments is the Comprehensive Assessment of Team Member Effectiveness (CATME)), which is an online system of tools for facilitating the formation of teams, teamwork training, team communication support, and peer evaluations.

Additional tools:

- Perception of teamwork skills – Perception of teamwork skills

- [Team contributions – Fink Method](#) – Given 100 points to divide among team members, students assign each team member a score based on the extent to which they believe their teammates contributed to the overall team performance. An individual student's grade is then based on their average peer ratings, multiplied by the group score.

Direct assessment

There are a variety of assessment instruments available to guide direct assessment of teamwork behavior, interprofessional collaboration, and teamwork knowledge and skills, via observations or processes and evaluations of work products. Examples of these assessment instruments are described in the following table:

Instrument	Measure	Notes
AAC&U - VALUE Rubrics – Teamwork	Teamwork behavior	Performance descriptors include: ▪ Contributes to team meetings ▪ Facilitates the contributions of team members, individual contributions outside of team meetings ▪ Fosters a constructive team climate ▪ Responds to conflict Cost: Free Access: https://www.aacu.org/value/rubrics/teamwork
Interprofessional Collaborator Assessment Rubrics	Inter-professional collaboration	Made up of 6 distinct rubrics measuring: ▪ Communication ▪ Collaboration ▪ Roles and responsibilities ▪ Collaborative patient-/client-family-centered approach ▪ Team functioning ▪ Conflict management/resolution Cost: Free Access: http://tinyurl.com/jzbhw7d Note: developed for health-care fields, but adaptable to other disciplines

Instrument	Measure	Notes
Teamwork Knowledge, Skills, and Abilities Test	Teamwork knowledge & skills	Assesses: 1. Conflict resolution 2. Collaborative problem solving 3. Communication 4. Goal setting/management 5. Planning and task coordination Cost: $312.80 for 10 tests/1 manual + fees Access: http://tinyurl.com/gl9o7fp

Questionnaires for self-assessment (The Israeli National Institute for Testing and Evaluation):

Refer to components of the work of the team which are currently in progress in class.

Can be adjusted for use at different times: after the task – referring to the task, at the end of the period – referring to the process.

Components of the questionnaire:

- Behavioral (what did I do)
- Reflective (how did I feel)

Parallel questionaries for the teachers and students can be developed.

Behavioral observation

Behavioral observation is the most common approach to assessing collaborative skills. An instructor or rater observes a team and uses a rubric to assess different behaviors and their level of performance. Rubrics clearly outline the behaviors required and provide instructors with guidelines for what to look for and how to assess the behaviors.

Behavioral observations can also be made by peers during or after collaboration tasks using the same rubrics as those used by instructors. Such peer evaluations can be as reliable and valid as instructor ratings. Peer ratings have the further advantage that the students may also learn about the appropriate behaviors through the process of monitoring their peers.

Evidence can also be processed automatically with computers. Computer-based administration of collaborative tasks can provide some level of control over collaborative situations, providing the materials, media, and means for the students to interact. The computers also provide a means to automatically collect and analyze the evidence. With the ubiquity of student use of computers, there has been increased development of environments that support and/or train collaboration. These environments include shared writing platforms (e.g., Google Docs), MOOCs (Massive Open Online Courses), Intelligent

Tutoring Systems for multiple students and collaborative gaming environments around academic domains. In each of these computer-based environments, the events and student actions are logged. Statistical models can then be used to analyze the process data.

Most recently, artificial-intelligence technologies have been used to assess collaboration skills. The approaches have primarily been used for systems with computer-based agents and for automated natural-language analysis of the communication stream. Computer-based agents or avatars can serve as simulated collaborators and interact with the students through language and/or actions. The agents can be programmed to take on different roles and abilities working with the student and other computer agents, thereby exposing students to different types of collaborative situations. For example, if students need to be assessed on their ability to handle conflict, two agents can disagree over a particular path to a solution, and the system can monitor how the student resolves the situation in terms of behavior. As such, an agent-based system provides more control over the assessment situation and allows a more refined collection of evidence. This approach has been incorporated into the 2015 OECD PISA assessment of collaborative problem-solving, since it is compatible with controlled assessment across diverse student populations. Although students may not be interacting with other humans, research has shown that the assessments can be as reliable and valid as human-to-human collaborative situations.

Overall, automated techniques allow more control over the collaborative situations and provide mechanisms for automatically capturing behaviors and converting them into scores and feedback. This approach is obviously labor-intensive in terms of developing scoring models and may be more costly to develop than approaches requiring less control over the conditions of the interaction.

Automated approaches cannot detect all the subtleties that can be extracted from human observation, and their use requires all information (e.g., actions and speech) to be recorded by means of computers. Nevertheless, the field is moving very fast, and with further developments in natural language processing, speech recognition, and machine learning, we see this as an area that will continue to grow, both by having students interact with agents through natural language and by automatically assessing multiple students who are talking or writing to each other (Lai, DiCerbo, & Foltz, 2017).

Standards-Based Report Cards.

Example

Table 16 : Standards-Based Report Cards

Skills	Behaviors / products	0 Below Expectations	1 Emerging Expectations	2 Meets Expectations	3 Exceeds Expectations
Teamwork, cooperation and collaboration, interpersonal communication	Students participate successfully in teams by building positive and respectful relationships, developing trust, and acting cooperatively and with integrity.				
	Students learn from others and contribute to their learning as they co-construct knowledge, meaning, and content.				
	Students assume various roles on the team, respect a diversity of perspectives, and recognize different sources of knowledge, including indigenous ways of knowing.				
	Students address disagreements and manage conflict in a sensitive and constructive manner.				
	Students interact with a variety of communities and/or groups and use various.				

Additional examples are available on the website of the Israeli Ministry of Education, Teacher's portal-pedagogical space (in Hebrew):

- Indicator for the evaluation of teamwork – three levels of behavior:

https://meyda.education.gov.il/files/Pop/0files/praktikot-horaa/mehvan-aarahat-tzevet.pdf

- Indicator for cooperative learning:

https://meyda.education.gov.il/files/Pop/0files/praktikot-horaa/mahvan-co-learning-tool.pdf

Question for the survey – Evaluation and measurement tools

Kindly rank your acceptance of each of the relevant evaluation and measurement tools of the skill teamwork, cooperation and collaboration, interpersonal communication in the table.

Name of the Component	Totally Disagree (1)	2	3	4	Fully Agree (5)
Direct assessment					
Peer assessment					
Behavioral observation					
Self-feedback questionnaire					
Utilization of advanced technologies such as simulations and AI					

Please add any missing components of "Teamwork" not included in the above table:

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Comments or remarks:

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Complex problem solving and critical thinking Definitions, methodologies, evaluation and survey questions

Definition

Critical thinking and problem solving involve locating, processing, analyzing and interpreting relevant and reliable information to address complex issues and problems, make informed judgements and decisions and take effective action. With critical thinking skills comes an awareness that solving problems can have a positive impact on the world, and this contributes to achieving one's potential as a constructive and reflective citizen. Learning is deepened when it occurs in the context of authentic and meaningful real-world experiences[16].

Eisenberg and Raveh (2020) indicate that critical thinking emerges through the use of skills and strategies that increase the probability of achieving a desired result. Critical thinking involves systematic thinking and goal orientation and is associated with problem solving, forming conclusions and calculating probabilities. This skill is particularly needed in an environment of uncertainty.

According to the OECD (Drake et al., 2018) **Critical thinking** can be defined as questioning and evaluating ideas and solutions. This definition of critical thinking skills embodies components of metacognition, social and emotional skills (reflection and evaluation within a cultural context), and even attitudes and values (moral judgment and integration with one's own goals and values), depending on the context.

In many cases, definitions of **critical thinking** emphasize logical or rational thinking; i.e., the ability to reason, assess arguments and evidence, and argue in a sound way to reach a relevant and appropriate solution to a problem. However, critical thinking also includes a dimension of "critique" and "perspective-taking." In addition to rational or logical thinking, critical thinking includes two additional dimensions: the recognition of multiple perspectives (or the possibility of challenging a given one) and the recognition of the assumptions (and limitations) of any perspective, even when it appears superior to all other available ones (Vincent-Lancrin et al., 2019 p.24)

Problem-solving skills refer to an individual's capacity to engage in cognitive processing to understand and resolve situations where a method or solution is not

[16] https://www.dcp.edu.gov.on.ca/en/program-planning/transferable-skills/critical-thinking-and-problem-solving

immediately obvious. Problem solving takes time and includes several stages that presume different subskills and can include a variety of forms starting from "interpersonal problem solving" (problems are solved alone) to different forms of collaborative problem solving (Drake et al., 2018).

While analytical capabilities and critical approach may appear to be individual characteristics, they are in fact derived from a set of tools and experiences gained over time (Eisenverg and Selivansky-Eden, 2019).

The BECF[17] (Explore SEL[18]) defines **critical thinking and problem solving** as an important outcome of quality education in teaching learners how to think critically. The British Council (2015) identifies three types of thinking: reasoning, making judgements, and problem solving. Learners can reason uncritically. When learners are empowered with critical thinking, they avoid subjectivity and use logic and evidence to arrive at conclusions. Critical thinking also facilitates exploring new ways of doing things and learner autonomy. Learners learn that there are multiple perspectives that they can explore for every issue, rather than rigid recall and regurgitation of information.

WHO Skills for Health[19] combines three parameters in **critical thinking skills**: analyzing peer and media influences; analyzing attitudes, values, social norms, beliefs; and identifying relevant information and sources of information[20].

Decision-making/problem-solving skills composed of information-gathering skills, evaluating future consequences of present actions for self and others – determining alternative solutions to problems and analyzing skills regarding the influence of values and of attitudes about the self and others on motivation (WHO Skills for Health[21]).

Problem solving in VaLI[22] refers to students that demonstrate the ability to find solutions to both simple and complex issues, the ability to think through various steps, identify and understand a problem and devise a solution to address it[23].

Critical thinking, an instrumental life skill conducive to academic achievement, is a long-standing life skill, which allows "reflective thinking": By thinking critically, children, youth and all individuals who learn to assess situations and assumptions ask questions and develop various ways of thinking. Consequently, critical thinking involves higher-

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[17]**The Basic Education Curriculum Framework (BECF)** for pre-primary through secondary education in the Republic of Kenya.

[18] Explore SEL (harvard.edu)

[19] The Word Health Organization (WHO)'s Skills for Health outline life skills important for skills-based health and life skills education.

[20] http://exploresel.gse.harvard.edu/terms/622

[21] http://exploresel.gse.harvard.edu/terms/621

[22] Kenya TVET Values and Life Skills (VaLI) Framework

[23] http://exploresel.gse.harvard.edu/terms/697

order executive functioning: This is a "meta-skill" through which one learns to think about thinking and develop purposeful thinking processes, such as being able to discern and evaluate whether an argument makes sense or not (UNICEF MENA Life Skills and Citizenship Education).

Problem solving according to UNICEF MENA[24] is a higher-order thinking process interrelated with other important life skills, such as critical thinking, analytical thinking, decision-making and creativity. More specifically, being able to solve problems implies a process of planning, i.e., the formulation of a method to attain the desired goal. Problem solving begins with recognizing that a problematic situation exists and establishing an understanding of the nature of the situation. It requires the solver to identify the specific problem(s) to be solved, plan and carry out a solution, and monitor and evaluate progress throughout the activity.

Pearson (n.d.) has defined critical thinking as consisting of four core skills: 1. systems analysis: the ability to determine the relationship between variables in a system; 2. argument analysis: the ability to draw logical conclusions based on data or claims; 3. creation: the ability to construct a strategy, theory, method or argument based on a synthesis of evidence (the artifact that is created goes beyond the information at hand); 4. evaluation: the ability to judge the quality of procedures or solutions. Evaluation involves criticism of a work product using a set of standards or specific framework.

Critical thinking according to the Israeli Ministry of Education[25] is the ability to review and evaluate information, opinions and ideas intelligently; form an opinion and formulate a position independently; choose between alternatives and make reasoned decisions. It includes four core capabilities: **evaluation of information and data sources, argumentation, decision-making and doubting**. The actions involved include:

Core capabilities	Actions
Evaluation of data and information sources	▪ Define appropriate indices and use them to evaluate reliability, relevance and assessment of data and information sources ▪ Distinguish among beliefs, positions and facts ▪ Identify propaganda, demagogy and manipulations

[24]The Life Skills and Citizenship Education (LSCE) - Conceptual and Programmatic Framework (CPF) has been developed as part of a regional initiative in the Middle East and North Africa (MENA), led by UNICEF.

[25] Ministry of Education (2022) https://boger.openfox.io/%D7%9E%D7%99%D7%95%D7%9E%D7%A0%D7%95%D7%99%D7%95%D7%AA:%D7%97%D7%A9%D7%99%D7%91%D7%94_%D7%91%D7%99%D7%A7%D7%95%D7%A8%D7%AA%D7%99%D7%AA

Core capabilities	Actions
Argumentation	▪ Formulate a claim and justify it with information and data ▪ Identify the differences between the reasons for a claim and evaluate the relations between them (whether the claim results from the reasons? Do the reasons sufficiently support the claims?) ▪ Identify biases and fallacies of logic in the claims
Decision making	▪ Analyze the problem, issue or dilemma from diverse points of view ▪ Compare available solutions to a theoretical or practical question and evaluate the theoretical or practical impact of choosing one of them ▪ Identify and neutralize biases, extraneous considerations and prejudices ▪ Distinguish between questions and issues that require expertise and those that require independent thinking, identify areas of expertise and experts (discern between experts and charlatans) and use advice wisely.
Doubting	▪ Think independently when considering the views of sources of authority and peer groups ▪ Ponder sources of justification of positions, decisions and claims, and raise questions (such as whether the person making the claim has the authority, whether the reasoning is sound in view of the facts?) ▪ Delay judgement (refrain from forming a position) until after evaluating the justifications and finding compelling arguments)

Problem-solving and decision-making skills are important components in a digital environment and make up one of the core skills of digital orientation (Zohar & Boshrian, May 2020): The aggregation of these skills includes the ability to identify and solve technical and theoretical problems. This includes a range of capabilities associated with intelligent decision-making while using digital tools, including identifying needs, available resources required to meet these needs and the technological ability to use these resources. In addition, it is essential to know the limits of our digital expertise and where to find assistance for problem-solving, including creativity and openness to try and evaluate new solutions. The ability to make decisions is associated with different types of cognitive skills that are essential in the 21st century. Thus, for example, creative thinking is needed to identify the options available to the student, and critical thinking to disqualify inapplicable alternatives. The development and application of these cognitive skills in a digital environment is a challenge in of itself, and this issue needs to be addressed separately from the development of these capabilities in general.

Student Descriptors

- Students engage in inquiry processes that include locating, processing, interpreting, synthesizing and critically analyzing information in order to solve problems and make informed decisions. These processes involve critical, digital and data literacy.
- Students solve meaningful and complex real-life problems by taking concrete steps – identifying and analyzing the problem, creating a plan, prioritizing actions to be taken, and acting on the plan – as they address issues and design and manage projects.
- Students detect patterns, make connections and transfer or apply what they have learned in a given situation to other circumstances, including real-world situations.
- Students construct knowledge and apply what they learn to all areas of their lives – at school, home, and work; among friends; and in the community – with a focus on making connections and understanding relationships.
- Students analyze social, economic, and ecological systems to gain an understanding of how they function and interrelate.

Questions for the survey – Definitions

Kindly rank your acceptance of each of the relevant components of the skill of complex problem solving and critical thinking in the table.

Description of the component	Totally Disagree (1)	2	3	4	Fully Agree (5)
Locating, processing, analyzing, and interpreting relevant and reliable information to address complex issues and problems					
Questioning and evaluating ideas and solutions					
Understanding and resolving situations where a method or solution is not immediately obvious.					
Three types of thinking: reasoning, making judgements, and problem solving.					
Learners learn that for every issue there are multiple perspectives that they can explore					
Evaluating future consequences of present actions for self and others					
Ability to find solutions to both simple and complex issues in uncertain situations.					
Thinking involves higher-order executive functioning: This is a "meta-skill" through which one learns to think about thinking and develop purposeful thinking processes, such as being able to discern and evaluate whether an argument makes sense or not					

Description of the component	Totally Disagree (1)	2	3	4	Fully Agree (5)
Being able to solve problems implies a process of planning, i.e., the formulation of a method to attain the desired goal. Problem solving begins with recognizing that a problematic situation exists and establishing an understanding of the nature of the situation. It requires the solver to identify the specific problem(s) to be solved, plan and carry out a solution, and monitor and evaluate progress throughout the activity.					
Using digital tools in the process of problem solving and identifying the relevant digital resources for the required solutions					

Please add any missing components of the skill of complex problem solving and critical thinking not included in the above table: ____

Any comments or remarks: ____

Methodologies for learning, teaching and experiencing

When designing activities for teaching and assessing critical thinking, it is important to consider all four skills—systems analysis, argument analysis, creation and evaluation—and to design activities that are accessible to students across varying ability levels. Different types of tasks require varying amounts of each skill. Thus, task demands—what students are asked to do—should be carefully designed to correspond to a specific skill or set of skills. For example, if the goal is to teach argumentation, teachers should employ tasks that require a student to draft and write an argument based on a set of information provided to the student (e.g., other arguments, data). Similarly, if the goal is to teach evaluation, the student should be provided with a work product that they can evaluate and produce documentation regarding the evaluation (e.g., written report, spreadsheet). Teachers should design classroom assessments by matching learning objectives to problem types that are well aligned with the target disciplines of instruction. In addition, educators should consider using concept-mapping activities, simulations and structured argumentation exercises to foster systems- and argument-analysis skills, as these have proved to be effective in the literature (Pearson).

instructional model

According to Fahim & Eslamdoost (2014), a model of critical thinking needs to foster the cognitive characteristics of individual learners. In this context, an instructional model of critical thinking is required that includes instruction and practice phases. The logic for the instruction of critical thinking is that systematic intervention is mandatory to enable the individual learners to reach their potential zone of proximal development in their higher-order thinking. The strategies that are indispensable in the instruction phase must include:

1. Clarification:
    a. Questioning: doubting and searching the fundamentals related to the problem.
    b. Outline: making a bright sketch of cognitive structure.
    c. Authentic evidence: gathering the related and supporting evidence as well as counter-evidence.
2. Judgment:
    a. Selecting the best, most closely related as well as most supportive evidence.
    b. In-depth analysis of the supporting and counter-evidence.

c. Considering values, standards, and urgencies as well as noteworthy and vital points.
d. Exhaustive analysis of the arguments and counter-arguments.

3. Strategies:

   a. Having a clear definition of the matter at hand.

   b. Distinguishing the actual purpose of the issue.

   c. Making adaptations between the purpose and evidence as well as values.

   d. Making values-driven inferences on the basis of previous findings.

   e. Not claiming a definite inference: Have an evolving and iterative rethinking process over the issue in order not to propose a fixed deduction.

Explicit instruction

Many researchers have noted that critical thinking skills are unlikely to develop in the absence of explicit instruction (Ventura, Lai, & DiCerbo, 2017).

What form should this instruction take? An infusion approach, specifically teaching critical thinking skills in the context of a particular topic.

Ennis (1989) introduced an illustration that suggests three models: a general model, an infusion model and a mixed model for critical-thinking instruction. The general approach is taken to mean teaching generalized critical thinking skills in a critical-thinking course. The infusion approach is suggestive of self-consciously teaching critical-thinking skills as part of a subject course. Finally, the mixed-model approach is introduced as a general course in combination with either the infusion or immersion approach.

According to Halpern (1998) a depositional or attitudinal component that consists of modeling critical-thinking and actively inspiring thoughtful responses is obligatory. In this regard, the explicit instruction of critical-thinking skills, including structured training activities designed to facilitate the transfer of critical thinking techniques across innumerable contexts, in addition to nurturing metacognitive strategies that include having students discuss the thinking process, is called for. (Fahim & Eslamdoost, 2014).

There appears to be a consensus that the explicit teaching of problem solving is better, not only because it recognizes problem solving as an explicit skill to be taught, but also because it provides guidance in the form of specific problem-solving methods and the problem situations to which these apply (Matthee & Turpin, 2019).

Case Libraries

Experienced problem solvers in systems match new problems to prior experiences and apply those solutions. Case libraries can serve as experiential knowledge and be an effective form of instructional support for systems analysis. The case library can consist of potentially hundreds of experienced problem-solvers' solutions. Rather than relying only on a theoretical description of a system, the learner can access the case library to gain insight into systems.

Worked Examples

Worked examples are instructional devices that typically model the process for solving a problem. Worked examples can highlight the subgoals of the problem, which may include identifying fault symptoms, constructing a system model, diagnosing the fault, generating and verifying solutions and adding experiences to the personal cases.

Concept Maps

The concept map is a widely used instrument for learning complex systems. This tool can be described as a graphical illustration of a knowledge concept consisting of central terms that are represented as nodes linked by labeled arrows. The arrows represent the quality and the direction between the nodes. The process of constructing and evaluating concept maps for clarity, completeness and accuracy is believed to support the development of critical-thinking skills, and there is some empirical evidence to support this claim. For example, Yue, Zhang, Zhang and Jin (2017) meta-analyzed eleven studies examining the effects of concept-mapping interventions on the critical-thinking skills of nursing students. The authors found that students who were taught to construct and use concept maps had significantly higher critical-thinking scores than did students in the control group, who were typically taught using more traditional, lecture-based approaches.

Simulations

Processes, systems, or functions of real-life phenomena are simulated in an authentic. manner to enable understanding of a system or device. Studies have found that practice on computer simulations resulted in learning that was comparable to that achieved from traditional lectures. And higher learning gains are achieved when simulations demonstrate high fidelity, or a high degree of similarity, to the physical systems they are designed to represent. For example, an animated simulator teaching electronics troubleshooting resulted in shorter learning times and fewer trials than a static simulator.

Computer-supported collaboration scripts (CSCLs)

CSCLs support collaborative argumentation and argumentative knowledge construction in digital environments. CSCLs provide detailed and explicit guidelines for small groups of learners around argumentative knowledge construction. Prompts are also given to provide learners with guidelines, hints and suggestions to facilitate effective argumentation strategies. In a CSCL interface, the student is prompted to enter a claim, the rationale for the claim and the limitations of the claim. This information is then shared with other students via a discussion board to facilitate collaborative argumentation. Empirical evidence suggests that CSCL can improve the construction of counterarguments and sound argumentation in transfer tasks afterwards, and co-construction of arguments with peers.

Rubric methodology

Researchers share an overall common understanding on the key dimensions of creativity and critical thinking. However, transferring the concepts to an educational application requires further translation. This is where rubrics come in (Vincent-Lancrin et al., 2019). The OECD rubrics (Vincent-Lancrin et al., 2019) can serve the teachers as a methodology of teaching and learning (as well as evaluation).

Rubrics are a way to simplify, translate and construct a social representation of what creativity and critical thinking look like in the teaching and learning process. They aim to create a shared understanding of what creativity means in the classroom, and share expectations among teachers, and among teachers and students. The function of rubrics is to simplify the big concepts of creativity and critical thinking so that they become relevant to teachers and learners in their actual educational activities. They also allow teachers to monitor and formatively assess whether their students develop those skills. Rubrics are a metacognitive tool that helps make learning visible and tangible and teaching intentional.

The OECD rubrics capture different dimensions of critical thinking through four high-level and easily memorable descriptors: imagining, inquiring, doing, reflecting. Each of these active words is then associated with a descriptor of critical thinking. Two domain-general conceptual rubrics have been developed: a “comprehensive” rubric and a “class-friendly” rubric. The development of a portfolio of rubrics rather than of just one is an outcome of the fieldwork: Some teachers called for a simplified rubric, others for domain-specific rubrics corresponding to the typical teaching activities in their subject, while yet others preferred to stick with the comprehensive rubric.

	Questioning and evaluating ideas and solutions	
	"comprehensive"	"class-friendly"
inquiring	Understand context/frame and boundaries of the problem Identify and question assumptions, check accuracy of facts and interpretations, analyze gaps in knowledge	Identify and question assumptions and generally accepted ideas or practices
imagining	Identify and review alternative theories and opinions and compare or imagine different perspectives on the problem Identify strengths and weaknesses of evidence, arguments, claims and beliefs	Consider several perspectives on a problem based on different assumptions
doing	Justify a solution or reasoning based on logical, ethical or aesthetic criteria/reasoning	Explain both strengths and limitations of a product, a solution or a theory justified based on logical, ethical or aesthetic criteria
reflecting	Evaluate and acknowledge the uncertainty or limits of the endorsed solution or position Reflect on the possible bias of one's own perspective compared to other perspectives	Reflect on the chosen solution/position relative to possible alternatives

The Stanford d.school Design Thinking approach[26]

Design thinking is a methodology for creative problem solving.

The d.school's teaching and learning program is focused on helping people strengthen their creative abilities in order to apply them to the world. Students take on projects and challenges that require a new way of looking at what's possible in order to frame problems and produce innovative solutions both in class and beyond. The design approach consists of five phases: empathize, define, ideate, prototype and test.[27]

[26] https://dschool.stanford.edu/resources/getting-started-with-design-thinking#:~:text=Overview,can%20run%20with%20your%20students.

[27] https://web.stanford.edu/~mshanks/MichaelShanks/files/509554.pdf

Action-oriented approaches

As "social agents," learners fully engage in meaningful real-life situations to which they learn to respond in a wholly cognitive and emotional manner, mobilizing their unique linguistic and sociocultural repertoires. Here, the notion of "task" goes beyond the mere notion of a communicative activity, to encompass the realization of projects or problems rooted in reality, socially and culturally situated to be solved through a set of targeted and concerted "social" actions, "not exclusively language-related," to achieve a clearly defined objective. Communication is not the goal, it is the means, along with critical thinking, self-reflection, creativity and adaptability, to achieve the task.

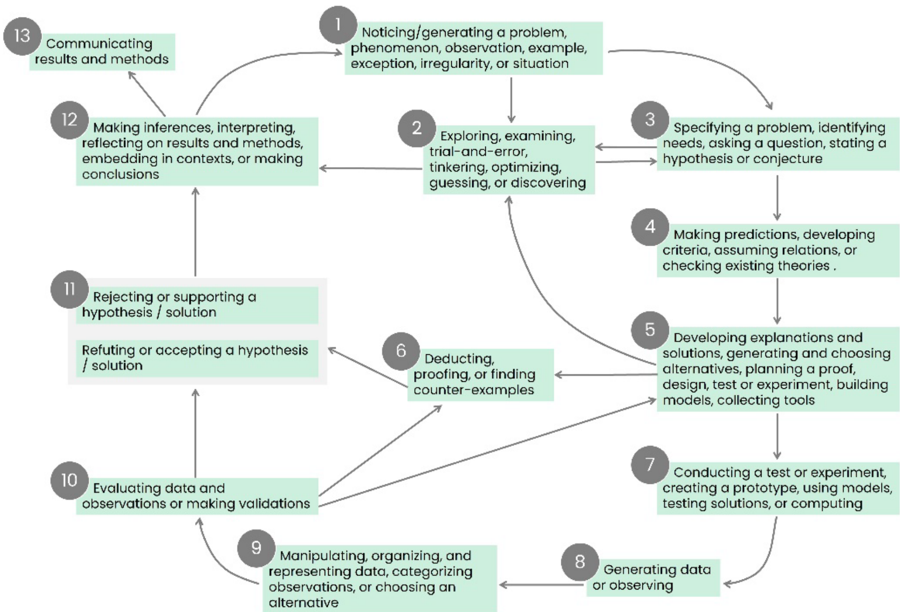
More details can be found in "Action-Oriented Approaches: Being at the Heart of the Action" p. 2. (Germain-Rutherford, 2021).

Integrated framework of problem solving (Burkhard et al., 2019)

The framework can support both practice and research by providing a common background that relates the means, steps, processes and activities to solve problems in the different domains to a single common reference. In doing so, it can support teachers in explaining the multiple ways in which science problems can be solved and in constructing problems that reflect these numerous ways. STEM and computer science educational research can use the framework to develop competences of problem solving at a fine-grained level, to construct corresponding assessment tools and to investigate under what conditions learning progressions can be achieved.

Figure 2 shows the multiple processes consisting of 13 steps, through which problems can be solved.

Figure 3: Visual representation of an integrated framework of problem solving.



The framework is visualized with arrows between the different steps, which are represented by boxes. Each step/box contains different but comparable activities that belong to the step, for example, specifying a problem, identifying needs, asking a question or stating a hypothesis or conjecture. These activities can be alternatives, or more than one activity can be relevant for solving a certain problem. The step involving the communication of results and methods is not necessarily a problem-solving step because it is a common practice to share the results derived from this process, and is an activity of high importance in education.

The benefit of the framework is that it offers a variety of different activities that help to solve a problem. However, the framework does not solve the specific problem for the students. Nonetheless, given that the students understand the steps, the framework can serve as a toolbox that offers options and helps them not to forget important processes.

The framework can be used for teaching purposes in a way that is acutely linked to meaningful problems and is applied to content. In this way, the framework can help students gain a comprehensive view of problem-solving methods and techniques used in STEM domains.

The framework can help to reflect problem-solving processes after a problem is solved or after students have given up. All steps taken can be identified, retraced and made visible in a representation such as Figure 2. This helps to focus on scientific strategies of problem solving, putting the solution into a larger context, and to relate the solution to the students' prior knowledge, which is a prerequisite to achieving competences in solving problems

Example

Imagine a high school class that wants to find out whether the noise on the street where the school is located is unhealthy for the students. This involves a general and authentic problem situation (step 1). Let us assume in our example that the students have sufficient information and prior knowledge to specify the problem (step 3), e.g., by asking: "Does the sound pollution of the street exceed a certain threshold?" The next step of the students could be that they begin to explore how sound levels are measured and how the conditions in which they want to answer their question can be specified in more detail (step 2). The result can be a more precise question (step 3): 'Does the maximal sound pollution of the street excel a certain threshold when measured in a classroom with windows closed?' After that, the students set a threshold value for the sound level (step 4) and plan an experiment (step 5) by selecting measurement devices, choosing rooms facing the street on different levels of the building and determining the number of measurements they need. These activities are followed by conducting the experiment (step 7), generating data (step 8), organizing the data (step 9) and evaluating the data (step 10). In the last step, let us assume that the students notice that to find out if the street is the only source of sound pollution, they need reference measurements. So, they modify their experimental plan by adding measurements in rooms of the building that do not face the street (step 5). Again, they follow steps 7, 8, 9 and 10. The result could be that the students discover that the street is a relevant source of sound pollution in certain rooms of the building (step 11). They then conclude that these rooms should be equipped with sound insulated windows (step 12) and communicate this to the head of the school (step 13).

Discussion and reflection

These tools are especially relevant for the encouragement of critical thinking, as they make it possible to expose the students to positions that they will not be comfortable with, thus motivating them to respond. The discussion revolves around the materials learned in class and their interpretation, and the ability to associate them with the knowledge gained in class and their personal experience. The discussions can be part of the curriculum and involve even short discussions between the teacher and students during breaks. The discussions can also be enriched with supporting items such as documentary videos. In the discussions to support the development of critical thinking, the teaching team will refrain from presenting their own preferences for one position or another, and help the students raise doubts about their own positions and not merely attack rivals' positions.

Game learning

Game learning is a very efficient tool for delivering messages that require practice involving time and effort, advancing social skills and understanding complex social dilemmas to foster motivation for higher-order reasoning. It enables deep learning, the development of problem-solving skills, critical thinking and creativity, collaboration and empowerment of individuals who belong to unrepresented populations in society. Game learning is based on advanced technologies, which include serious multi-participant computer games, virtual and augmented reality games, as well as games which make use of smart and natural interfaces such as gestures and speech, sensory and visual presentations. Game learning will enable new ways to apply methodologies for design, problem solving, collaboration and social incorporation, which will turn the learners into active players who are motivated to learn. The technologies for computer games can also enable monitoring and evaluation of learning and adjustment of its features to the learner in real time and in a dynamic mode during the game.

Research that studies the effectiveness of digital game-based learning (Yang, 2012) found that the strategy was very effective in advancing problem-solving skills, compared to control groups, which did not show advancement[28] .

"Signature pedagogies"[29]

Vincent-Lancrin et al. (2019) describe the term "Signature pedagogies" and outlines 11 pedagogical models. Four relevant models to problem-solving skills are presented here:

1. CREATIVE PARTNERSHIPS – This is a pedagogical approach that promotes partnerships between creative practitioners and schools. The program promotes changes in teaching methods by engaging creative practitioners – typically artists or people working in the creative industries – as actors and advisers in the teaching process. Creative practitioners engage in schools around a pre-identified problem and work with teachers to develop projects or new teaching techniques to address the problem, building on their creative experience as non-teachers – and without taking the teacher's responsibility away from them.
2. DESIGN THINKING – Design Thinking is an interdisciplinary approach to teaching and learning in which students have to develop an innovative solution to a complex real-world problem by going through certain design processes. Like professional designers, students are asked to generate multiple solutions and subsequently analyze, evaluate and progressively improve their proposals. The approach is student-centered and process-oriented.

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[28] Building Virtual Cities, Inspiring Intelligent Citizens: Digital Games to Develop Students' Problem Solving and Learning Motivation (in Hebrew)

[29] Signature pedagogies refer to structured pedagogical models that can be applied to pedagogical activities, projects or education as such. They go beyond pedagogical techniques that all teachers should master in addition to conventional teaching based on lecturing (Vincent-Lancrin et al., 2019).

3. RESEARCH-BASED LEARNING – Students learn about methods and procedures through the research process. Teachers need to plan, deliver and assess students' work in these research processes, while giving students hands-on responsibility as actual researchers.
4. TEACHING FOR ARTISTIC BEHAVIOR – In the Teaching for Artistic Behavior approach, students develop their own projects: they struggle to find inspiration, envision an idea, design a plan of action, reflect on their progress, persist through difficulties, evaluate the work as it proceeds and see the project through to completion. They do the research, exploration, create the artwork, then reflect on and revise it, before deciding when it is finished and, to some extent, whether it is successful.

Table 17: Operative settings for teacher

Knowledge	Skills	Attitudes/values/ethics
Reason effectively, use systematic thinking and evaluate evidence • Understand systems and strategies for tackling unfamiliar problems • Understand the importance of evidence in belief formation. Reevaluate beliefs when presented with conflicting evidence *Solve problems* • Identify gaps in knowledge • Ask significant questions that clarify various points of view and lead to better solutions *Articulation* • Clearly articulate the results of one's inquiry	*Reason effectively* • Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation. *Use systems thinking* • Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems. Examine ideas, identify and analyze arguments • Synthesize and make connections between information and arguments • Interpret information and draw conclusions based on the best analysis • Categorize, decode and clarify information • Effectively analyze and evaluate evidence, arguments, claims and beliefs • Analyze and evaluate major alternative points of view. • Evaluate. Assess claims and arguments • Infer. Query evidence, conjecture alternatives and draw conclusions • Explain. State results, justify procedures, and present arguments. • Self-regulate, self-examine and self-correct	*Make reasoned judgments and decisions* • Consider and evaluate major alternative points of view • Reflect critically on learning experiences and processes • Incorporate these reflections into the decision-making process *Solve problems* • Be open to unfamiliar, unconventional and innovative solutions to problems and to ways to solve problems • Ask meaningful questions that clarify various points of view and lead to better solutions *Attitudinal disposition* • Trustful of reason • Inquisitive and concerned to be well informed • Open and fair minded • Flexible and honest • Inquisitiveness and concern to be well informed • Alert to opportunities to use ICT • Trustful of and confident in reason • Open and fair minded, flexible in considering alternative opinions • Honest assessment of one's own biases • Willingness to reconsider or revise one's views where warranted

Source : Binkley M. et al. (2012), Table 2.3

Additional examples of applicable teaching practices on solving complex problems and critical thinking are available, in Hebrew, on the website of the Israeli Ministry of Education, Teaching Staff Portal – Pedagogical Space:

https://pop.education.gov.il/teaching-tools/teaching-practices/search-teaching-practices/defining-problems-and-resolve-them /

https://pop.education.gov.il/teaching-tools/teaching-practices/practice-map/

https://pop.education.gov.il/perceptions-trends/skills/critical-thinking/

Questions for the survey – Learning, teaching and experiencing methodologies

Kindly rank your acceptance of each of the relevant learning/teaching/experiencing methodologies of the skill: complex problem solving and critical thinking.

Name of the Component	Totally Disagree(1)	2	3	4	Fully Agree (5)
Instructional model					
Explicit instruction					
Case Libraries					
Worked Examples					
Concept Maps					
Simulations					
Computer-supported collaboration scripts (CSCLs)					
Rubric methodology					
The Stanford d.school Design Thinking approach					
Problem-Based Learning Combined with Computer Simulation					
Integrated framework for problem solving					
Discussion and reflection					
Game learning					
Signature pedagogies					

Please add any missing components of the skill complex problem solving and critical thinking, not included in the above table:

____

Any comments or remarks: ____

Evaluation and measurement tools for complex problem solving and critical thinking

The current prevailing concept in research is that critical thinking is not a general skill, but is dependent on context. The general cognitive skills required for critical thinking are interpretation, analysis and evaluation of claims, conclusions in view of the information and self-management (i.e., re-evaluation of previous concepts in view of new information and data). Yet, for each field of knowledge, the characteristic data, research methodologies and their suitability for evaluation of the basic assumptions (axioms and norms) are context specific (Leitmanovich 2021).

The evaluation of critical thinking is an important challenge for assessing the evolution of creativity over time, but it should be done in cooperation with the students through dialogue.

Considering the challenges posed by evaluation, it is widely believed that pre-test and post-test results in evaluating critical thinking skill do not reveal retention. Cognitive skills improve with practice and real effects of critical thinking will be apparent sometime later, while long term retention is difficult to assess. As a result, teaching-testing approaches in classroom can be changed in different ways to improve critical thinking abilities in students (Fahim & Eslamdoost, 2014).

Domain-General Measures

A variety of published measures that seek to assess generalized critical-thinking skills are available. These include:

- California Critical Thinking Skills Test (CCTST) – an educational assessment that measures all the core reasoning skills needed for reflective decision-making. The CCTST provides valid and reliable data on critical thinking skills of individuals and groups. It is designed for use with undergraduate and graduate students. It is available in many languages and its OVERALL skills score can be benchmarked using one of many percentile comparisons.
- Halpern Critical Thinking Assessment (HCTA) – The Halpern index is structured to assess critical thinking. In it, daily situations are presented and the students being tested are asked to indicate which questions need to be asked in order to obtain data that can make it possible to decide how to act in each situation. The questions are evaluated according to the logic they are based on, through decision making and the justification and probability of the tested scenarios. Tools of this kind are relevant to various fields of knowledge, but the research

and teaching teams are required to make adjustments to each field, and it is not always clear how valid these adjustments are.

- Watson–Glaser Critical Thinking Appraisal (WGCTA) – measures the critical skills that are necessary to present a certain point of view in a clear, structured, well-reasoned manner and convince others of your argument. The test questions look at the individual's ability to make correct inferences, recognize assumptions, make deductions.
- Ennis–Weir Critical Thinking Essay Test – is a general test of critical thinking ability in the context of argumentation.
- Cornell Critical Thinking Test (CCTT) – is an exam that helps teachers to determine their students' critical thinking abilities. First developed in 1985. the CCTT series offers two levels of testing: level X for grades five through twelve and level Z for grades ten through twelve. The tests may be used at the college level as well.
- ETS Proficiency Profile (EPP; ETS) – is a general education, knowledge and skills test designed to measure critical thinking and college-level reading, writing and mathematical skills in the contexts of the humanities, social sciences and natural sciences.
- Collegiate Learning Assessment+ (CLA+) – is a standardized testing initiative in the United States for evaluation and assessment in higher education. It uses a "value-added" outcome model to assess a college or university's contribution to student learning, which relies on the institution rather than the individual student as the primary unit of analysis. The CLA measures are designed to test for critical thinking, analytic reasoning, problem solving and written communication skills. The assessment consists of open-ended questions.
- Collegiate Assessment of Academic Proficiency (CAAP Program Management) – is the standardized, nationally normed assessment program from ACT[30] that enables postsecondary institutions to assess, evaluate and enhance student learning outcomes and general education program outcomes.

The CAAP, CCTST, and WGCTA exclusively use selected-response items such as multiple choice or Likert-type items, while the EPP, HCTA, and CLA+ use a combination of multiple choice and constructed-response items. The Ennis–Weir test is an essay-only test.

In order to assess all skills in critical thinking, educators should aggregate a mix of evidence from critical-thinking activities. Evidence can come from first-hand observations, work products from artifacts (e.g., writing samples, concept maps) or

[30] Admissions test https://www.act.org/

real-time performance data from simulations. Recent advances in technology can supplement observations by enabling real-time capturing and automated scoring of these aspects of writing and systems analysis. When possible, feedback around performance should be provided at both the skill level (e.g., argument analysis) as well as around the task (e.g., does the student make logical conclusions in the argument?). Providing both these types of feedback can ensure the student knows how they are progressing in critical-thinking instruction (Pearson).

Evidence-Centered Design[31]

Despite the availability of a wide variety of published critical-thinking measures, educators may want to design their own assessments of critical-thinking skills. Such homegrown assessments may be better tied to learning objectives and subject matter than are published assessments of general critical thinking, providing both a closer match to the specific aspects of critical-thinking that instructors want to target and a better measure of critical-thinking skills as they are practiced in a given discipline. Evidence-centered design provides a systematic framework for developing assessment tasks to elicit targeted skills. The evidence-centered design (ECD) framework consists of three models:

1. Student model: Define the claims to be made about learners' competencies.
2. Evidence model: Establish what constitutes valid evidence of the claim.
3. Task model: Determine the nature and form of tasks that will elicit that evidence.

Assessment Task Models[16]

Assessment Task Models describe types of activities students can engage in that are likely to elicit evidence of critical thinking.

- WRITING TASKS – Writing tasks are an effective way to elicit analysis, creation and evaluation skills. It is a widely accepted view that writing can be a valid way to show proficiency in argumentation
- SIMULATION TASKS – **A simulation-based assessment (SBA)** is the use of a simulation for purposes of assessment. In general, SBAs are good candidates for eliciting systems analysis. Specifically, SBAs are simulations of specific problems that must be solved in the simulation environment. The research thus far supports its validity as an assessment approach.

  Several notable advantages of SBAs:

  1. SBAs provide a much larger range of activities that can be used to elicit a large range of responses.

[31] Ventura, Lai & DiCerbo, 2017

2. As a function of a larger amount of data collected on any given student, SBAs can produce more accurate estimates of key competencies. SBAs may also enjoy advantages over traditional paper-and-pencil assessments with respect to student engagement.
3. By improving the inferences we can make about a student, we can also improve the feedback we can provide on how to fix misconceptions or fill in gaps in knowledge. Thus, the use of process data means that a student's proficiency development can be measured throughout the learning experience.

- CONCEPT MAP TASKS **–** In general, concept-mapping tasks are good at eliciting systems analysis and creation. These tasks allow students to illustrate complex relationships between concepts, which is difficult to do using traditional item types.

  There are two approaches to designing concept map tasks: *high-directed*, in which concepts and links are provided and students must simply slot entities and links into the correct spot on the map; and *low-directed*, where students must generate both the concepts and the links themselves.

  Computer-based concept maps offer several advantages in comparison with paper-and-pencil-generated concept maps:

  - Students can more easily construct, modify or maintain concept maps.
  - Software can deliver real-time feedback around student-constructed maps.
  - Teachers can provide students with constraints around concept-map construction.
  - Concept maps can be scored automatically and objectively.

Problem Types for Critical Thinking[16]

Conceptualizing different problem types that vary in accordance with their cognitive demands.

For example,

Problem	Description	Critical thinking skill elicited
Story	Requires the learner to engage in a process of breaking up a story into relevant parts. Generates the appropriate solution strategy and applies the solution strategy to generate an answer.	Systems analysis Creation

Problem	Description	Critical thinking skill elicited
Rule	Tends to have a clear purpose or goal that is constrained but not restricted to a specific procedure or method. Requires that learners deduce the rules governing how a system operates.	Systems analysis
Decision-making	Entails selecting from a set of alternatives and their associated consequences. Involves associated activities, such as generating additional alternatives and assessing the risks and benefits of alternatives.	Argument analysis Creation
Troubleshooting	Requires resolving goal-state and current state discrepancies. Involves error detection in other contexts such as detecting errors in a written argument, mathematical calculation or software code.	Systems analysis
Strategic performance	Entails real-time, complex activities. Learners apply a number of tactical actions aimed at solving an ill-structured problem. Usually under time pressure.	Systems analysis
Policy	Multiple positions and perspectives exist. Includes foreign policy, legal issues and economic and development issues.	Argument analysis Systems analysis Creation Evaluation
Design	Has vaguely defined or unclear goals with unstated constraints. Involves applying a great deal of domain knowledge. Possesses multiple solutions, with multiple solution paths. Possesses multiple criteria for evaluating solutions, and these criteria are often unknown.	Argument analysis Systems analysis Creation Evaluation

Problem	Description	Critical thinking skill elicited
Dilemmas	Considered the most ill-structured kind of problem because there are typically no widely accepted solutions. Many important perspectives to consider: constitutional, political, social, ethical.	Argument analysis Systems analysis Creation Evaluation

Problem types can be crossed with the different assessment approaches in any given assessment.

Evidence Models[16]

Evidence models describe the specific types of behaviors that should be measured and how those behaviors are linked to skills.

The evidence model for critical thinking must specify how to identify the behaviors and how they are tied to the constructs that need to be measured.

When creating evidence-centered design (ECD) models around critical thinking for the purpose of supporting learning, we need to consider the ways we give feedback about student performance as they complete tasks. There are two different types of feedback in the context of ECD:

1. Student-model feedback – This is feedback around performance on a specific skill or subskill in a student model. For example, feedback may tell the student the percentage of activities they have already completed on a particular learning objective or subskill, or it may report some estimate of a student's level of mastery or proficiency on that subskill.
2. Evidence-model feedback – This is feedback around behaviors identified in the evidence model. This type of rich feedback can provide an indication of what behaviors are associated with improving skills in the student model: It either tells the student exactly what aspects of their response need to be corrected (directive, which is especially good for novices) or suggests where there may be a problem and allows the student to correct their own mistakes (facilitative, which may be better for more advanced learners).

Both are needed in a comprehensive feedback system, which is critical to supporting learning within a formative assessment process.

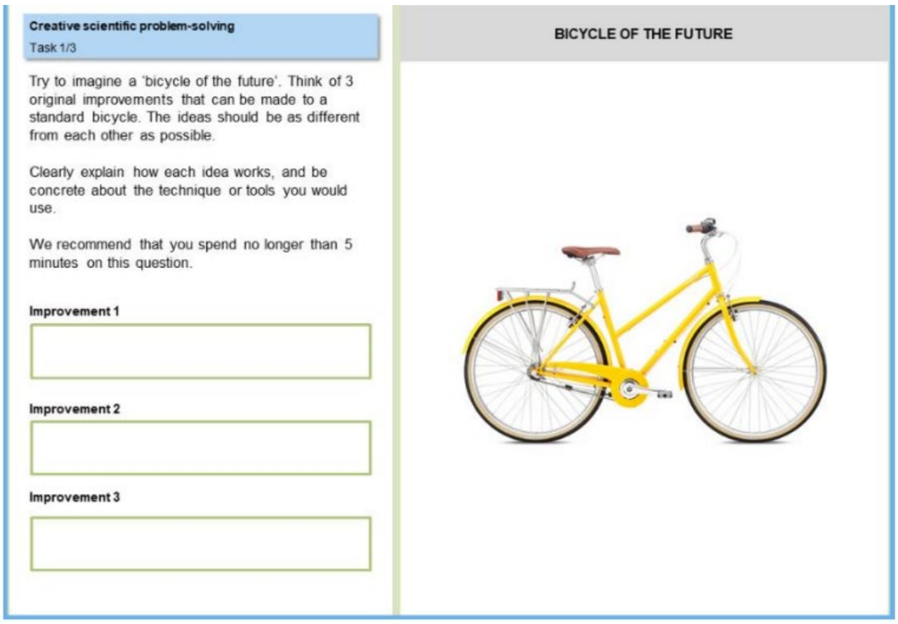
Unit model in scientific problem solving (**Examples from PISA tests)**[32]

The PISA assessment examines students' capacities to generate diverse and original ideas, and to evaluate and improve ideas across a range of contexts or "domains." The assessment includes four domains: written expression, visual expression, social problem-solving and scientific problem-solving. In each of these domains, students engage with open tasks that have no single correct response. They are asked either to provide multiple, distinct responses, or to generate a response that is not conventional. These responses can take the form of a solution to a problem, a creative text or a visual artifact.

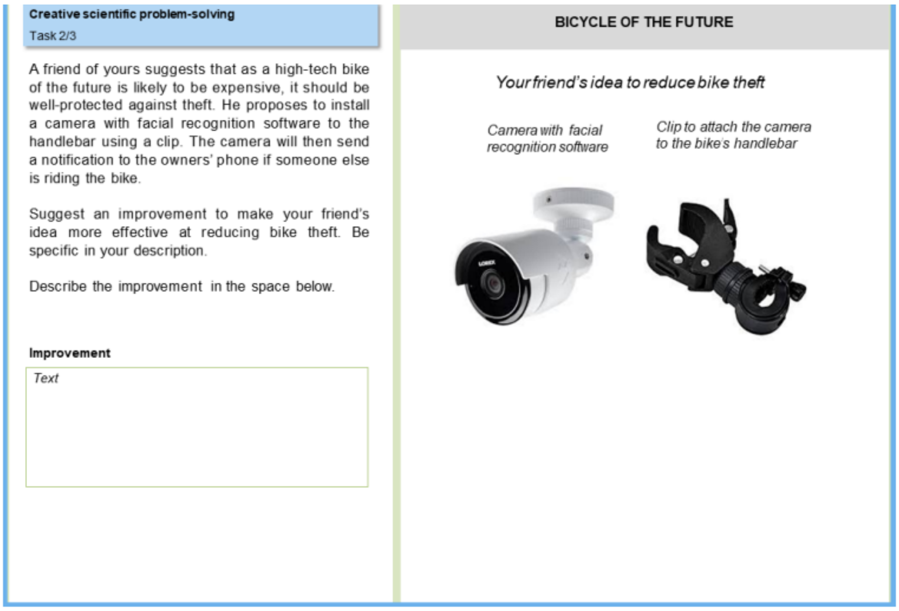
1. The first task of the unit asks students to describe three innovative ways that bicycles might change in the future. This task generates evidence for the facet "generate diverse ideas" of the competency model. Ideas are "appropriate" in this task if they represent a coherent suggestion for a way that bicycles might change, and if the suggested solution, if properly implemented, still maintains

[32] https://www.oecd.org/pisa/innovation/creative-thinking/

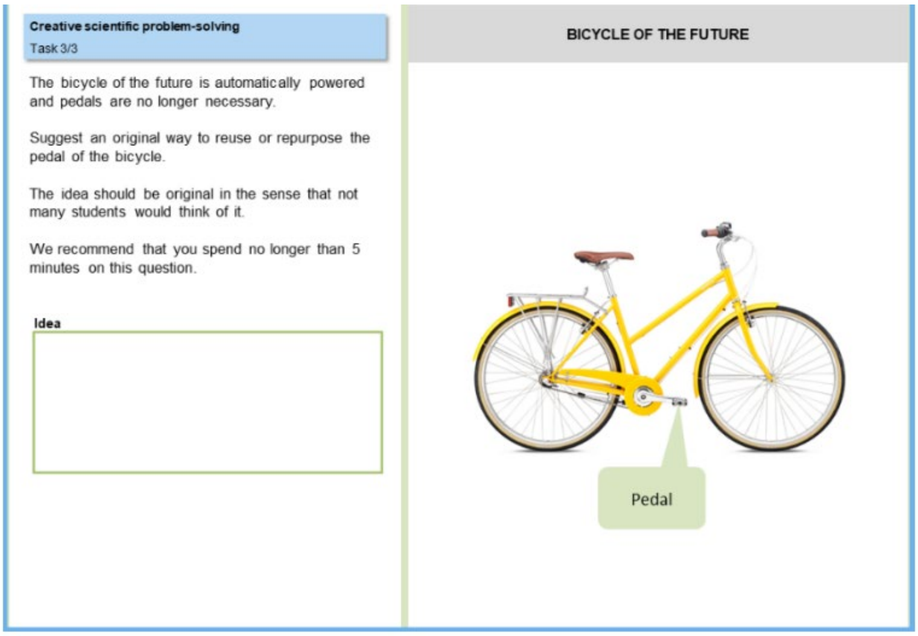
the essence of a bicycle (i.e., a transportation device for a single individual). Coders will be instructed not to consider the degree of efficiency and effectiveness of students' responses, beyond the criteria of appropriateness stated above, in order to reduce the influence of domain readiness in the scoring (for both the students and the coders alike). In order for ideas to be "different," they must suggest a different variation to the standard bike, for example replacing different elements.



2. In the second task of the unit, students are presented with a friend's suggestion for an anti-theft device and asked to come up with an original way to improve the suggestion. This task generates information for the facet "evaluate and improve ideas" of the competency model. The student should be able to evaluate that the friend's idea is flawed for at least two reasons: it would be easy for a thief to remove the camera from the bicycle, and that the notification sent to the individual's mobile device will likely be too late to stop the thief. An "appropriate" idea for this item therefore must represent a coherent suggestion for a solution that, if properly implemented, improves the anti-theft device by addressing the weaknesses in the friend's suggestion. The originality of the improvement will be determined on the basis of whether the suggested improvement is conventional.



3. The third and final task of the unit asks students to suggest a creative way that the pedals on the bicycle can be used for a different purpose, now that bicycles can be automatically powered. This item generates information for the facet "generate creative ideas" of the competency model. An "appropriate" idea in this item refers to any idea that resembles a coherent suggestion that, if implemented properly, might result in a new use for the pedals. The originality of the student's response depends on whether the response is conventional. Examples of conventional response themes for this item might include: (1) use the pedal as a hook (e.g., attach to the wall and hang a coat on it); (2) use the pedals as a door handle; (3) use the two pedals as limb extensions (e.g., to pick something up off a high shelf/off the floor).



Indicators

It is important that the use of indicators and the evaluation of the development of critical thinking be based on the interpretation that the students provide for the products of their work and not be dependent only on that of the teaching team. Consequently, this should be done in cooperation with the students through a dialogue with them.

Evaluation using indicators must be mostly carried out during the work in class, focusing on the processes and not based on outcomes. This requires the teaching staff to be directed with considerable focus and reflection (Leimanovich 2021).

- **STANDARDS-BASED REPORT CARDS**

Example (The behaviors indicated in the table are taken from section 1.1).

Table 18: STANDARDS-BASED REPORT CARDS

Skill	Behaviors/Products	0 Below expectations	1 Meets expectations	2 Meets expectations	3 Above expectations
Complex problem solving/Critical thinking	The student uses investigation processes that involve searching, processing, interpretation, synthesis and critical analysis of data in order to solve the problems and make rational decisions. These processes include data and critical digital knowledge.				
	The student solves significant and complex real-life problems by taking concrete steps – identifying and analyzing the problem, writing a plan, identifying priorities for actions to be taken according to the plan, where the student deals with issues, designs and plans the project.				
	The student builds know-how and applies what he/she has learned on the entire spectrum of his/her life – in school, at home and work, among friends, in the community – with an emphasis on building connections and understanding relationships.				
	The student analyzes societal, economic and ecological systems, in order to understand how they perform and are related.				

Additional examples can be viewed at:

- The website of the Israeli Ministry of education, teachers' portal – pedagogical space (in Hebrew):
    - Indices for evaluation of critical thinking https://meyda.education.gov.il/files/MinhalPedagogy/rikuz_machvan.pdf
    - Indices for problem solving/thinking flexibility https://meyda.education.gov.il/files/MinhalPedagogy/rikuz_machvan.pdf
- The site of DARCA (in Hebrew) – https://darca.org.il/wp-content/uploads/2020/06/Catedra_Aug2016_Tables_Critical-Thinking.pdf
- The Australian Curriculum, Assessment and Reporting Authority (ACARA web site) General_capabilities_-CCT_-_learning_continuum.pdf (acara.edu.au)
- Web site of the Israeli Institute for Democratic Education (in Hebrew) https://meyda.education.gov.il/files/MinhalPedagogy/rikuz_machvan.pdf

Open questions in tests

This methodology makes it possible to evaluate not only the contents of the answers, but also how they are written and the work method that led to the answer. In this type of evaluation, the teaching team makes use of a standard evaluation tool and adjusts it to test a skill and not just knowledge. In some of the cases, the teaching team conducts such an evaluation in every case, such as in homework and essays; in other cases, the tests need adjustments – for example, the students are asked to write all the stages of the solution to a math problem, to solve the problem in more than one way, to justify the solution or explain what the solution would be if one of the axioms were changed. Obviously, making use of different types of tests – not only written pen-and-paper tests but also practical tests and projects – are suitable for this case (Litmanovitch, 2021).

Question for the survey – Evaluation and measurement tools

Kindly rank your acceptance of each of the relevant evaluation and measurement tools of the skill problem solving and critical thinking in the table.

Name of the Component	Totally Disagree (1)	2	3	4	Fully Agree(5)
Domain-General Measures (CAAP, CCTST, WGCTA, EPP, HCTA, and CLA+ (p. 17)					
Evidence-Centered Design (p. 18)					
Assessment Task Models (WRITING TASKS, SIMULATION TASKS, CONCEPT MAP TASKS) (p. 19)					
Problem Types for Critical Thinking (p. 19)					
Evidence Models (student-model feedback, evidence-model feedback) (p. 20)					
Unit model in scientific problem-solving tasks (PISA) (p. 21)					
Indicators (p. 23)					
Open questions in tests (p. 25)					

Please add any missing components of the skill complex problem solving and critical thinking not included in the above table:

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Any comments or remarks:

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Appendix 3 - Meeting Summaries

Advancing STEM Excellence Skills –2nd Meeting Roundtable 5 July 2022

Participants:

Samuel Neaman Institute: Dr. Eli Eisenberg (lead), Prof. Arnon Bentur, Dr. Avigdor Zonnenshain, Inna Zertser, Tamar Dayan, Golan Tamir.

Ruchie Avital – interpreter English-Hebrew-English.

Ministry of Education: Naama Moshinsky, Dr. Gilmor Keshet-Maor, Shlomi Achnin

National Authority for Measurement and Evaluation in Education (RAMA): Dr. Hadas Gelbart.

Beit Berl Academic College: Prof. Linor Hadar, Prof. Aviva Klieger

Afeka Academic College of Engineering: Prof. Ami Moyal**,** Dr. Anat Ratnovsky**,** Dr. Irma Jan

JDC Israel: Sharon Fisher

IDF Behavioral Sciences Department: Lt. Col. (res.) Yair Noam

Henrietta Szold Institute: Dr. Tal Berger-Tikochinski

OECD, Deakin University: Prof. Russell Tytler

TIES (Teaching Institute for Excellence in STEM) USA: Jan Morrison

European Training Institute (ETF): Jolien van Uden

Jewish Federation of Cleveland: Oren Baratz

Bet She'an ECOSTEM: Ofer Ben-Shabbat

SFI (Social Finance Israel): Orly Rauch

Link to recording: https://youtu.be/-AhhYdgsi04

Opening remarks

Dr. Eli Eisenberg **–** I am excited to open the second roundtable meeting on advancing STEM Excellence Skills discussing Self learning and Lifelong learning competencies and skills.

We are trying to develop a common language, as far as possible, in respect to the characterization of the components of the selected competencies and skills, methodologies of teaching and learning and evaluation tools.

When we speak of a common language, it means that we need to agree on the skills, competencies, methodologies and assessment tools that we believe are essential components in the skills, and that they can be applied.

We all agree and understand that the quality of the teacher and lecturer and their experience are no less important than the adoption of a specific methodology. Here, too, we must try to reach a common language regarding the relevant methodologies out of the understanding that teachers will do their best. We are also aware that the learning and the experience of the learning environment needs to be tailored to the implementation of the skills, and perhaps at a later stage we will consider discussing this too.

Prof. Arnon Bentur – Would like to emphasize again the overall objectives of the round table initiative of the STEM excellence skills:

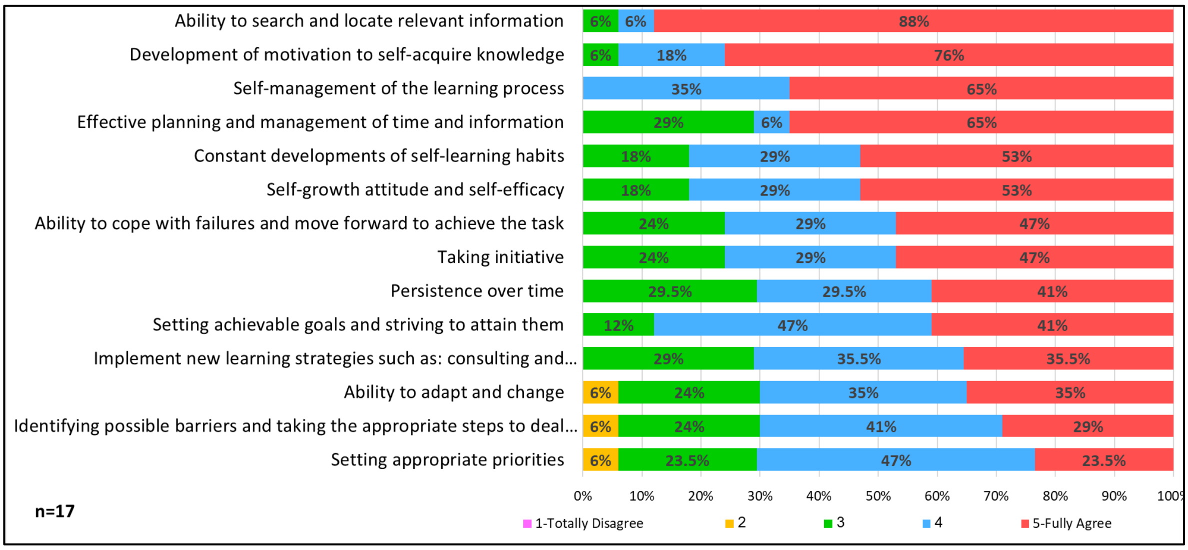
- To identify the components, methodologies and evaluation method upon which to focus.
- To resolve the needs for further in-depth characterization of the items which have been agreed upon.

There are many options to consider and it is important to prioritize – it is important to define the most important components.

The current meeting will focus on the competency of self-learning.

Part I: Components of self-learning

We have provided the background material and the results of a survey for the components which make up the competency of self-learning, identifying those upon which there is a general agreement with regard to priority, as outlined in the data regarding the level of agreement:



It can be seen that 87% agree on the component of the ability to search and locate relevant information.

76% agree on the development of motivation to self-acquire knowledge.

We also tried to determine a priority list based on a combination of the results of the survey (1-5) and standard deviation (indication of whether the consent is focused or diffused). 7 priorities selected according to the survey

- Ability to search and locate relevant information
- Development of motivation to self-acquire knowledge
- Self-management of the learning process
- Constant developments of self-learning habits
- Self-growth attitude and self-efficacy
- Effective planning and management of time and information
- Setting achievable goals and striving to attain them

2 points for discussion:

- Provide more components to self-learning or consolidate some in which there is overlap?
- There are some which are more emotional in nature – can they be readily acquired in school and if not, should we postpone addressing them to a later stage in our project?

Discussion

Prof. Linor Hadar would like to relate to:

- The ability to adapt and change
- Identifying possible barriers and taking the appropriate steps to deal with them

- Ability to cope with failures and move forward to achieve the task

I assume everyone is familiar with Carol Dweck's mindset theory.

A fixed mindset is a pattern of thinking whereby a person believes that their abilities are static and predetermined, that abilities such as intelligence and talent are fixed abilities that cannot be changed and developed.

A growth mindset is a pattern of thinking whereby a person believes that their abilities are dynamic and changeable, and that through effort and learning, basic abilities such as intelligence and talent can be developed and fostered.

The research demonstrates that people with a fixed mindset believe that they are unable to move forward and those with a growth mindset are able to contend with failures.

If we are talking about LLL and self-learning, we are aiming for a growth mindset. We want to encourage a growth mindset and these components are very important. That is why I ask to include them as well.

Prof. Russell Tytler – I support what Prof. Hadar said. I think the survey was a very interesting exercise and especially reading the responses. I was struck by one of the comments in the survey that talked about identifying three separate components: a skill set that relates to how we learn and search, attitudes and metacognition. Perhaps we need to think of it as a single composite skill.

In agreement with Prof. Hadar, it would be a mistake not to include the personality/attitude as a second priority – the development of optimism and persistence as part of the study, the development of strategy, interest and curiosity.

Dr. Tal Berger – We relate to the subject of growth mindset but also to grit (Angela Duckworth – *Grit: The Power of Passion and Perseverance*). And we include this as part of the evaluation studies we do. Two things that came up: We have here a fairly long list of various aspects. My approach in filling out the questionnaire was in terms of content. At the next stage, when we talk in terms of assessment and measurement, the question comes up as to whether the graduate needs to master all the components equally. Do we have key domains that we would like to rate higher and others that are "nice to have."

The question also arises as to how to relate to components that cross different skills and how to evaluate.

Sharon Fisher – I think we need to discuss the methodology:

How were these components selected, because we can take apart any skill and rebuild it in multiple ways? I suggest looking at the literature: Cambridge Life Competencies Framework and more.

We need to create a hierarchy because there's a mix of different types of skills and locuses. We found it useful to break down the components into components and factors. For example, self-learning and LLL are made up of cognitive aspects (metacognition, planning, breaking things down into information…), practical strategies and skills (searching for information, screening information, using the information effectively) additional factors are related to motivation (initiative, proactiveness, management), and factors related to the reflective aspect of the learning process, such as using feedback, assessment of knowledge, etc.

In addition, I see a mixture of aspects such as grit and self-efficacy, that once you break it down this way, there's a different way of looking at it. And that's my question of how to look at the list. The list is not conducive to understanding how something is constituted.

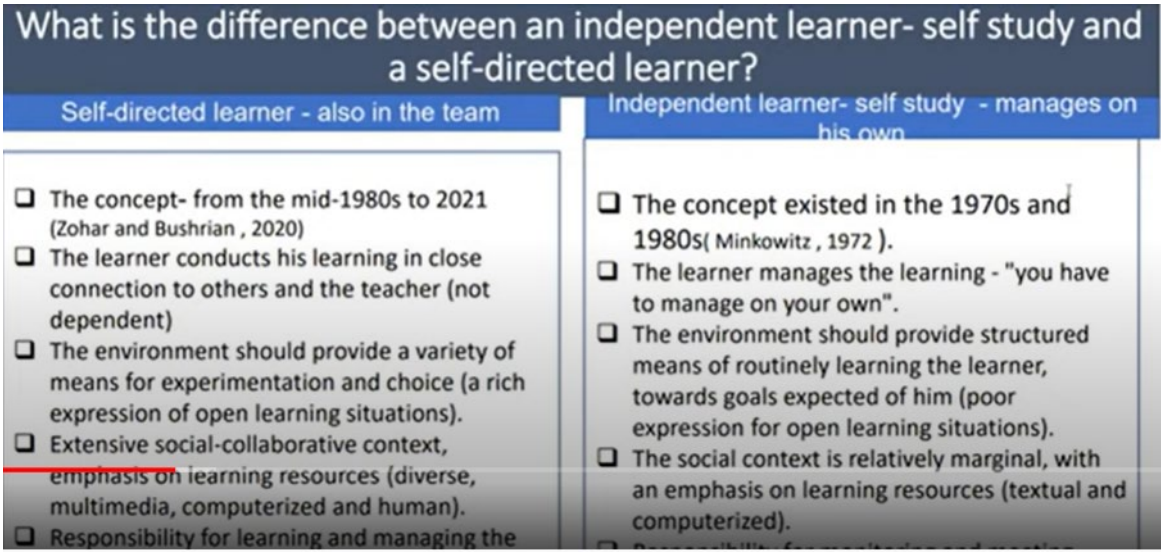
Sometimes you can find changes in very specific aspects of the learning process, for example breaking down information – that is a process that can be easily taught and assessed.

We have here a mix of issues!

Jolien van Uden – I wanted to reflect on the hierarchy of the survey results. Some of the components that scored lower are important. Such as self-growth attitude and self-efficacy is similar to the ability to cope with failures and move forward to achieve the task. However if you want to keep developing yourself it's also important to know what your resources are. I suggest adding self-reflection and metacognitive skills. This is an important skill if you want to keep developing yourself. One last comment is development of motivation to self-acquire knowledge. Is this something we need to develop or do we need to maintain it and how do we need to do that?

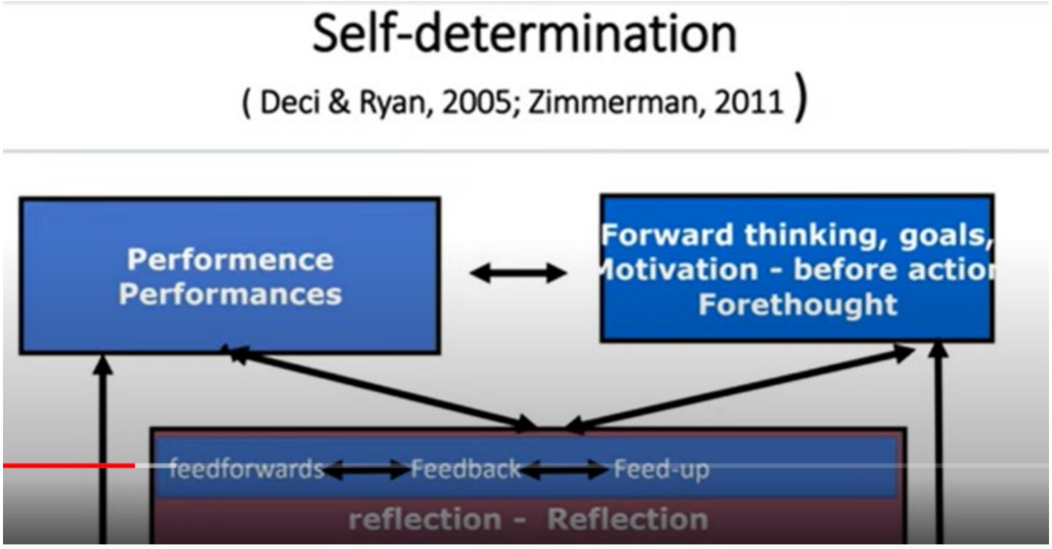
Prof. Arnon Bentur – I would like to relate to remarks by Prof. Haim Dotan, a member of the 21st Century Engineering Education Forum. He maintains that we are suppressing the motivation of our young people.

Prof. Aviva Klieger: I'm a little confused. Do we mean self-study (OECD) or self-directed learning (Ontario)? There's a difference.



It's important to use the correct term. All the components are more suited to self-directed learning.

In our view, we should divide up the components into forward thinking, performance and reflection and to note which is most important at each stage and then the hierarchy will change.



(The PowerPoint presentation was sent to Eli).

Dr. Gilmor Keshet: I agree with what has been said about the emotional side and the metacognitive skills. I believe that epistemic thinking is crucial for self-regulation (self-directed learning) because it's related to how to turn information into knowledge, evaluating the information.

Regarding the skills that were selected, I would like to point out critically that they are generic and not relevant to STEM. Scientific literacy is missing and solving engineering problems, which are relevant for self-learning in STEM.

Prof. Ami Moyal: I have a few comments. 1. We need to decide which skills we are advancing. 2. I personally distinguish between self-learning, which is basic learning, and lifelong learning, which is a broader ability and requires self-learning, but also the ability to cope with difficulties. 3. There are skills that are necessary in various competencies, for example coping with difficulties in both self-learning and teamwork.

I recommend finetuning the skills and defining three levels for each skill:

- Basic – without it you do not have the skill.
- Basic – nice to have
- High level.

This will allow us to finetune the discussion and then we'll be able to arrive at an agreed-upon textual definition for each of the levels.

Prof. Arnon Bentur: – I'd like to emphasize that at the first meeting, the approach of focusing on high-priority competencies was presented and adopted, based on preliminary work and surveys we and others conducted, including in the industry, and these were already presented in the first meeting in the slide below. It was agreed at that meeting that we would focus at this stage of the initiative on the first three competencies, and that later we would focus on others as well.

Prioritizing: Survey of Competencies and Skills

Competencies –Neaman and Technion Surveys and Studies	Related skills- Aharon Inst. High-Tech Industry Survey
Self-study / Lifelong learning; Metalearning skills	Self-study (84%)
Teamwork, cooperation and collaboration, interpersonal communication	Team-work (82%) Communication skills (88%)
Complex problem solving and critical thinking	Problem solving (93%) Critical thinking (83%)
Entrepreneurship creativity and innovation	Creative thinking (80%)
Adaptability/ Flexibility thinking/ Adjustment/ Agility, Compassion, emotional resilience	Motivation for tasks (84%) Openness & agility (83%)
Multicultural awareness, global competency; inclusion and empathy	
Responsibility, decisions making, ethical awareness/morality	

It should be noted that each of the competencies is in fact an entire world in of itself and difficult to define in a detailed and agreed upon way. These are aspects that are being investigated and that are discussed extensively in the research and academic literature. Our goal is to get started already at this stage so that we can give teachers and lecturers tools that will allow them to focus on the most important skills and to incorporate components that are agreed upon, and ways to instill them through teaching already at this stage.

To advance this goal we need an approach that allows for simplification!!!

Dr. Eli Eisenberg – I am happy to hear all the comments and clarifications, and it doesn't surprise me at all. After all, that's why we're holding the roundtable! We have examined extensive literature of research and surveys over three years and we found that there are components of one skill that are related to other skills. And the question is: Should we wait for the academy to reach a consensus (which could take years), or should we try to reach a consensus as to which components are must haves, that must be part of the skills, for example self-learning. We would like to reach a consensus and then try to expand and try to simplify. The counselor/instructor who will reach the teacher and lecturer will enable application in the classroom, and it is important that the language be simple and clear and tools that are easy to apply are presented. Every comment here is being recorded and will be discussed, for example the subject of coping with difficulty. We will also perhaps try to expand the survey to include a factor analysis. The objective is to move the discussion forward.

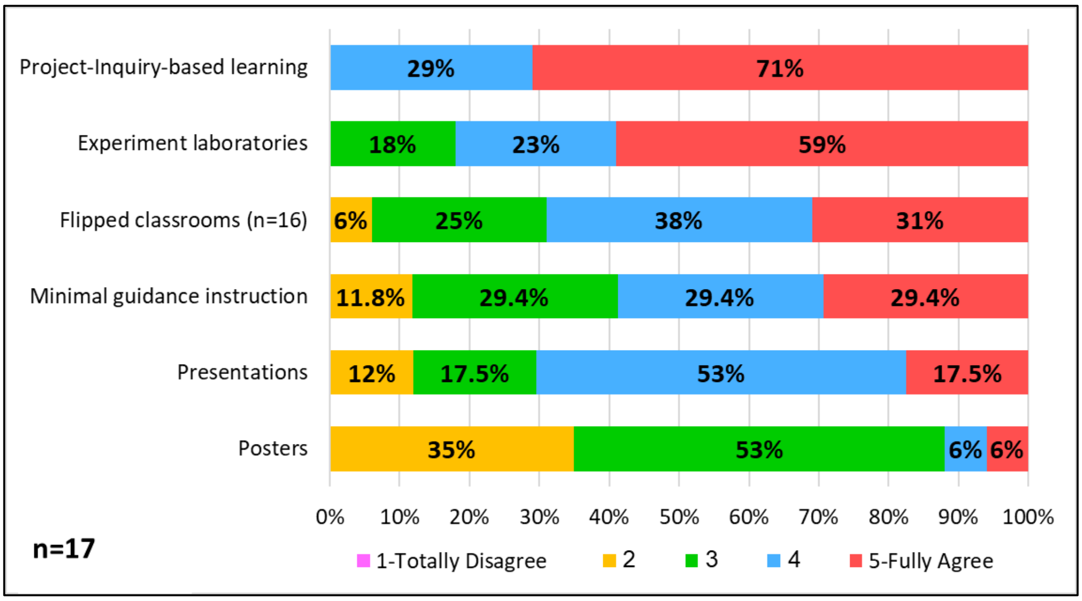
Dr. Gilmor Keshet – We are creating a set of skills that are not necessarily STEM.

Dr. Eli Eisenberg – I emphasize skills that **advance** STEM excellence.

Prof. Arnon Bentur – I'd like to point to a survey conducted among Technion graduates which shows that the most important skill they acquired in their undergraduate studies at the Technion was self-study.

Part II: Learning, teaching and experiencing methodologies

Dr. Eli Eisenberg – The results of the survey contain 6 components and we can see that Project-Inquiry-based learning scored high, with a very low standard deviation. Eli notes that he would add curiosity to Project-Inquiry-based learning. Surprisingly, experiment laboratories 'was chosen in second place. And the third is the flipped classroom – practicing information and knowledge acquired at home in the classroom.



There were a lot of comments about the quality of the teacher. Of course, this is important, but we would like to offer a natural methodology of teaching, which makes it possible to realize the acquisition of skills.

I'll quote some of the feedback, such as that it is important to distinguish between assessment and evaluation. The assessment should be part of the learning methodology. A feedback dialogue comes with questions and answers as in Talmudic study.

It's important to address teacher training. It is important not only to implement them but also to talk about them, conceptualize them, discuss them with the students, and say, "You have now improved in listening," "You were very good at identifying the information." That can significantly impact the success of instilling the skills in the student.

Discussion

Jan Morrison – It strikes me that there is important terminology here that may be missing: We talk a lot about argument and evidence. I think that the engagement of the student in their own education in their own formation of understanding of their own learning is critical. There's a difference between active learning, between the acquisition of learning and being a receptacle of information. I think when we're talking about the methodologies, the research is absolutely clear and is longitudinal on this. We have a tendency in STEM to reduce it to a methodology that we will call PBL, when we're actually speaking about dialectic and discourse. There's a logic in it – we're talking about dialectic and discourse, and these are very important terms to give the correct guidance to schools and those who develop methodologies.

In STEM, it is the construct that sets up the question, but it also is what values the argument and the evidence that is inextricably linked to that kind of lifelong self-learning. There has to be feedback, enjoyment and a sense of accomplishment. (Agrees with Prof. Tytler).

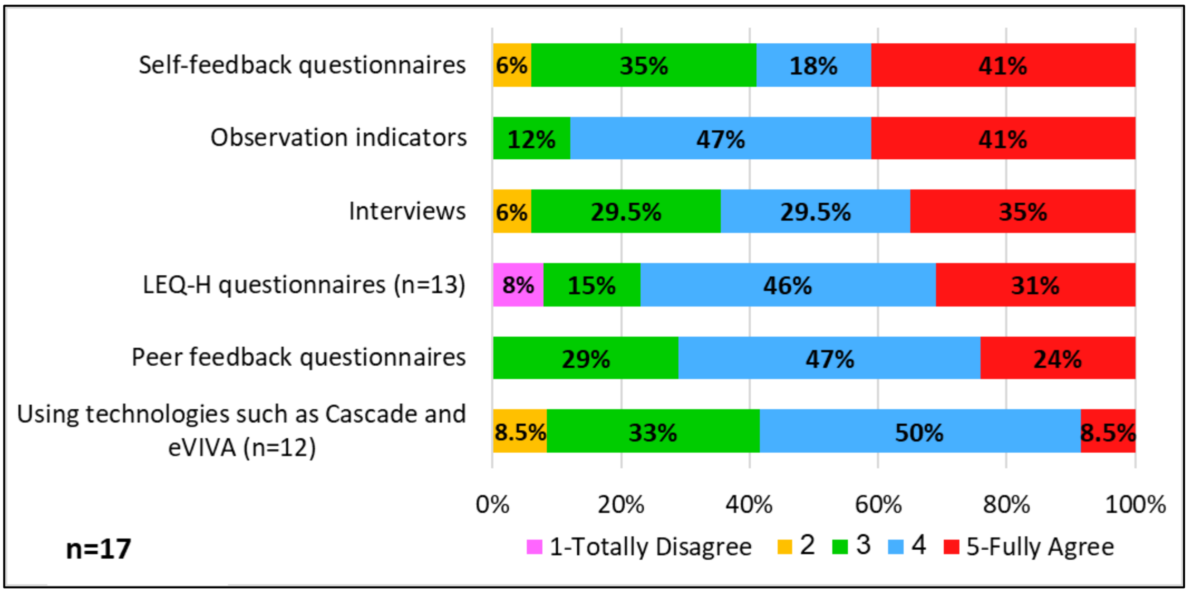
Dr. Eli Eisenberg – In Israel we learned a lot from the teachers, for example, regarding the attitude of the students to the demand to study at home or whether it should be done in class and then move on to work at home.

Prof. Russell Tytler – I support what Jan Morrison has said. it's absolutely essential that students have a chance to exercise that skill or capability. You can't allow untutored direction. There's tension between allowing autonomy and having guidance. It is a discourse issue and not a question of whether a student prepared a presentation or not, but what happens around that. The task has features that allow the student autonomy for inquiry and a possibility of dialogue where the teachers enable and support the process via the feedback and frames the task in supportive ways.

Part III: Evaluation and measurement tools

Dr. Eli Eisenberg – A general comment: In all studies and surveys, and in the implementation in the field, the students are asked, "How do you evaluate us?" Ultimately, assessment determines behavior. And if the teachers are assessed according to the acceptance conditions to the academy and achievements on standardized national tests, it will make implementation difficult over time if we don't address assessment tools too. It is important that the assessment be valid and reliable, and also fair.

Survey results:



Observation indicators: These were developed for the JDC's Skala program, in SFI, in the Ministry of Education's Pedagogical Administration, by inspectors and more.

Self-feedback questionnaires

Interviews – held by teachers or colleagues.

Comments noted – formative assessment, summative evaluation, which are tools that meet psychometric standards

Simulations and AI tools – EdTech. We can take advantage of technological tools that exist in medicine and the financial world and are not often employed in the education system. Technological assessment tools will allow us to do large-scale assessment.

The various assessment tools must meet the constraints of human resources, money and time.

Discussion

Sharon Fisher – The JDC has a series of self-reports that examine LLL, working with a task and with people. At the next stage, new methodologies will be included, such as:

- SJT – tests that examine judgment in specific situations (Situation Judgment Task). For example, you walked into a room and there is nowhere to sit.
- There is an option to create a group discussion in a zoom, to present a situation or problem and observe how it's resolved with the assessment focusing on the process.
- To create a type of learning modules which include both learning and assessment as you go, for example how you deal with multiple cultures.

Dr. Tal Berger – Skill assessment must be a continuous event and cannot be assessed with a single tool. It is an ongoing event that is measured at several different points. If we address the explicit acquisition of skills, assessment can be done during the learning/acquisition process itself (self-report).

This is true for the use of technology – it is difficult to disconnect the acquisition of the skill from its assessment, and I suggest measuring it at different points.

Jan Morrison – In the work we've done on the ground, the edtech community has provided excellent e-portfolios and digital portfolios. If the learning is a journey across the education system, where is it captured in the way in which the student presents? Can the student (and not just the teacher) document the process? Where does the culture change when the students pass through the various interface points where they shift from one part of the system to another from k-12 to the IDF to higher education? How can these capabilities be demonstrated? What we've seen is that the edtech world not only provides the simulations and some of the tools but the gathering of it too.

Dr. Eli Eisenberg – In your comments, please try to relate to national and international standardized tests.

Jolien van Uden –

- High-stakes evaluation. Do these tests hinder the development of these skills? Assessment steers your behavior and I'm asking if assessment could hinder the development of these skills.
- Skills that advance STEM – do we need to measure these skills or would there be a high-stake exam related to stem where they will have to show these skills that would determine and assess?
- The feedback dialogue could be a really useful tool to constantly reflect on what learners are doing.
- To what extent do we need these summative assessments or other assessments to support learners continuously to develop themselves?

Dr. Eli Eisenberg – In our pilot project, we emphasized that the interface is no less important than any of the links in the chain of education. How you go from one step to another throughout life.

Noam Yair – I am interested in what this roundtable will produce to obtain things that are practical for the IDF. In the army, at the stage of mandatory military service, there is a system that has been in place for 15 years that tests for skills such as information processing, teamwork, communication empathy. We are weaker at development and assessment. It is important for us to assess the recruits at the start of their service and we are now working on integrating soft skills in the military. We are not as good at developing people during their service.

In the situation of the career soldiers, those who sign on for continued service after their mandatory service, we are in the opposite situation. We do a lot to develop people and are weaker at measuring their abilities, with an emphasis on competencies, abilities and tendencies.

We are in the midst of a process of change. From the rank of Captain (about 24 years old), the soldier undergoes a battery of tests to acquire competencies for soft skills and the ability to make decisions, withstand pressure, independent learning and mental flexibility (people's development tools). The organization's desire is to develop a track for its people based on competencies rather than on the army's needs.

As for Yom Hamea (screening, identifying and matching day), we have a great deal of data collected for research and intervention.

Summary

Prof. Arnon Bentur – This has been a very enjoyable meeting and I have gained many insights on the various issues. On August 23, we will be holding our next meeting, very similar in structure to this one. The meeting will address teamwork and collaboration.

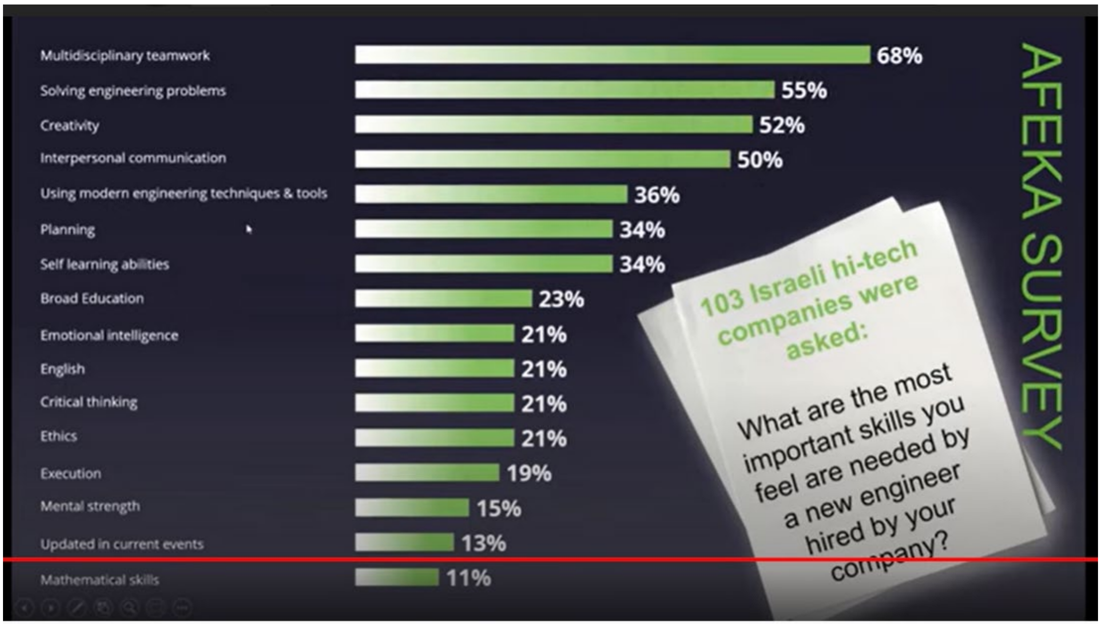
The issues for the next steps with regards to characterization and detailing:

- What is the right balance between setting up a very comprehensive and detailed account and on the other, we need to funnel it to teachers and lecturers and so that it will be helpful for them. We don't have to agree on everything.

- What steps are required to strengthen credibility and open the discussion to a larger number of people?

Prof. Ami Moyal – I am participating in this roundtable for the sake of the national and educational agenda.

I agree with what Prof. Bentur said about the survey and I am presented data from the survey of Afeka College.



The high-tech community in the perspective of different companies and of different sizes.

There are skills that everyone needs in the job market than an engineer needs to a greater extent. Afeka College has defined the profile of its graduate (I believe that every educational institution should do so). It was decided to focus on four basic competencies: effective communication, critical thinking, self-learning and teamwork. In the context of what Dr. Gilmor

Keshet noted, we have also developed engineering competencies and it may be necessary to develop STEM competencies, for example, problem solving, engineering design.

We are in the midst of this and it is a multi-year process.

Prof. Aviva Klieger – I suggest perhaps that regarding the next skill that we do our homework and everyone send what teamwork is. We will thus gain a broader and more interesting picture. What's missing is that it did not come from us and we are just reacting.

Ofer Ben Shabbat – I'm listening, learning, digesting. Next year, out project will start its pilot, and the question arises to what extent do we insist on precision and start out, or to work on it on the job.

Prof. Arnon Bentur – Both. As was said, we need to look at this as an ongoing process. We will try to come up with conclusions or guidance at the end of the process and at the same time collect additional data.

Dr. Avigdor Zonnenshain – It has been a very interesting meeting. Two things were mentioned.

- We can learn a lot from the IDF and I suggest that we continue in this direction.
- Artificial Intelligence – AI – there is a tendency to use AI for assessment and measurement. Perhaps we can also put in efforts to see how AI can be helpful for us.

Dr. Eli Eisenberg – I would like to thank everyone from the bottom of my heart. I appreciate all the time and effort you put in. We will discuss and consider all your comments and insights, which have been very helpful during the meeting. Our next meeting is scheduled for August 23.

Advancing STEM Excellence Skills –3rd Meeting Roundtable 23 August 2022

Participants:

Samuel Neaman Institute: Dr. Eli Eisenberg (lead), Prof. Arnon Bentur, Dr. Avigdor Zonnenshain, Inna Zertser, Tamar Dayan, Golan Tamir.

Ruchie Avital – interpreter English-Hebrew-English.

Ministry of Education: Dr. Gilmor Keshet-Maor

National Authority for Measurement and Evaluation in Education (RAMA): Dr. Hadas Gelbart.

Beit Berl Academic College: Prof. Aviva Klieger

Afeka Academic College of Engineering: Prof. Ami Moyal, Dr. Anat Ratnovsky, Dr. Irma Jan, Alon Barnea

JDC Israel: Sharon Fischer

IDF Behavioral Sciences Department: Lt. Col. (res.) Yair Noam

Henrietta Szold Institute: Dr. Rinat Itzaki

OECD, Deakin University: Prof. Russell Tytler

TIES (Teaching Institute for Excellence in STEM) USA: Jan Morrison

European Training Institute (ETF): Jolien van Uden

Jewish Federation of Cleveland: Oren Baratz

Bet She'an ECOSTEM: Ofer Ben-Shabbat

SFI (Social Finance Israel): Orly Rauch

National Institute for Testing and Evaluation (NITE): Dr. Tzur Karelitz

Rashi Foundation – Campus Gustave Leven – Beit Yatziv: Dr. Maya Lugassi-Ben Hamo

Technion – Dr. Olga Chuntonov, Dr. Keren Sagi

Link to recording: https://youtu.be/Zb3mNh7iSQg

Opening remarks

Dr. Eli Eisenberg **–** It is our pleasure to welcome you all to our third meeting of the skills' Roundtable and we appreciate your participation in the third meeting despite of summer holidays.

Listening and reading your remarks and comments, we are starting today with two presentations, one from Prof, Russell Tytler and the other from Sharon Fischer, and we will then continue with other presentations from others in the coming meetings to enrich and empower ourselves with the enormous expertise and experience you have gained on skills R&D and implementation.

I would like to reiterate again the main objectives of this Skills' Roundtable:

- To develop a common, agreed-upon and coherent language with respect to characterization of the inescapable components which make up the skills required for excellence in STEM.
- To develop a common language of teaching/learning/experiencing methodologies and evaluation tools for high school students and academic students during their first degree
- We all agree that we need to impart skills and competencies from early childhood, kindergarten, primary and secondary school, university and lifelong learning. But in this project, we will focus on high school and first-degree students.
- To set priorities and the basis of the importance and being teachable.

Prof. Arnon Bentur – Presenting the agenda

Subject	Time	Presentor
Opening remarks	14:30-14:35	**Eli Eizenberg**
assessment and evaluation methodologies and tools of skills	14:35-14:50	**Russell Tytler**
Discussion	14:50-15:00	
assessment and evaluation methodologies and tools of skills	15:00-15:15	**Sharon Fisher**
Discussion	15:15-15:25	
Definition: presentation & discussion	15:25-15:40	**Arnon Bentur**
Methodologies: presentation & discussion	15:40-15:55	**Eli Eizenberg**
Evaluation: presentation and discussion	15:55-16:10	**Arnon Bentur**
Summary	16:10-16:30	**Avigdor Zonnenshain**

Prof. Russell Tytler **Thoughts on the STEM skills of problem solving and collaborating** (a presentation is attached).

Some questions to consider:

1. What is the particular nature of these generic skills in relation to STEM?
5. To what extent are these "skills" separate from conceptual knowledge and conceptual learning?
6. Can these skills be reliably measured out of context?
7. How can teachers balance assessing and supporting these skills?
8. What is the role of classroom culture in supporting the development of these skills?

Prof. Tytler presented 3 case studies dealing with:

- Problem solving in relation to science: Science Inquiry Assessment
- Collaborative reasoning on a socio-scientific issue
- Collaborative problem solving in science with a creativity focus

In the case of Science Inquiry Assessment – a task was given to seven-year-olds to measure the length of a shadow (a measuring activity) and to ten-year- olds to design and analyze a study to compare different types of glue.

Some principles and issues

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Principles:

- The attempt to situate the task for teachers as an engaging activity illustrating learning principles as well as an assessment exemplar
- The balance between group and individual work, and between teacher guidance and teacher monitoring
- The tasks involved students in utilizing the multimodal discursive practices of science measure, data modeling such as tables and graphs, interpretive and explanatory text

Issues & reflections on trialing so far

- The difficulty for teachers in identifying the meaning of generic rubrics- the need to re-interpret for each task
- The challenge of keeping track of individual students
- Teachers showed some reluctance to use these tasks out of content area of their learning sequences
- Some teachers tended to wanted to modify to open the tasks up to exploration, to maximise engagement

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Discussion

Oren Baratz – Comment/elucidation: I'm very happy to see Prof. Tytler's presentation, which addressed primary school children as well, and not just high schoolers. I think that at some point, we're going to have to focus on primary school children too. It's important to start as early as possible.

Dr. Gilmor Keshet – The presentation was very interesting and in depth. It requires a lot of thought and provokes questions. I need time to think about it and delve into it more deeply. I would like to hear about the connection you see between skills involving the drawing of conclusions and epistemic thinking.

Prof. Russell Tytler – These skills should not be thought of as technical things that the student has absolutely, but they are always situated contextually. The measurement depends on the context and what we are measuring and how transportable it is.

Prof. Arnon Bentur – Regarding evaluation, do you have methodologies for training teachers in evaluation?

Prof. Russell Tytler – Some of the comments regarding teacher responses came from a workshop held 3 weeks ago, and it seems to me that further professional development is needed to enable the teachers to do this automatically. The goal is not only to measure and validate, but also to see how we can improve the teachers' understanding.

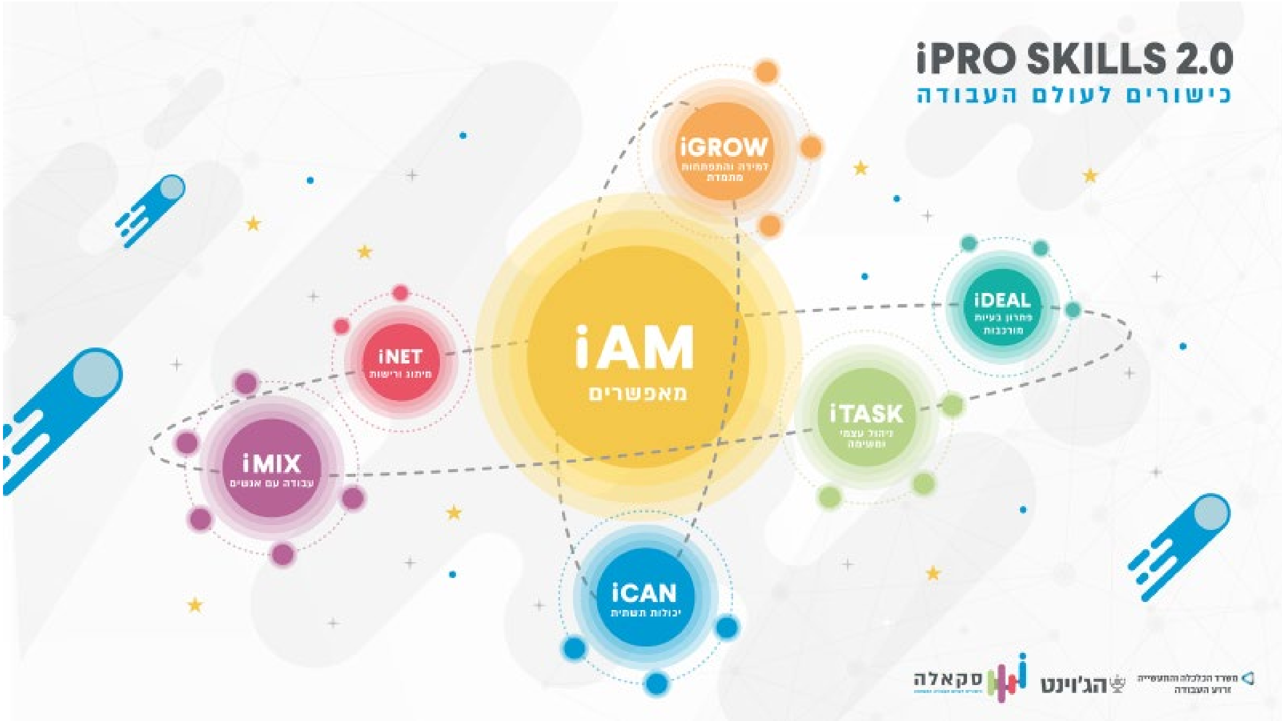
Regarding Dr. Gilmor Keshet's request, we have a paper on socio-scientific reasoning and there is a link to it in the PowerPoint. In the paper we don't talk about STEM skills per se. I draw the points out of it.

Prof. Aviva Klieger – There is a very nice connection here between justifications and presenting arguments, something that we are very weak on in the PISA tests, and the way in which this can be strengthened by means dialogue, discourse and teamwork. Perhaps we need to strengthen the discourse and teamwork in order to strengthen the skill of presenting justifications and arguments.

Dr. Gilmor Keshet – Relative to the other skills, we are good at justifications and raising arguments (not relative to other countries).

Sharon Fischer **Measuring 21st Century Skills SKALA Project** (a presentation is attached).

- The goal is to create a workforce with appropriate competencies, especially among underserved populations.
- The Skala program – We developed the iGROW model which is aimed at preparing workers for employment. We created a breakdown so that the skills can be translated into something useful.
- We are trying to create formats for pedagogy and measuring – trying to promote programs to train, develop and measure the various populations.
- We work with the education system, technological colleges and schools.
- The iPro questionnaire is made up of 23 items.



iPRO SKILLS 2.0
כישורים לעולם העבודה

iPRO2.0 Skills 2.0

I AM Enablers מאפשרים	Self-efficacy & growth mindset Resilience and GRIT Proactivity Motivation
I CAN Basic Skills יכולות תשתית	Digital Literacy Language Literacy Mathematical Literacy
I GROW Lifelong learning & Growth למידה והתפתחות מתמדת	Lifelong Learning Learning skills and strategies Reflection and assessment of learning

I TASK Self & Task Management ניהול עצמי ומשימה	Time management Task management Work-Life balance
I MIX Working with others עבודה עם אנשים	Interpersonal Communication Teamwork Empathy Multiculturalism
I NET Branding & Networking מיתוג ורישות	Personal Branding Networking
I DEAL Problem Solving פתרון בעיות מורכבות	Troubleshooting Decision Making Creative and innovative thinking Critical thinking

סקאלה הג'וינט

Further information can be found at https://www.skalaisrael.org (in Hebrew).

Discussion

Dr. Eli Eisenberg – How many schools and colleges have you tested? Have you found differences between the younger and older populations?

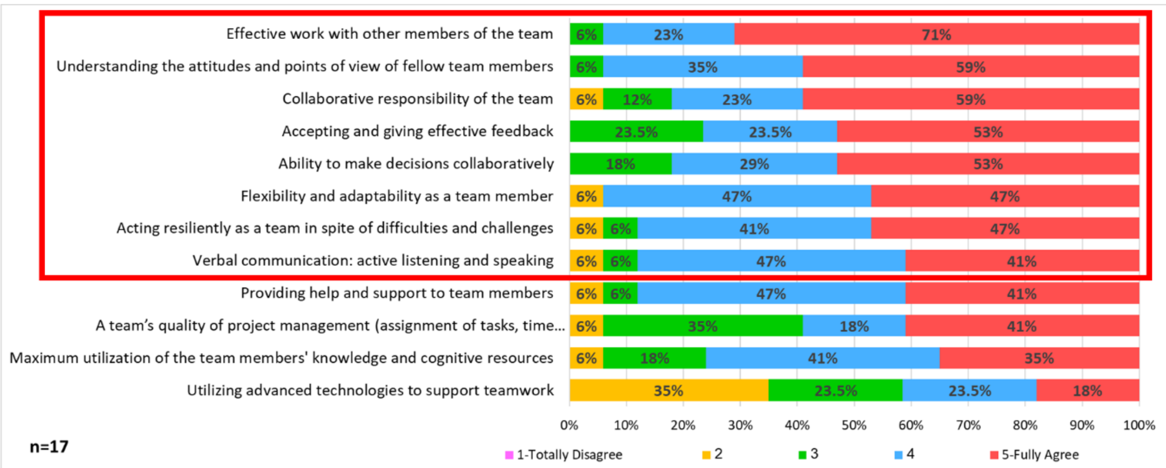
Sharon Fischer – The study is currently based on results from a representative survey of 17-70. The methodology and pedagogy are implemented using a variety of methods in technological colleges too, where the work is mainly TtT – Training the Trainers, how to impart the subject matter optimally, and that is what we are planning to do in schools. It will be starting in the middle of next year. I don’t know the scope.

Dr. Eli Eisenberg – Regarding Training the Trainers, can you present any preliminary insights?

Sharon Fischer – It is very important to be able to present the dimensions well, to place it in context and provide behavioral anchors. This is something that makes it practical and also enables pedagogical methods, when we found is that the emphasis is actually on decreasing frontal teaching, and diverse pedagogical methods are taught in order to implement the teaching, and this is done by means of the MAHAT project (colleges for technicians and junior engineers), members of the team and those not on the team in the field.

Prof. Arnon Bentur – **Components of Teamwork – Focus ranking**

We have provided the background material and the results of a survey for the components which make up the competency of teamwork, cooperation and collaboration, and interpersonal communication, identifying those upon which there is a general agreement with regard to priority, as outlined in the data regarding the level of agreement:



We want to draw your attention to the last item which received low priority grading (utilizing advanced technologies to support teamwork). Is it less important or is this the result of our not being aware of the various IT technologies?

In order to better understand the contribution made by technology, we may consider bringing in experts in the field who can present the developments in recent years, which have been very rapid and that we may not be aware of.

2 more points for discussion that came up from your remarks:

- Empowerment of the team vs. empowerment of the individual
- Supporting a team leader

Discussion

Oren Baratz – This teamwork is important and there's also a point of connection between teamwork and values.

Jolien van Uden –

- When I reviewed the various components, some were more on the level of teamwork and some were more on the individual level. The question is who needs to acquire each of the skills? Do they need to be formulated on the individual or team level?
- Resolving disputes is related to the subject of resilience, and that could be a very important part of teamwork – to allow different views and perspectives.
- To work with diverse team members with different backgrounds, ideas and opinions. Can team members deal with that?

Prof. Arnon Bentur – That is part of cultural behavior and I think it’s included in it: how one learns to hear and listen to different opinions.

Dr. Eli Eisenberg – I would like to talk about integrating evaluation technologies in the work of the team. Dr. Hadas Gelbart, Dr. Gilmor Keshet and I participated in a meeting with Dr. Yigal Rosen, who worked with the OECD on subjects related to PISA. When I asked him about evaluation of teamwork, he noted that the evaluation is of the individual, the individual within the group. It’s not evaluation of the group as a whole. They used advanced simulation technologies to evaluate the individual and with this tool, they evaluated the ability of the individual to participate in the group.

In our survey, the use of technologies received a low grade, both the on the subject of the components and evaluation. I would like to hear your views on the subject.

Dr. Gilmor Keshet – The special subject in PISA in 2018 was collaborative problem solving. It used a simulation style to evaluate the individual with a computer using avatars. My impression from the teachers who participated was that they did not feel that it properly simulated the ability to collaborate among the students. There is another example in the subject of biology that is part of the matriculation exams, and a grade is given to each of the students participating in a team effort, and the feeling is that this is more natural.

Prof. Russell Tytler – There is utilization of advanced technology to support teamwork. I was thinking of some digital means that supports teamwork.

Regarding the use of avatars – it’s a good way to work but I think of the complexity of the projects described before. It would be very hard to simulate a really natural environment because there are a lot of interpersonal factors involved. I think that we would only see part of the picture.

Dr. Hadas Gelbart – The evaluation simulations were very limited in terms of the simulative aspect and also in what they could offer comparing working in simulated groups to working in real groups. It’s “too clean.”

Oren Baratz – We are currently starting to work on the subject of simulations. We're at the start of teaching skills and there's also the evaluation and measurement, and work with the MSR Institute for Medical Simulation. The MSR (The National Center for Medical Simulation) Institute also works with teachers' colleges and is looking into the subject with them. We have a visit with them planned for early September to look into the matter, and anyone who wants to join us is welcome.

Dr. Eli Eisenberg – They are doing some very interesting work at MSR. They started with medicine and moved over to education. Real simulations using actors.

Prof. Arnon Bentur – I'd like to remind everyone that we're trying to focus on technologies that are mature and that are applicable, and that's different from subjects that have potential but require further development before we can recommend their implementation.

Jan Morrison – I agree with Prof. Bentur. There's an entire body of research that is two decades old from the aerospace and maritime communities that have been involved in simulation in education and evaluation supported by advanced technologies in the classroom on the level of post-graduate work throughout the English-speaking world.

I would like this group to be assured of what is actually there and what can be leveraged, and to get some insights on what has actually gone from research to practice.

Prof. Arnon Bentur – It would be nice to get some insights on the level of maturity of these technologies in order to know how to continue.

Jan Morrison – I'll send a list.

Dr. Eli Eisenberg – I'd like to raise another topic that emerged from the comments in the survey: engineering leadership, STEM leadership, is it necessary to develop leadership among the individuals in the groups? Should the role of leader be rotated among team members?

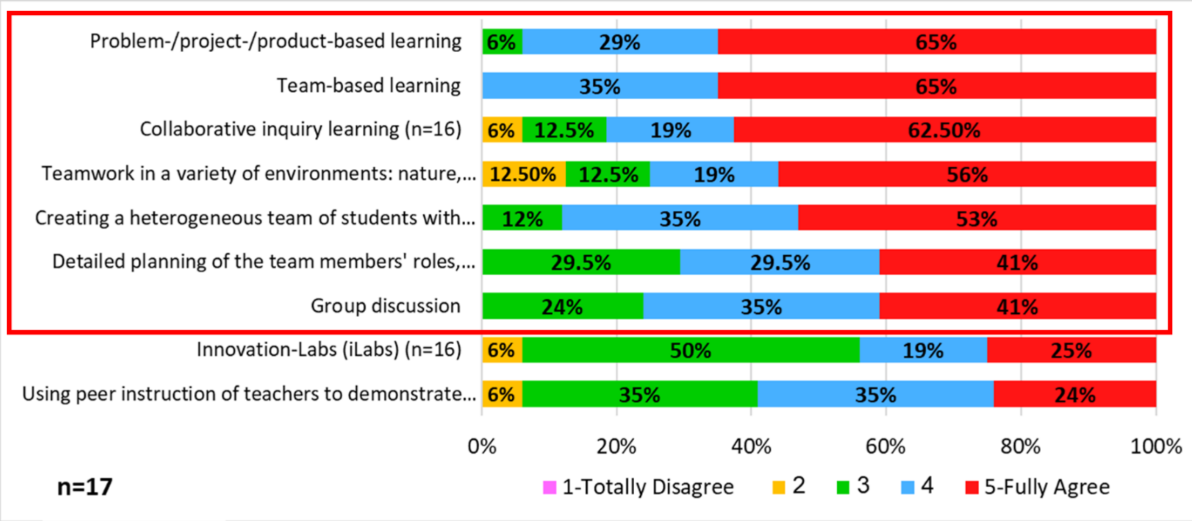
Prof. Aviva Klieger – It is clear that there should be rotation of the roles within the group. We did not address how to introduce explicit teaching of teamwork. We need to address the division of roles and we haven't discussed the recommended size of the group.

Dr. Avigdor Zonnenshain – There is a great deal of material on the makeup of the group and how it affects the work of the team. Also, on the subject of the group leader and how the leader is assisted by the members of the team.

Prof. Arnon Bentur – I agree and I think we'll need to focus more on that and also on the goal of the teamwork.

Dr. Eli Eisenberg – **Learning, teaching and experiencing methodologies: Focus ranking**

Which technologies appear most natural?



I would like to speak to the quality of the methodology: We all agree that the quality of the application is very important, but we still believe that product-/project-/problem-based learning is the most natural methodology for the application and impartation of the skill of teamwork.

I would also like to address the size of the group, as Prof. Aviva Klieger mentioned. What is the ideal size? In my opinion 2-6. Should the team be heterogeneous and is it the teacher's responsibility to determine the team members in accordance with their strengths? What about varying the learning environments (industry, work, nature – not just in the classroom)?

- Rules of engagement within the team
- Feedback by peers and moderators as a teaching and learning tool, not just for evaluation

Discussion

Dr. Gilmor Keshet – It depends on the context of the activity. There are activities in which each student performs a different role and together create a whole that is greater than its parts, and there are activities in which each member brings a different quality, and there is work that requires a homogeneous group. For example, a subject is studied together homogenously and the groups forms to solve a problem, and the solution is arrived at heterogeneously.

Example: a challenge involving risk management or a challenge related to health. In this area, experts in various areas are needed (engineering, biology, chemistry…). The subject is studied homogeneously and the problem is solved heterogeneously in the group. An example of learning in a homogeneous group is to allow outstanding students to learn together with other high-level students so that they can feel that they are advancing.

It needs to be tailored to the nature of the activities.

Dr. Eli Eisenberg – I am in favor of a heterogeneous group because one always learns more from the other, from those who are different, and the creativity is greater in heterogeneous groups.

Jolien van Uden – Do we always need heterogeneous groups? I think it depends on how you define it. It's important to introduce different views and it depends on how you define heterogeneous or homogeneous. For example, different levels of performance. Sometimes you want a similar group so that everyone can progress and still bring in different skills because everyone is different. It depends on the criterion of the roles in the group.

Regarding the methodology – there is the jigsaw methodology. Each team is responsible for a specific part of a large assignment. It's something that depends on the kind of assignment you want to achieve and how you define homogeneous or heterogeneous.

Prof. Aviva Klieger – There is no such thing as a homogeneous group. There can be homogeneity in the study of the same subject. I personally am in favor of heterogeneous groups. And if we're talking about training for employment, then the groups are heterogeneous.

The work method can be shared or collaborative. Shared is when everyone brings their own expertise and solves their part (jigsaw). Collaborative is like Wikipedia – Each member builds on the others and corrects. The decision whether to work using the shared or collaborative approach depends on the subject, the project – choosing the teaching methods for the teamwork.

Prof. Arnon Bentur – I would like to comment on the heterogeneity of age. Should we create groups consisting of different ages? We did this at the Technion in certain projects that were made up of teams with students from the second, third and fourth years and we continued over a number of years, so that the students continued in ongoing work teams, from year 2 to year 4. Over time, the younger students became the leaders. This is another aspect of heterogeneity that needs to be considered.

Oren Baratz – Regarding multi-age groups, I had some experience with this in the area of informal education in the Jewish community in St. Petersburg involving the joint study of Jewish texts in a heterogeneous group ranging from age 13-30.

Prof. Russell Tytler – Regarding heterogeneous and homogeneous groups, in primary schools, there is a lot of effort by teachers to set up a culture of within the classroom of respect for ideas and for others. The teachers not only form groups and give instructions, but also reinforce and model teamwork, and strengthen the ideas.

Dr. Eli Eisenberg – Modeling of the teamwork of teachers – I believe in peer teaching and when there is chemistry with the other teachers and collaborations, it can be fantastic.

Prof. Aviva Klieger – Regarding study in different environments outside the classroom, we send our students out to the chemical industry, and the project this year is to investigate STEM skills – which skills are needed in the industry. The work is done in pairs.

Dr. Eli Eisenberg – In a study, Prof. Andreas Schleicher described *havruta* study (traditional study in pairs) in a yeshiva as a teamwork skill in a yeshiva high school.

Prof. Arnon Bentur – When talking about learning or teaching in teams, we need to address the numerical ratio between teachers/instructors and pupils/students and whether the system can allocate enough teachers/instructors so that the ratio is reasonable? How many students per teacher?

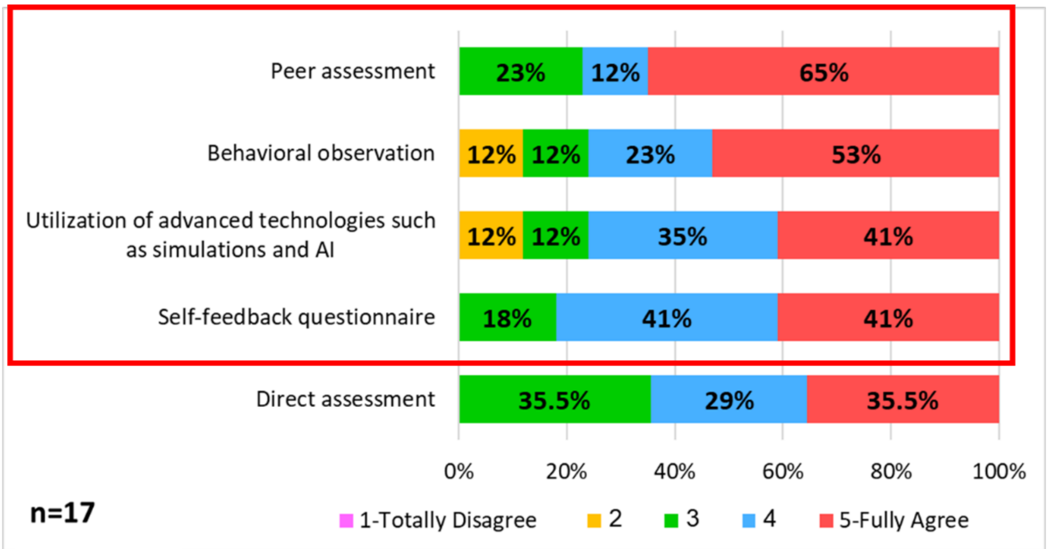
Dr. Eli Eisenberg – In teamwork, a teacher for every 20 students, and I think that two teachers for 40 students is preferable.

Comment from Prof. Tytler in the chat: When I talked of the complexity of the teamwork construct, I was really talking of the unusually high importance of context because we are talking of conceptual and also interpersonal factors. The construct is probably more robust in relation to particular coherent fields, such as engineering teams.

Prof. Arnon Bentur – **Evaluation and measuring tools: Focus ranking**

The results show on the one hand simplicity, few measuring tools, but on the other, there is no clear consensus regarding priorities, i.e., there is no agreement on evaluation methods.

How do we carry out the evaluation? It can be seen that all the methods are equally important.



Discussion questions:

- The importance of peer assessment
- Applying digital tools for assessment
- Peer assessment – Assessment or as part of the methodology?
- Direct assessment – What does this refer to?
- How can we apply digital tools and which digital tools are mature enough?

Dr. Eli Eisenberg – When reading the reports of those implementing the pilot project of the Samuel Neaman Institute on evaluation of teamwork, there is a discussion of how the students evaluated their fellow team members further to their self-assessment and the assessment by the teachers. In addition, one of the teachers compared the students' self-assessment to their own assessment of the students and found a good correlation between them. Do you have any experience with this?

Dr. Avigdor Zonnenshain – I have experience with this in the military, when we worked in groups and we had to give feedback and peer assessment. It was very valuable.

Yair Noam – I am not familiar with measurement of teamwork or group assessment, but once a year, all career soldiers do a peer assessment and sociometric assessment of commanders, and one of the metrics addresses interpersonal relations and teamwork. The evaluation of performance in a group is a very important metric, one of the most valid metrics we have. Peer assessment is done in short-term screening processes too.

We learn how to look at social networks as a very significant metric – it presents the connections in the group and its structure, how the team members were selected and who chose whom. This is a very powerful sociometric tool and it is used mainly to gain knowledge about the individual.

Prof. Aviva Klieger –

- Peer assessment is different in writing and orally and this should be taken into account.
- Based on our experience, our students gave themselves a higher assessment than the lecturer did.
- From the pilot, the impression is that the teachers took the evaluation form of the National Institute for Testing and Evaluation and worked on that form, and there was nothing there about how the student expressed themselves and it wasn't always suited to the situation in the classroom.

Jolien van Uden – When I looked at the assessment methods, I thought it also depends on whether it's a formative or a summative approach. I think that it all depends on continuously supporting the learning to work in teams. One can also think about a combination.

It wasn't clear to me what the difference is between behavioral assessment and observation or direct assessment. It is difficult to follow the whole teamwork process unless you have very short assignments where the team works for an hour, but with longer assignments it's very different to observe the process from beginning to end and see everything.

Regarding peer assessment, I think it's very interesting. It could be used to stimulate a dialogue on what to do next, what to do differently in different assignments or to invite learners to reflect on what they have been doing. This is in addition to peer assessment and the observation by the teacher. In a feedback discussion between the teacher and student or in the group, they can reflect on their behavior and ask questions about why the student did what they did, in order to emphasize their strengths. This is also true regarding evidence of the student's performance with an emphasis on strengths and feedback for weaker performance, facilitating a discussion on where they could act differently in the next situation.

Dr. Eli Eisenberg – I would like to note that Jolien always emphasizes the integration of assessment as part of the study process.

Dr. Rinat Yitzhaki – Peer assessment is a very strong and valid tool. And it is suitable for primary school age too. It is a tool for dialogue with the teacher about improvement. The team members know about themselves best.

Prof. Arnon Bentur – With regard to peer assessment, how should it be structured? I think that Prof. Aviva Klieger addressed this. Should it be in rubrics where someone sets up the criteria, or should it take shape as the result of brainstorming as part of a discussion by the team with the teacher before they start the work so that everyone understands what is expected of them? What form should the peer assessment process take?

Prof. Russell Tytler – The more I listen, the more I realize that this is a very complex and context-dependent skill. When I think about what makes someone an effective team member or not, perhaps it will depend on the conceptual skills they bring to the task and also on the interpersonal relations within the team (if there's some friction or tension between members).

We are talking about a certain type of personality – it could be very individual. The structure is very complex when we're talking about teamwork.

Dr. Eli Eisenberg – Some of the gifted students don't want to work in a group; they prefer to work on their own. What can a teacher do in a situation like this?

Jan Morrison – This is indeed a complex subject and what is the level of mastery we're talking about against the competencies? Eight years ago, the World Economic Forum polled the CEOs of multinationals and asked them what the reason was that they fired employees. 90% of them said that the main reason was that the employees were unable to work in teams, that they were lone rangers. Teamwork may not be a natural skill but it is one that should be developed. The skill of working collaboratively is a must even if you didn't come into the world with it.

Prof. Arnon Bentur – I would like to add that we all agree that evaluation is complex, but if we send a message to teachers and faculty members that it's complex, then no one will do anything with it because it's too complex and ambiguous. What is the compromise? There are tools that can be used. That is what we are trying to achieve: assessment tools for a complex and ambiguous situation.

Oren Baratz – The discussion of the subject of measurement and evaluation is an outstanding example of the principles that were defined at the beginning of the discussion. We want to base ourselves on existing tools but there will apparently be no alternative and we'll need to develop some too.

Jan Morrison – I agree with you fully. I think that lessons from the engineering process are really quite important. A number of countries have taken this very seriously already from kindergarten – particularly in PK-12 (Virtual Academy), where the engineering solution is clear, when the engineering process brings mastery on different levels of skills, whether as a formative or summative peer assessment. Even if done only partially, it's important. The complexity of the assessment is predictive and there's a nature to it. And when we're talking about the engineering design process, Afeka College is an excellent example of what the nature of learning should be.

Summary

Dr. Avigdor Zonnenshain – This has been a very interesting meeting and we got answers to questions that came up at the beginning of the meeting and that will enable us to write a better and more conclusive report on teamwork.

The skill of teamwork is important and crucial in all areas of life, and I feel that I received very important information regarding the components of the methodology and also about learning and teaching and experiencing teamwork.

Regarding assessment, we heard your comments and we have now information to summarize this skill and we also have some agreement in this very good forum.

Thank you to Prof. Tytler and Sharon Fischer for their very informative presentations.

Dr. Eli Eisenberg – We didn't discuss all the components of teamwork, for example global groups, especially now that we are facing real global problems, like the climate crisis. In the coming meetings, I would be happy if other roundtable members could contribute from their experience and expertise.

And at this opportunity, a special thanks to Tamar Dayan, Ruchie Avital and Golan Tamir, and thanks to all of you.

Oren Baratz – Beyond the subject under discussion, it is a rare pleasure to be part of this process.

Samuel Neaman Institute for National Policy Research

Advancing STEM Excellence Skills –4th Meeting Roundtable 8 November 2022

Participants:

Samuel Neaman Institute: Dr. Eli Eisenberg (lead), Prof. Arnon Bentur, Dr. Avigdor Zonnenshain, Inna Zertser, Tamar Dayan, Golan Tamir.

Ruchie Avital – Interpreter English-Hebrew-English

Beit Berl Academic College: Prof. Aviva Klieger Linor Hadar

Afeka Academic College of Engineering: Dr. Anat Ratnovsky

JDC Israel: Sharon Fisher

IDF Behavioral Sciences Department: Lt. Col. (res.) Yair Noam

OECD, Deakin University: Prof. Russell Tytler

European Training Institute (ETF): Jolien van Uden

Jewish Federation of Cleveland: Oren Baratz

SFI (Social Finance Israel): Orly Rauch

National Institute for Testing and Evaluation (NITE): Dr. Tzur Karelitz

Henrietta Szold Institute: Dr. Tal Berger-Tikochinski

Technion – Dr. Olga Chuntonov, Dr. Keren Sagi

Harvard medical school and PEAR center: Prof. Gil Noam

Link to recording: https://www.youtube.com/watch?v=t1jJPEDWlGM

Opening remarks

Dr. Eli Eisenberg **–** It is our pleasure to welcome you all to our fourth meeting of the skills' Round Table and appreciate your participation in the fourth meeting despite the summer holidays.

I would like to introduce a newcomer, Prof. Gil Noam, who is a very close collaborator with Jan Morrison on the STEM ecosystem and is focusing on assessment and data systems. Noam is a professor at Harvard medical school in the area of social, emotional and academic resilience and success, He founded a center called Partnership in Education and Resilience (PEAR). Prof. Noam's work is measurement development in the area of 21st century social and emotional skills, in the area of STEM learning.

I would like to start again, reminding us the Skills' Round Table objectives:

- To develop a common, agreed upon and coherent language, with respect to the characterization of the inescapable components which make up the skills required for excellence in STEM.
- To develop a common language of teaching/learning/experiencing methodologies and evaluation assessment and measuring tools for high school students and academic students during undergraduate degree.
- To set priorities and the basis of importance that are teachable, inescapable and generic must haves.

Prof. Arnon Bentur – presents the agenda

Presenter	Time	Subject
Eli Eisenberg	14:30-14:35	Opening remarks
Orly Rauch	14:35-15:00	Presentation and Q&A
Yair Noam	15:00-15:25	Presentation and Q&A
Arnon Bentur	15:25-15:45	Definition: presentation & discussion
Eli Eisenberg	15:45-16:00	Methodologies: presentation & discussion
Arnon Bentur	16:00-16:20	Evaluation: presentation & discussion
Avigdor Zonnenshain	16:20-16:30	Summary

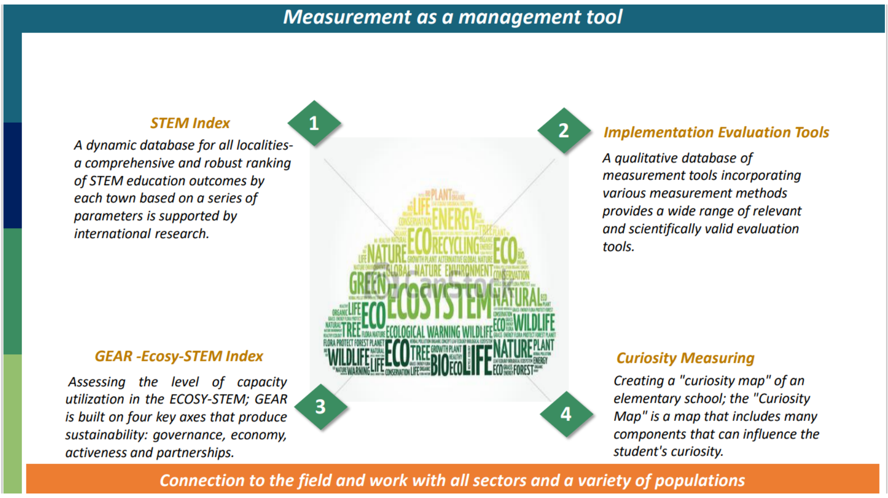
Orly Rauch – **Thoughts on the STEM skills of problem solving and collaborating Measurement and Evaluation STEM Project 2020-2022** (A presentation is attached)

Social Finance Israel (SFI) – is a non-profit organization that creates measurable change in people´s lives by deploying innovative financing tools to solve social challenges, all while developing the Impact Investment sector in Israel.

The long-term goal is to reduce gaps in STEM.

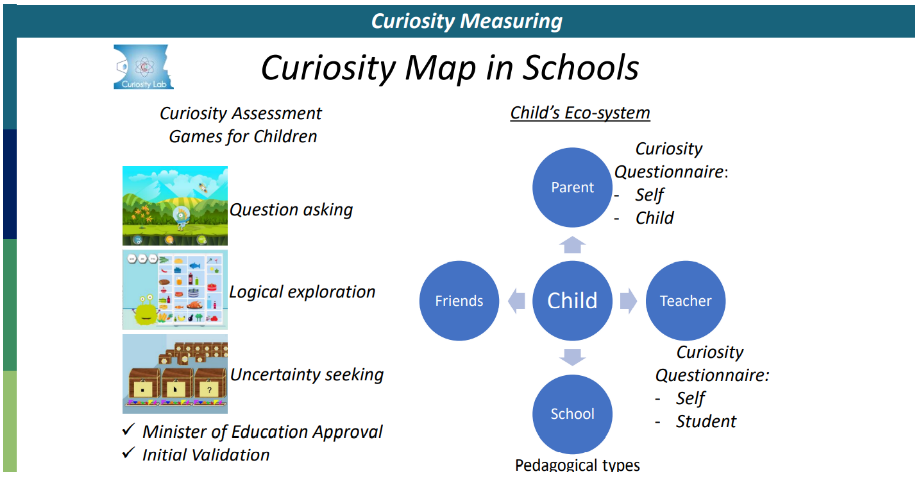
SFI believes that the correct way to be impactful is through measurement and evaluation, and thus it makes sure to use a variety of tools that aim to keep a finger on the pulse over time to make sure that we are moving in the desired direction. SFI has created a comprehensive database that makes it possible to track STEM studies in all communities in the country based on data received from students throughout the country, all across the educational continuum (from elementary to higher education), as part of a sophisticated index we call the STEM index. At the same time, 120 STEM-related tools have been developed. The tools are used to investigate the perceptions of the participants in the field, the implementation in programs that also operate on multiple target groups (students, teachers, school principals...). This provides the field coordinators in the communities with an accurate snapshot of the situation. This approach is based on the idea that every disadvantage is an opportunity for learning and improvement.

Measurement serves as a management tool in the project to help us know what to fix and what to improve.



GEAR-Ecosy-STEM Index- Helps localities advance – depending on their capabilities and resources – toward excellence in sustainability, efficiency, equality, and collaboration.

An example of a tool designed to test the measurement of students' curiosity via computer games:



We are currently at the pilot phase in a certain locality to see if we can also measure skills, in addition to assessing skills.

The challenges are to give an accurate picture of the situation, to obtain the balance point from a variety of assessment tools, to obtain an accurate picture of the situation and to understand that failure is an opportunity for improvement.

Discussion

Oren Baratz – Notes two additional subjects under development. 1. The issue of measurement rather than assessment of skills. We are currently at the pilot stages as well as other methods of developing skills. 2. Finding a correlation between the GEAR that measures the impact of the ecosystem and the national STEM index

Dr. Avigdor Zonnenshain – How does that affect the investments policy in the area of education? How does this affect the education system in practice?

Oren Baratz – We are currently working with the Ministry of Education and the Ministry of Science so that they adopt this tool to mediate decision-making. Mohana Fares of the Ministry of Education is connected to the tool and receives annual reports from 26 localities.

Prof. Linor Hadar –

1. How are the skills measured and how is it related to the context? Because it is very important to measure in context

9. What about transfer? Are these skills transferable? Is it possible to generalize? Do the students know how to use "critical thinking" in all areas of knowledge?

Orly Rauch – In the presentation, we demonstrated tools for teachers. We investigate the entire target population so that we can get a snapshot of the students, parents, teachers and more. Regarding the context, this year we will be starting a pilot related to developing skills in a scientific context.

To date, we have dealt with attitudes and perceptions towards STEM studies and their application. We checked whether there were disparities between the teachers' and students' responses. The teachers were more pessimistic than the students. It helps in the work plan because it makes it possible to know where to place the emphasis and what to improve.

Regarding the inclusion of the data, we are a learning community. When we see something that succeeds in one school, it makes it possible to copy and replicate it in other schools.

Prof. Linor Hadar – Thanks for the clarification regarding the difference between measuring attitudes rather than abilities, because this is a significant difference.

Orly Rauch – We have no information on the individual student.

Prof. Aviva Klieger – I understand that the impartation is per discipline and we are talking about integrative STEM.

Prof. Arnon Bentur – This is a major topic that should be dealt with and perhaps discussed at the next meeting.

Yair Noam – **Measurement of capabilities in the IDF** (a presentation in Hebrew is attached)

The purpose of the presentation is to describe what the IDF measures at the entry gate for service candidates (ages 16-17), how it measures and what the challenges are with an emphasis on what the IDF focuses on (remote diagnosis and assessment, supporting technology).

I represent the aspect of occupational psychology – all the areas related to diagnosis and matching abilities to the needs of the organization. I do not represent the discipline of placement.

The IDF understands that it is necessary to measure abilities and not just the a candidate’s generic qualities. The expectation of the individuals we meet today and the society that the army is part of is that there will be more transparency, speed, fairness, receipt of information and supporting technology.

We are moving from the IDF as a "black/closed box" to the IDF as a link in the chain of life: the education system-service-academy-industry.

That is why we investigate more capabilities and strive to reach a certification of capabilities at the exit gate and during career service. We are engaged in collecting functional information about the servicemen and servicewomen, such as abilities, inclinations, competencies and motives.

Upon entering the military system, the following are currently measured: aspects of adjustment and adaptation, aspects of thinking, aspects of interpersonal skills, performance and aspects of leadership and command (in civilian terms – management). Each individual is scored on a scale of 1-5 for each capability.

- We are trying to introduce the executive functions – mental flexibility, regulation and working memory, but this is not yet happening for technical and technological reasons.
- Regarding maintenance technicians (disassembly and assembly of parts), because the evaluation is done online, it is not possible to check actual performance capabilities.

- Measurement methods: multiple tools for measurements is the winning combination

Advantages of remote measurement: Suitable for emergency situations, efficiency and ease of use, the candidates feel less stress in relation to the on-site screening, and it can be done in smaller groups.

Neither the distributions nor the validity (predictive abilities) were different. Very effective, convenient and also less expensive.

The challenges: Does not simulate an IDF working environment, burnout and exposure of tools, technological difficulties, partial evaluative information, may highlight social gaps among populations.

Another issue – screening and technology. Many companies know how to measure advanced abilities in a friendlier fashion, such as mental flexibility (easier to measure using technological tools). We don't always know what we are measuring; the technology can affect the ability (for example, examinees reported headaches when using VR).

Discussion

Dr. Eli Eisenberg – Two comments:

1. We work with the army and also with the civilian national service (those who are not candidates for the IDF). There too the subject of entry and exit skills is very important and there is cooperation between the National Civic Service Authority and the JDC in this matter.

10. The army possesses vast knowledge and it is advisable for a civilian system to learn about what has been developed in the army. There are also collaborations on the subject of instruction.

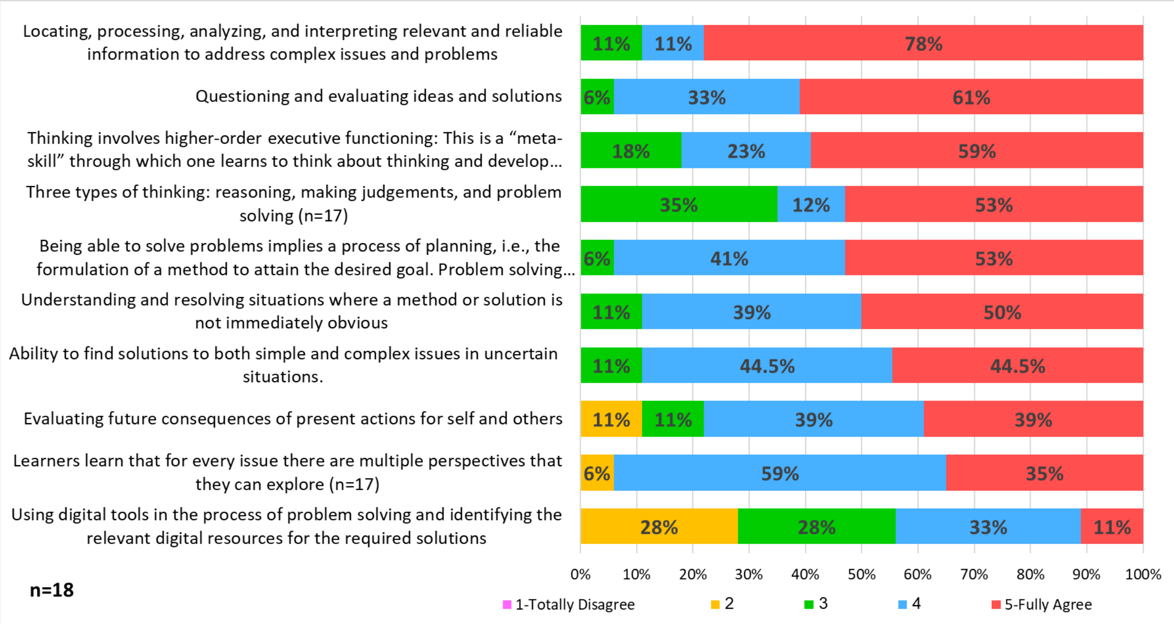
Sharon Fisher – Yair has presented the screening process in the IDF, which uses a special methodology: group simulations and experience in "real-life" situations. At the JDC, similar to the IDF, we want to assess and measure 21st-century skills.

The issue of problem solving – In the IDF, the focus was on cognitive work and the thinking about multiple technical tasks. We have not yet found a solution to drawing a distinction between intelligence and problem solving in a clear, applied and practical way.

Prof. Arnon Bentur – **Components of Problem solving – Focus ranking**

We have provided the background material and the results of a survey for the components that make up the competency of complex problem solving and critical thinking.

There are about ten definitions, but it can be seen that we agree with almost all of them. Is the multiplicity of definitions due to the use of different words that depict the same thing?



A number of comments that came up in the survey:

- Covered everything – indication of the many viewpoints; the survey shows that six were given more than 50%
- Missing the discipline specific nature of critical thinking and problem solving – transforming to other disciplines
- A mix between statements on what a student needs to be able to do and description/definitions of critical thinking – this was intentionally done in order to be practical
- In cases of problem solving it could also be interesting to look at "spotting opportunities" as conceptualized in EntreComp and DigComp

Discussion

Jolien van Uden – All the statements dealt with what the student needs to know to prove that he/she knows how to solve complex problems/think critically.

I prepared a short presentation of EU definitions (attached) on the elements of solving complex problems and critical thinking.

There are 8 central competencies and for some of them we have developed frameworks to show how the competencies are defined within these frameworks:

Critical thinking: LifeComp defines what you need to know how to do and everything with action words.

Critical thinking: GreenComp – This is more related to the context because it refers to problems of sustainability.

DigComp – Challenges of educational technologies. Identifying needs and the ability to use digital technology, creativity in the use of technology, finding gaps in digital competence. Because problem solving also deals with disparities.

EntreComp – A more indirect approach that can find, identify and exploit opportunities, using existing and new connections. Seeking out opportunities and combining knowledge and resources to solve problems.

Dr. Eli Eisenberg – I would like to hear a clarification from Prof. Tytler regarding the transfer of skills between different disciplines.

Prof. Russell Tytler – The point is that skill development is different in math and technology. Clearly, there is transfer and overlap in abilities, but characterization of things such as data processing and evaluating ideas has elements of knowledge and representational tools such as graphic and visual tools. If we're discussing STEM problems, is STEM different from other areas?

As for transferring to other disciplines, potentially for complex problem solving, we are familiar with this because we have students who tend to do this in multiple situations.

In conclusion, it has to be a mix of some elements that are more easily transferable than others.

Prof. Arnon Bentur – Regarding the definitions presented - are they different definitions for skills or essentially the same definition but using different wordings? What is meant when we talk about critical thinking?

Dr. Tzur Karelitz – It makes sense to use a single definition, but it is very difficult to reach a consensus among everyone. There needs to be compromise. Once there is a single definition of a structure according to which we are trying to teach and measure, we can define levels of mastery from novice to expert.

One of the reasons for different definitions is that each definition focuses on different things and at different levels.

To sum up, it is possible theoretically to reach a compromise on the structure and makeup, but then different stages of learning require the development of different levels of skills (with a focus on different things in school/academy). It is a solution of sorts to the different definitions because at each stage, the focus is on something slightly different, and as progress is made through the stage, the focus is on a higher or more improved level of skill.

Dr. Eli Eisenberg – In reference to Prof. Tytler's comments: The Technion encourages learning to contend with complex problem solving and the approach is that you can transfer from one discipline to another. This does not mean that if one is good at solving problems in STEM, one will be good at solving problems in social situations or in other humanistic areas.

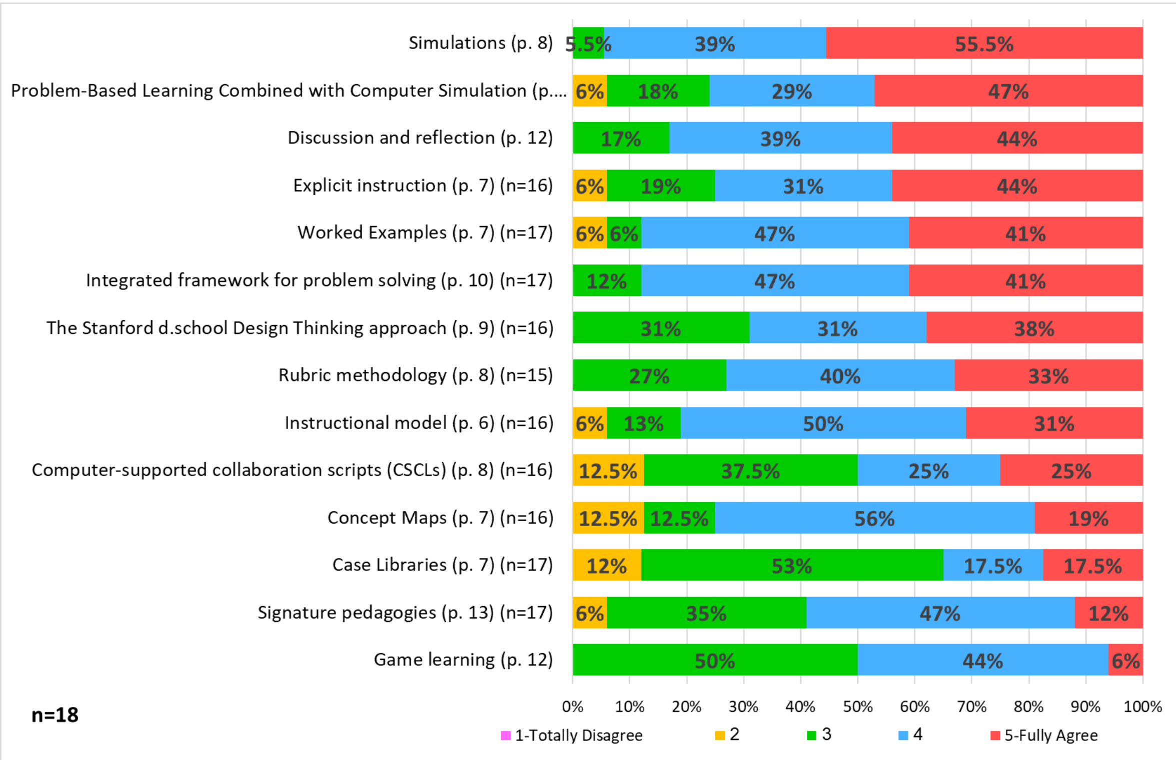
Jolien van Uden – I'm thinking about critical thinking in STEM, maybe we need to look for evidence, trials to see if it's correct or not. In history, for example, the approach is different. It is subjective to a certain extent. But the overall approach of critical thinking is identical.

In solving problems you always need specific knowledge and skills to solve the problem.

Prof. Gil Noam – One observation – Piaget distinguishes between content and structure in the world of cognition. There are differences, not especially dramatic, and there is always the issue between the content/domain and the thinking pattern. The content domain affects the use of skills and their development. That is why we need to see the connection between the two.

Dr. Eli Eisenberg – **Learning, teaching and experiencing methodologies: Focus ranking**

It can be seen that there is agreement on the first six, mainly there is broad agreement with regard to simulations and learning to solve problems with computer simulations. Discussion and reflection are also important but they are relevant to all cognitive skills.



Points for discussion:

- There are several methodologies of systems thinking, which can be helpful in problems solving and critical thinking, such as Systemigram. It is recommended to explore these methodologies of Dr. Robert Edison
- Design concepts:
  - An engineering design approach of having to develop alternatives and choose the best one.
  - Design thinking as a general approach not as Stanford d. design school.

- Design structured tasks that challenge and support students to critically apply disciplinary ideas and practices.

- The meaning of the instructional model – provides flexibility, depending on the nature of the skill and the instructor's competency
- Rubric for assessment and not as a methodology

Discussion

Dr. Avigdor Zonnenshain – I relate to Systemigram as an example of a tool and approach to systems thinking. The area of systems thinking is very important in engineering and systems management. There are several systems thinking methodologies and how to use them effectively in the implementation phase. This can also be used in the education system. I mentioned one visual system for how to approach the problem and how to analyze it from different aspects and understand what is more important, what the challenges in the problem are, what the gaps that we are trying to deal with are.

Dr. Eli Eisenberg – The process of complex problem solving is a planning/design tool for an engineer.

Prof. Aviva Klieger – I agree that we have not dealt with design and planning and have not looked at the concept of problem solving. This is a slide from a presentation by Prof. Ami Moyal.

It provides a depiction of engineering design for solving problems, and there are differences and commonalities with various disciplines.

I would like to also raise a discipline that has not yet been mentioned – mathematics. Mathematics uses the mathematical modeling method which is a teaching strategy that produces mathematical thinking and knowledge to solve real-life or authentic problems. There are numerous models for mathematical modeling. Prof. Klieger worked with students on the Blum & Niss model, which is a cyclical model. It starts like in engineering: with a real problem, understanding the problem and then illustrating it with a mathematical model. Mathematical data are extracted from the mathematical model and these are analyzed and validated in light of the real-life problem being analyzed.

I recommend a new article:

Kohen, Z., & Orenstein, D. (2021). Mathematical modeling of tech-related real-world problems for secondary school-level mathematics. Educational Studies in Mathematics, 107(1), 71-91.

Dr. Eli Eisenberg – Through mathematical modeling – from a practical problem to mathematical modeling, for example by solving a linear equation, this can be applied in different disciplines, for example Ohm's law in electricity, Hooke's law in mechanics and more.

Prof. Arnon Bentur – We have to keep in mind that there is an accompanying challenge to the model and this is information and data used for the model. One of the first stages to meet this challenge is searching for data, finding and evaluating data. What do you do when no data are available? This means one has to design with uncertainties. People often forget that to apply mathematical modeling, you need good data. That is a very important level in problem solving.

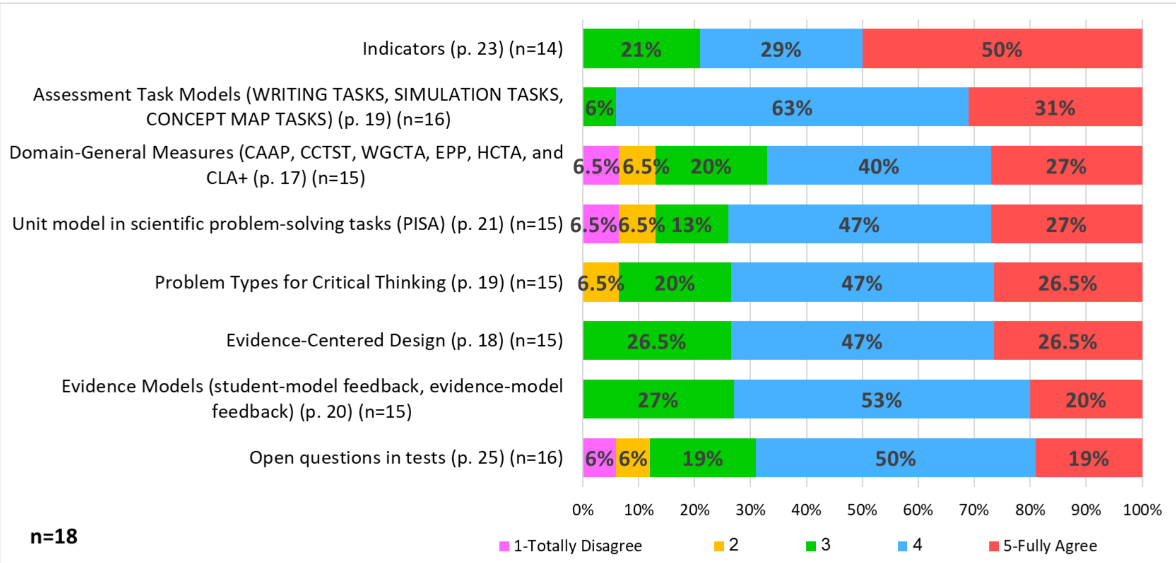
Dr. Eli Eisenberg – In reference to the previous comment, the meaning of the instructional model provides flexibility, depending on the nature of the skill and the instructor's competency.

The significance of a training model obviously depends on the nature of the skill and ability of the teacher/instructor.

Regarding the previous comment, the rubric for assessment and not as a methodology – teaching and assessment should be combined, because effective formative assessment improves learning and teaching.

Prof. Arnon Bentur – **Evaluation and measuring tools: Focus ranking**

This is an undefined situation and there is no single evaluation method that we all agree on. This is one of our challenges if we want to move forward in terms of assessment and measurement of competencies and skills.



Points for discussion:

- The concrete proposals here seem to look at problem solving and critical thinking almost without a context.
- Ask to report on the process – how did they analyze the problem? How did they come up with different solutions? How did they decide which solution is the best?
- Problem solving requires the engineering design process. It also requires measurement, not evaluation or assessment.
- It is recommended to use rubrics instead of indicators. Neither is an assessment method on its own; they only support the judgement of the assessor.
- These approaches all suffer to an extent from the assumption that critical thinking is a domain general skill. Disciplinary context should be a feature and the framing of critical thinking should be within the STEM disciplines.
- EdTech, such as AI.

Discussion

Jolien van Uden – In reference to the first and second comments:

Regarding asking to report on the process – in problem solving, it is an approach – if you look at the concrete tools that were given. It appeared to be a textual rather than thinking skill.

Regarding the recommendation to use rubrics instead of indicators – this is also related to the learning activities. The rubric itself only provides an indicator of sorts and rubrics are used to determine at which level the learner is. The rubric is not a methodology or means of evaluation in itself, but supports the assessment of the performance level of the learner.

Prof. Russell Tytler – There are different ways of looking at the world and understanding problems in order to solve them. There are different levels of specificity that can be learned in mathematics to solve problems, or one can think about the general structure of how engineers design solutions and how this can be applied in different design contexts. There are three levels in the assessment: If there is a creativity test in a particular area, one can think in different ways, but perhaps an intelligence level is actually being tested.

Dr. Eli Eisenberg – Perhaps the next meeting should be devoted to the subject of EdTech or technologies used in teaching. If we want to learn summative assessment and formative assessment, which are useful and effective in large numbers, we will have to use technological tools, such as the use of simulations.

For psychometric tests too, we need to dare and move forward in the direction of using educational technologies as well.

At the OECD, a think tank was established that deals with issues related to EdTech, with members representing companies, educational entities and experts.

Prof. Arnon Bentur – The topics that Dr. Isenberg raised in terms of evaluation are also important in terms of screening and admission to the academy too – not only for psychometrics and matriculation exams, but also for the testing of abilities in competencies and skills. It will be difficult to do this without technology that supports the evaluation of thousands of candidates in a short time. The same applies to the interface between schools and universities.

Oren Baratz – I would like to share the development of a pilot on the subject of developing skills and technology being carried out together with the Messer Institute in Israel. Work with the teaching faculty and the students. The Messer Institute specializes in the development of medical simulations (e.g., for potential medical students). The Messer Institute works with the Ministry of Education on the subject of simulations as part of the teacher training process.

Sharon Fisher – Problem solving is a skill that consists of many layers or is a hierarchy. We are talking about core abilities, such as intelligence, cognitive function, such as flexibility, generic abilities such as creativity, the ability to look at situations from different aspects and abilities specific to certain areas, such as mathematical reasoning as a tool for solving problems in STEM. There are different applications in different disciplines, and this can be taught not only in STEM. We need to decide where to focus the assessment. This ability must be broken down into multiple factors and components.

Prof. Arnon Bentur – In reference to Oren's remarks, the cost of a simulation for a medical student to test abilities and character traits is about $550. This means that the cost is too high to be practical.

Sharon Fisher – That is a very high price and there are less expensive ways to do it. It is advisable to check with Yair Noam to see what they are doing in the IDF.

Summary – Dr. Avigdor Zonnenshain

Today we addressed one of the most important and complex abilities. We have seen throughout the discussion, in every aspect, that this is not an easy competency, but it is clear to all of us that it is important in actually every field.

What emerged from Orly Rauch's survey from SFI on the STEM Index is that we need to learn how to use what was presented in measuring complex problem solving and critical thinking. Another important subject that was raised is measuring in context.

Yair Noam's presentation serves as inspiration for what can be done even in the case of large volumes of candidates. The virtual model enables the use of technological tools. We ought to learn how to use these tools to measure complex problem solving and critical thinking.

The issue raised by Prof. Aviva Klieger in the context of systems thinking, problem solving and critical thinking is that all are subjects for which it is necessary to create "good neighborly relations" between them.

All your comments are valuable and we will learn from then how to move on from here.

Dr. Eli Eisenberg – Thanks to Golan for his help and support, as well as to Tamar, Ruchie and all the participants.

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Samuel Neaman Institute for National Policy Research
Technion City, Haifa | +972-4-8292329 | info@neaman.org.il