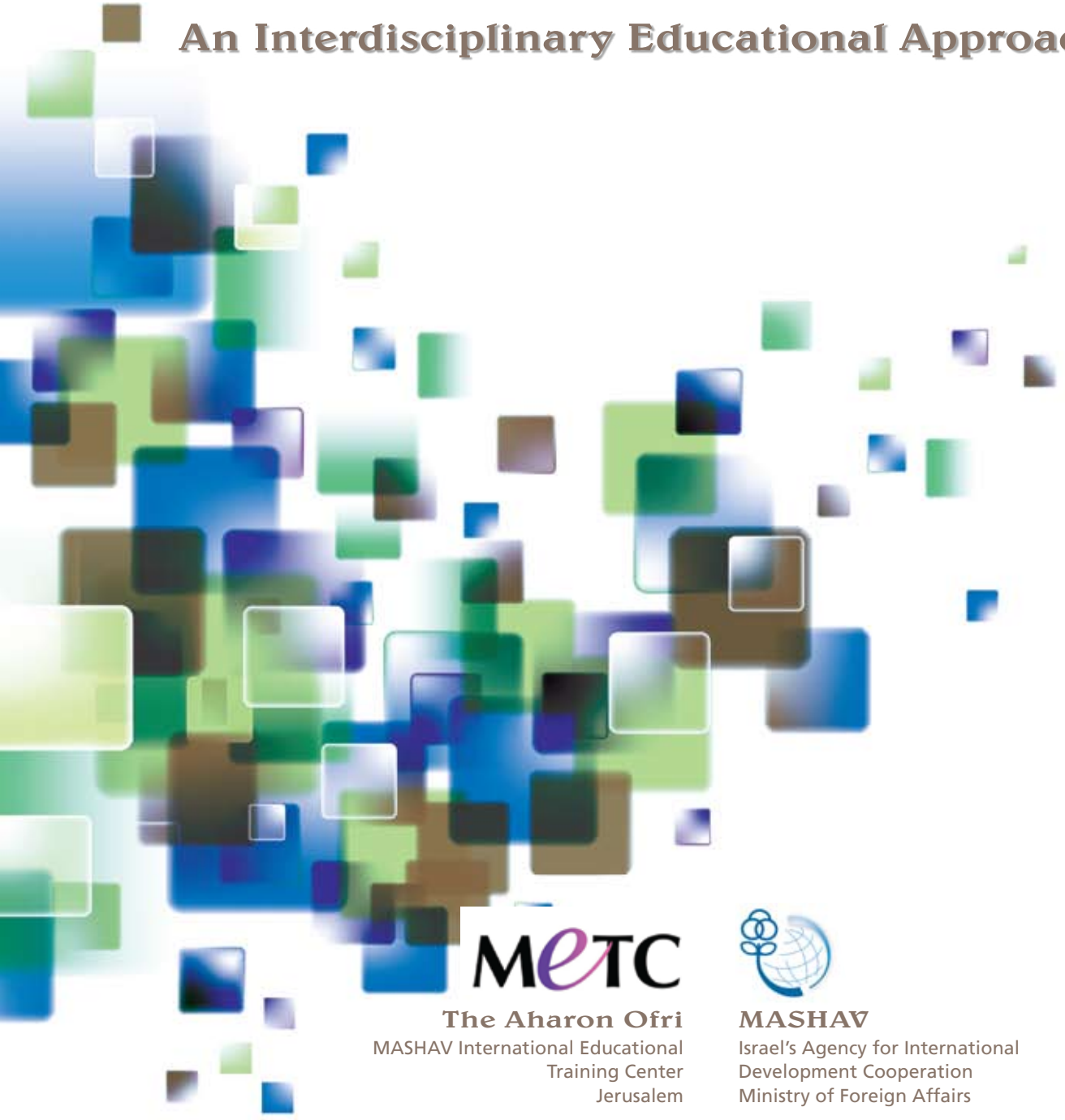
State of Israel

STEM
Science Technology Engineering & Mathematics
An Interdisciplinary Educational Approach



METC
The Aharon Ofri
MASHAV International Educational Training Center
Jerusalem

MASHAV
Israel's Agency for International Development Cooperation
Ministry of Foreign Affairs

Foreword

The A. Ofri International Educational Training Center (METC) was established in 1989 by MASHAV - Israel's Agency for International Development Cooperation, Ministry of Foreign Affairs. Since its establishment, METC has trained thousands of education professionals from all over the world, equipping them with the knowledge, expertise and experience cultivated over the course of the state of Israel's own development process, and shared by top experts in the fields of education and social development. Through the sharing of Israeli know-hows and expertise in these fields, METC invests in human resource enrichment and capacity building in order to contribute to global efforts to achieve social, economic, and environmental sustainable development.

The last decade ushered in changes in the way we understand education, and its relation to life and the environment around us. Upon primary education completion, a student often emerges from the education system facing a complex and integrative reality that does not necessarily reflect the one that he/she was exposed to in the classroom during school. As a result, it was imperative to find the means to bridge the gap between these two worlds by introducing educational practices that integrate the interdisciplinary aspects of life, and reflect the world that surrounds us.

The STEM approach, which integrates four separate academic disciplines – Science, Technology, Engineering and Mathematic – into one cohesive and holistic educational framework, is based on an understanding of the interdisciplinary aspects of life and real-world applications. These academic disciplines are therefore taught in an integrated and unified fashion, taking into account each student's background and experiences. Likewise, the STEM approach motivates and inspires students to learn according to the holistic approach and deepen their knowledge in each of these disciplines, as well as contribute to the development of life-skills, which are essential to cultivate in an ever-changing world. For both developed and developing countries alike, these academic disciplines are crucial for the ongoing progress of each of their societies and the future of their workforce

The aim of this booklet is to help fulfill MASHAV and METC's overall mission of sharing best practices and tools to overcome development challenges, and elicit sustainable transformation within each of their countries' own societies. As we believe that "sharing is inspiring," we chose to display six different educational approaches and models that were developed by Israeli experts from the public and private sectors, civil society/NGOs and academia in Israel. Each of the following articles offers a different perspective on the STEM approach, and together present the current status of this approach within the Israeli Education System.

REAL STEAM for Developing the Next Generation Problem Solvers

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The next position paper presents a proposal for a teachers' professional development program for teaching STEAM (Science Technology, Engineering, Art and Math) in junior high school. The developing team of this program come each from a different scientific discipline and with wide experience in developing teaching and learning programs for pre-service and in-service teachers.

Background: Our era is characterized by rapid development of information, science and technology, with a growing understanding that future citizens will be required to deal with complex challenges that require a holistic trans-disciplinary and interdisciplinary perspective. A central feature of this development is the emergence of new areas that combine traditional disciplines, for example: Bioinformatics, Biomimicry (also termed Biomimetics), Environment and sustainability, Nano-technology, Robotics. For learners, significant integration of the fundamental disciplines can be facilitated within frameworks such as these that enable them to experience engineering problem solving thinking, applied toward developing a product, based on understanding of the relevant scientific and mathematical principles and laws (Johnson, Peters-Burton, and Moore, 2015). Problem solving is a cognitive process, behavior, activity or set of activities that reduce the gap between a current situation and a desired one when there is no prepared procedure to find a solution (Baker & Mayer, 1999; Schon, 1983). The student-oriented process of developing a solution for a problem should be made similar to the process conducted in academia and industry, i.e., working in multi-disciplinary teams, where each member brings in expertise from his/her field, but also understands the potential and existing tools of other fields. Such a framework has better chances of enabling the construction of ground-breaking reach, creative, and innovative solutions. STEAM, as a learning domain, is inherently interdisciplinary and maintain links between these disciplines. Hence, it enables building close ties between issues learned at school and the real world. Teamwork based on the different skills and perspectives contributed by team-members benefit for enabling interdisciplinary innovation. While addressing complex societal challenges was traditionally seen as mainly the role of professionals in research, technology, industry and the market place, it is currently recognized that addressing such challenges is a built-in component of daily decision-making of all citizens. Active and responsible

science-informed decision-making on the part of citizens requires a better understanding of science and technology. This requires greater interaction among all key stake-holders – professionals, industry, enterprise, specialist and citizens. Education plays a crucial role since a central means in this transformation of society is bringing the research, innovation and technologies into the classroom (European Commission, 2015).
Furthermore, it is agreed that Art should be integrated within the STEM education since similar approaches are used in both science and art, for example: noticing, wondering, visualizing, exploring, communicating and being creative (Fulton and Simpson-Steele, 2016). Linking the arts (and humanities) with STEM, by bringing into the dialogue the artist and designer, expands the opportunities for experimentation and innovation. Meaningful education in today's world requires connecting between disciplines (areas of knowledge) and connecting with the community, since science and technology do not exist in isolation (European Union, 2015).

The rational for establishing a teachers' professional development program: One of the current challenges reported by the OECD is recruiting teachers in the areas of sciences, mathematics, Technology and ICT (OECD, 2005). Society's future depends on the quality of education, and the quality of education depends, largely, on the quality of the teachers – competent teachers with up-to-date skills and innovative ideas, capable of high quality teaching are central to education improvement (OECD, 2005). Hence, teacher education and professional development are important and necessary steps. Most teachers hold a degree in a particular discipline, while many of them did not complete their studies recently. Further, Math or Science teachers in middle and high schools frequently lack a knowledge foundation in Technology and Engineering, and with shortage experience in collaborative teamwork for developing a product. This program aspires that teachers experience the way nowadays research and development is conducted. This will contribute to relevant and meaningful teaching, by exposing their students to authentic challenges of society, different experiences, empowering the students' with skills and vision, and inspiring their innovative thinking and entrepreneurial approach. The teachers that graduate this program, will be equipped and motivated to function as leaders of change and will contribute to the advancement of interdisciplinary STEAM approach, utilizing the methodology taught in the program. The effect can be, for example: to encourage youth-led projects that integrate areas of science and technology in industry and academia; to develop activities for informal settings implementing innovative constructivist learning approaches; to conduct research in the areas of integrated STEAM using the skills vested in the program. (Literature around the world concerns the teacher role and their preparation. E.G. from the last year Bush, and Cook, 2016; Jho, Hong, and Song, 2016).

Guidelines for the program: Training will be based on the participants' knowledge of the major disciplinary in science, engineering and art. The learning process will implement the Project Base Learning (PBL) approach (Sanders, 2012), with an emphasis on the understanding of the disciplinary knowledge as a basis for understanding the integration between them. The projects will be carried out in heterogeneous teams of teachers with different disciplinary backgrounds where at least one member has an Engineering degree. Team work will promote critical and creative thinking, develop problem-solving skills and enhance collaborative working (all are highlighted by the OECD as Collaborative Problem Solving Skills (PISA 2015 - draft collaborative problem solving framework, 2013). Interdisciplinary knowledge and the possibility to apply it and develop cognitive skills and soft skills will be cultivated in three phases, all based on the PBL method:

(1) Analysis of existing multidisciplinary projects and innovation in industry and academia;

(2) Development of an integrated interdisciplinary project that applies engineering design processes in order to solve problem and/or design a product for a specific purpose;

(3) Development of an educational intervention to be implemented in formal or informal education settings. This stage aims to promote the implementation of teaching and learning **REAL STEAM**.

The professional development program will combine scientific and pedagogical content knowledge. The program will incorporate ethical aspects of science and technology to emphasize the relevance of this education for the citizens and the society in which we live.

Teachers have the ability to lead changes in society, education, industry, and labor market. The ultimate goal is to advance teachers that have this ability to make the necessary synthesis between the relevant areas in order to design solutions.

Program Highlights:

Integrated and relevant – The courses in the program will be related to the traditional disciplines, but from an interdisciplinary perspective of the disciplines as complementary in their contribution to achieving a meaningful solution to a given problem. This emphasizes the integration of art, technology and engineering design processes needed in STEAM and missing in most of the current programs (Sahin, and Top, 2015).

Project-Based Learning – A central organizing element is the application of Project Base Learning (PBL) in heterogenous teachers' groups. This framework of study enables authentic experiencing in context (Capraro, and Slough, 2013).

Updated methods of teaching and learning – The training methods implemented in the program will provide a modeling for future application at schools. For example: (*) The role of the teacher as a guide and facilitator of the learning process where dialogue with the learner is at the center; (*) Involvement and responsibility of learners regarding their own learning (engagement); (*) Long-term learning activities; (*) Focus on investigative processes, problem solving and critical and creative thinking; (*) Learning in teams while developing members' soft skills (for example, team work, giving and receiving feedback and time management).

Partnerships – The rationale of the program is to create partnerships with the academic world, the industry, schools, informal educational institutions and local authorities. Emphasis will be placed on developing meaningful projects to serve the large community.

In Israel, different STEAM curricula for middle and high schools exist but there is a lack of teachers qualified to teach in these programs. The proposed STEAM program aims to fill this gap by developing teachers that have previous teaching experience, and are open-minded and ready to address the current challenge of educating and empowering students who are motivated and equipped for active engagement in social-scientific challenges of their lives. We believe that the responsibility for educating the next generation lies not just on the shoulders of the education system. Industry and the academy are responsible as well. We trust that there will be no obstacles in recruiting those communities into the process of educating the teachers of the Next Generation STEAM Problem Solvers.

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The ORT iSTEAM Programme

The ORT Israel network of schools is currently developing and piloting a new Project Based Learning (PBL) curriculum based on Innovation, Science, Technology, Engineering, Art and Mathematics (hence i-STEAM). The purpose of the ORT iSTEAM programme is to empower young students with the essential knowledge, skills and values needed for living in the 21st century. The project is a radical innovation of R&D based on robust experimental field studies. One of the novelties of the programme is the integration of the ARTS within STEM education, providing the tools to harmoniously engage with technology and improve the creativity and aesthetics of engineering solutions. In addition, integral to the iSTEAM programme are issues of sustainability, ethics, responsible citizenship and commitment to the community.

iSTEAM: Moving beyond the era of disciplines....

Our current era consists of a complex and rich world of diverse and highly accessible information. New tools and complex communication systems allow us to effortlessly transverse space and time. The aspects of such a plethora of knowledge, communication channel and options affects all aspects of human life. Among others, it also poses challenges and raises critical questions about the existing learning culture and the relevance of the education system for future life and careers. The new information era urges a shift from an organized disciplinary approach governed by absolute knowledge to imparting of complex, multidisciplinary and changing knowledge.

In recent decades, the need for transition from a closed and disciplinary curriculum to a developing dynamic curriculum and flexible learning environment is increasing. Unlike the disciplinary approach, an integrated multidisciplinary approach require to develop learning processes that explore the different areas of life skills and encourage creativity and expression of a wide array of contexts. At the heart of this new approach is the belief that the epistemological knowledge of a discipline alone does not enable an individual to represent the transformations, changes and creative outcomes that occur in a meaningful learning process, and that exclusive reliance on a discipline is seen as artificial and restrictive. As part of a global paradigm shift in education, a new national curriculum with an emphasis on deep and meaningful learning has been introduced in Israel in 2014. The core of this programme focuses on adapting education to the 21st century with a greater focus on skills. In response to this new curriculum, ORT Israel developed the unique iSTEAM curriculum, based on multi-disciplinary learning processes. The iSTEAM initiative was created to respond to the skills today's students

will need when facing future prospects. Growing up in a fast-paced, highly technological world, students need to develop a wide set of skills including the ability to think critically and creatively, work collaboratively within a team, integrate knowledge from different sources and different disciplines, and develop articulated metacognitive abilities.

The iSTEAM (Innovation, Science, Technology, Engineering, Art, and Mathematics) programme is an example of an innovative educational approach that includes the perspectives of different disciplines merged together. The programme aims to bridge the gap between knowledge acquired in school and that of the 'real' world. The programmes graduates poses an arsenal of skills and tools appropriate to the flexible, dynamic lifestyle of a complex, diverse and ever-changing world.

The innovative iSTEAM pedagogy stresses 21st century skills as defined by PISA, using a wide variety of teaching techniques which provide a thorough understanding of useful performances and behaviours in the real and virtual worlds. It is also a lab for learning to deal with management and leadership opportunities and challenges.

The iSTEAM roadmap for adopting these ideas is laid out through PBL (Project Based Learning) techniques. The use of ICT (Information and Communications Technology – or Technologies) and collaborative learning improves readiness of young people for the social skills needed in the real world and future world of career and work. In the iSTEAM programme, ICT serves as a platform for any collaborative communication. For example, over the course of the programme students use infographics to present their products, collaborative tools to engage group challenges, etc.

Following are the guiding principles of the iSTEAM programme, as defined by its Steering Committee:

- Obscuring the boundaries between school disciplines, while strengthening disciplinary and interdisciplinary teaching and learning.
- Restructuring of school schedules as to accommodate the iSTEAM model of multidisciplinary, PBL and ICT components to become a sound foundation for the pedagogical and social activities in school.
- Establishing a school-wide learning process that combines meaningful project-based learning with an emphasis on innovation and entrepreneurship.
- Incorporating principles of alternative assessment such as project portfolios and presentations.
- Implementing educational work processes based on ICT technologies and encouraging collaborative work processes with a variety of digital tools.
- Deepening linguistic literacy by developing a cross-disciplinary vocabulary. The iSTEAM model serves well the principal of deepening the linguistic literacy, as well as deepening other literacies.

The iSTEAM learning approach allows for an overview of the areas of science and engineering with different depths of knowledge in the field. This type of learning develops a broad perspective on science and engineering disciplines, on product design processes and a holistic approach.

iSTEAM in action

Activating this innovative programme needs a special preparation phase in school. The following aspects have to be considered:

- Developing a school model based on deep learning of the iSTEAM disciplines.
- Setting up a new school subject which focuses on the interface between several traditional disciplines.
- Focus on processes. It is important that an emphasis is placed not only on the end product but also on active skills such as teamwork, research and development, problem analysis and presentation of ideas to the public.
- Placing an emphasis on developing positive affective factors such as motivation, self-efficacy and emotional involvement.
- Teacher training with an emphasis on process expertise must be as a preliminary stage for introducing the programme to schools. This means paying special attention to the major agents of change, namely the teachers. In order to understand and adopt the iSTEAM PBL method teachers need to be trained by doing. Thus teachers experience the programme first-hand (i.e. teacher as a student). Teachers thus go through the process of building their own iSTEAM product just as their students would.

The programme will promote students to expand their intellect and skills in areas including inquiry, research, critical thinking, problem defining and solving, team work, presentation, time and resource management and financial literacy. The iSTEAMORT programme fosters innovation, the start-up culture, career education, Hi-Tech economy and social inclusion.

Thoughts About STEM

Oved Kedem , Ph.D

"Whenever *a theory appears to you as the only possible one, take this as a sign that you have neither understood the theory nor the problem which it was intended to solve."*

Karl R. Popper

STEM is the newest trend of the educational system in the USA. And therefore, it is expected that most countries in the American-influenced world would adopt it.

STEM is the newest trend, but not the first one. Since the 1960's researchers and educators developed several programs and systems, which in turn were financed, applied and… eventually cancelled. With these programs and systems came kits, tools, books, software, sensors, etc. All of which were designed, produced, and purchased by states, and schools… and abandoned a few years later.[1]

According to the Occupational Outlook1 Quarterly "STEM workers use their knowledge of science, technology, engineering or math in order to try to understand how the world works and to solve problems."

Are the components of STEM important? Of course, they are. But for who? Let's make a parallelization between STEM and musical education.

Nobody, I believe, will deny that musical education for all is important and necessary in order to empower students and explore their personalities and sensibilities. In the same way the themes of STEM may serve to empower all students and explore their personalities.

But almost nobody would declare that the k-12 educational system has to aim to a formation of professional composers and musical performers! In most cases, students with musical talent and motivation will be educated after school in private lessons, conservatories, or in special schools dedicated to it.

Applying a similar approach to STEM, the k-12 educational system does not have to orient itself to a formation of professional scientists, technicians, engineers and mathematicians. Students with STEM talents and motivations, could and should be educated after school in "STEM Centers" or in special schools dedicated to it.

Taking another angle, the argument of channeling children to professions needed by the national economy, transforms students into tools for the economy, and distorts the deep meaning of education, or in the words of John Dewey:

"Education is not preparation for life; education is life itself. Education, therefore, is a process of living and not a preparation for future living."[2]

I am not against providing students with knowledge, skills and methods which are the basis of STEM, but this has to be done in flexible contexts, linked to the needs and interest of students as well as the conditions, possibilities and limitations of the teachers and schools.

Integrative approaches are a great idea, but they have to be truly integrative and not forced. For example, implementation of multidisciplinary programs in primary and middle schools about themes like toys or musical instruments, would probably be closer to the students' lives. Therefore they might be more relevant and motivational to the vast majority of students than courses about computer sciences or biotechnology.

Another consideration rarely taken by trendy curriculum designers is that each country and every region has its own characteristics and needs. Therefore, curricula designed for the San Francisco area, such as Robotics, would probably not fit the needs of students in an African or Latino American country

Another crucial issue for STEM is teacher training. There are many declarations, and very few concrete and research based programs which discuss how to go about it

In my experience and opinion, the key to resolve this issue is by team teaching. On the one hand, no single teacher could ever provide all the necessary contents and skills. On the other hand, a group of disciplinary teachers is not a multidisciplinary teaching team. They have to be trained to work as a team by going through and experiencing multidisciplinary activities and by tailoring programs which fit their school environments. In this endeavor, they would also learn to collaborate with teachers of other disciplines i.e. History, Arts, Language, Social Sciences, etc.

A dogmatic, inflexible, standardized (one size fits all) STEM program, will not help students, teachers and schools, and like previous trends in education, it will also fail. In order to survive and succeed, a clever, flexible, dynamic and evolutionary toolbox has to be developed. To my understanding, the educational and research establishment is yet to confront this challenge.

Education is a means for people to help people to grow and realize themselves and not a place where we teach STEM.

Let me finalize the subject with another John Dewey's quotation:
"The aim of education should be to teach us how to think, rather than what to think – to improve our minds, so as to enable us to think for ourselves, rather than to load our memory with the thoughts of other men."

[1] *Occupational Outlook Quarterly • Spring 2014 – p. 5*

[2] *The School Journal, Volume LIV, Number 3 (January 16, 1897), pages 77-80.*

Chemical escapism:

An Aesthetic analysis of a chemical educational escape room

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Escape *rooms are very popular, non-virtual games in which participants solve puzzles to successfully escape a room within a certain time frame. Tapping on their big popular buzz, a mobile educational escape room based on the Chemistry curriculum was developed at the National Centre for Chemistry Teachers at the Weizmann Institute of Science. In this paper we discuss the design principles of a mobile escape room. We then analyze how these design principles attempt to lead the participant to an aesthetics experience and to desirable learning outcomes.*

Introduction

Imagine being locked in a room and having to use your brain, intuitions and a pinch of luck to escape within an hour, else … This is the concept behind "escape rooms" which are extremely popular in recent years and are popping up around the world. In Israel alone over 300 rooms have popped up in the last two year. In a project by the National Center for Chemistry Teachers at the Weizmann Institute of Science, a mobile escape room was designed and built to suit secondary schools. The motivation was to bring the buzz and fun of the escape room experience to chemistry students to further engagement and enthusiasm towards chemistry.

The mobile educational escape room

Our motivation to design and build the educational escape room was to harness the magic, power and popularity of the escape rooms to raise the motivation of students to study chemistry. Regular escape rooms are not readily suitable for educational purposes since they are fixed, allow limited number of participants at a time and are fairly expensive to construct. Hence, we decided on the following design constraints for the mobile room:

(1) Mobile – The escape room must be mobile in order to reach a maximum number of people. A fixed room would place a financial burden due to student transportation costs.

(2) Big groups – a normal chemistry lab class in Israel consists of 20 students. The room should fit an entire class simultaneously. To overcome this restriction we divide the participating class into groups of 4-5 students who work alongside each other.

(3) Costs – Materials must be inexpensive to allow for considerable wear and tear. Working on a low budget meant finding materials that would fit the budget yet sufficiently support the aesthetic experience.

(4) Adherence to the curriculum – Working with 11th and 12th grade students preparing for the national high-stakes examinations, the room must tightly link to the curriculum.

(5) Aesthetic experience – The room must lead to an aesthetic experience. The purpose of building the room was to raise motivation towards learning chemistry and show chemistry in another, distinct light.

The resulting 'escape room' is a kit which teachers can borrow. Non-perishables are provided and schools provide perishables (chemicals) from their labs. The room consists of nine puzzles, the solution of each leads to the next puzzle. In addition to solving puzzles there is also an element of luck in that students must find pieces of information hidden in the room in order to proceed, i.e. a combination of luck and brain.

Aesthetics in the design of the chemical escape room

There are several definitions for "aesthetic" in the science education literature: something being beautiful, something associated with art, something associated with sensing or something associated with understanding of aesthetics. Another view of aesthetics relates to the subjective interactive experience of the viewer with an object (Dewey, 1934/2005). While we constantly have experiences, an aesthetic experience according

to Dewey is an occurrence that reached completeness and is demarked from other experiences (Dewey, 1934/2005; Pugh and Girod, 2007). Such an experience is differentiated because it brings about a transformation of how we see the world. We will analyze how the escape room was designed to provide an aesthetic experience. Chemistry and aesthetics meet to form a puzzle

The puzzles can be divided into two categories: (1) 'Wet' puzzles that require doing a short experiment or practical work. For example identifying acids and bases in unlabeled test-tubes, injecting acid to reveal a code, or making a conductive dough that closes and electric circuit; (2) 'Dry' puzzles that do not require doing an experiment, but rather require the application of chemistry knowledge. For example, sorting a number of cards containing data of solutions according to their pH, identifying atomic numbers from the periodic table or balancing chemical equations.

The narrative

The escape room experience takes place in a fictitious narrative. Participants are shown a short introductory video presenting a narrative in which four bombs are hidden in the chemistry lab. Participants must dissipate the bombs within an hour. The narrative serves as an entry point and provides legitimization for playing.

When encountering a new narrative the brain partly believes and partly skeptically disbelieve the narrative and it is the goal of the aesthetic experience to lead the subject to a 'willing suspension of disbelief' (Holland, 2008) as happens when we enter the theatre or observe a work of art. It is the job of the escape room to transport the participants into a space where they are engulfed in the story and the activities. A successful aesthetic experience will thus occur when participants have suspended their disbelief for major part of the activity. In commercial escape rooms elaborate scenery aids this suspension. Having a mobile escape room, the ability to set the room up is necessarily limited. If the story was too detached from the physical setting it might jeopardize the suspension of disbelief. Hence the story was aimed at taking place in the physical space of the lab. This aspect can be researched by investigating participant's transportation into the narrative and attitudes towards the narrative, settings and the props.

Aesthetic doubling

Learning that occurs in fictitious environments can be characterized by aesthetic doubling – the ability of the participant to take on a character yet remain herself throughout the activity, thus seeing the activity with two lenses (Iser, 1978). This enhances the aesthetic experience by allowing the learner to bring with her real-life chemistry knowledge and take the experience with her to the real-world post-activity. Research into this should look at how participants used real-world chemistry knowledge to the activity and what knowledge they take from the activity to the real-world.

The aesthetics of the puzzles

The puzzle design drew on several design principles: (1) Beautiful, surprising or mysterious phenomena (TEMI project, 2015)(e.g. ink that magically disappears upon heating); (2) Presentation in a way that is appealing or surprising (e.g. the jar in figure 2a which reveals a code upon becoming clear); (3) Level of difficulty should not be too easy as not to bore or too hard as not to frustrate. This can be controlled by the amount of information provided to solve a puzzle; (4) Only one possible solution. In pilot runs we discovered that participants sometimes had alternative ways of solving a puzzle, such opening a jar when it was not meant to. Such shortcuts, deter from the aesthetic experience, since a challenge was removed; (5) 'Spacing' the puzzles so that every few minutes a "ah-ah" effect takes place keeping participants engaged; and (6) An aesthetic experience must be a complete experience. In the case of our escape room, this meant dissipating a 'bomb' thus solving and completing the fictitious narrative.

Conclusion

In this paper we analyzed the design principles that led to the creation of a mobile educational escape room from an aesthetic experience point of view. This is the first stage in investigating the educational benefits and learning outcomes of an educational escape room activity.

STEM Education – Why Do We Need It?

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The world is changing ever so fast. Technology is changing the way we communicate, work, play and even love. Societies are reforming, reshaping, and redefining themselves. Everything we know may give in, at any moment, to something new and improved. Did anyone say Walkman?

What drives these changes? Where are they taking us? Will things get better, or worse? While these are very important questions, I'm not going to try and answer them. It's an academic discussion that puts us in a bit of a passive position, as if we are spectators of a sci-fi apocalyptic movie. Let's not go there. Let's take the active path. With all these changes taking place, let's ask ourselves: where do we want to go? Where do we want to be in 10, 20 or even 50 years from now? A change is not necessarily a threat, it is also an opportunity, one that may go by unnoticed. What is the nature of this opportunity? How can we seize it? Where and what should we aim for? For that I can try to provide some answers. Are you with me? Yes? Then let's go.

First thing's first. Let's analyze this opportunity, look at it from an objective position, saying things as they are, without judging, or deciding which are good and which are bad. At the base of this opportunity, I see how dogmas are abandoned.

People no longer see things as a given. People are willing to take action and try new things, new ideas. In a way, the world is shedding its old skin, ready to accept whatever form fits it best. Next, there is the technological revolution. Setting aside the good/bad discussion, we can definitely agree that with all that technological progress, almost anything is possible. Looking at these two key points, I believe the world is ready for a revolution. We are in a time where we can almost start anew.

Reshape our lives, and the lives of our children, the way we want them to be. This brings on that philosophical, always there question:

What do we want?

Without going into specifics, I can assume we all want better lives. I will even avoid listing things like less wars or better healthcare. I think this can be summed up by just asking for more love. Love conquers all. It heals pain and fights off fear. It is the foundation of the human race, even at times when it seems to be forgotten. And may I dare say, free love.

So what does love have to do with STEM and education? I am going to show you it has everything to do with STEM and education.

Let's move on to the next question: What is STEM? it's the acronym for Science, Technology, Engineering and Math, and sometimes referred to as STEAM (A for Arts).

STEM education is the interdisciplinary approach of teaching these subject matters. Unlike your regular classes where each topic is taught as a silo, standalone topic; in STEM each lesson brings in all those subject matters into one cohesive learning activity, enabling the student to experience the interconnectivity that makes up this world.

Here is an example:

***J**ames was asked in his STEM class to come up with a project. His passion to racecars brought him to design a modeled racecar of his own. Since racing is all about speed (distance per time), he was trying to figure out how the size of the wheels would affect the car's speed. In order to figure that out, he needed to experiment, scientifically. James came up with this hypothesis: the bigger the car wheels (in Diameter), the faster the car will go. James then needed to validate his hypothesis. For that, he set up an experiment in which he designed the same car but with different wheel size. He engineered such a car using a modular construction set, and accessorized it with sensors and motors. After the engineering part was over, he needed to find a way to collect the data (distance per time). Using basic coding, James was able to record the data for later analysis. After conducting multiple tests (n), with different wheel sizes, James had enough data to start evaluating his hypothesis. Applying basic math skills (statistics and such) he was able to show, and back up with objective data, that the racecar did indeed go faster with bigger wheels. He presented this to his classmates but was confused when was asked by one of his peers a very strange question. It goes like this: "If bigger wheels mean higher speed why do race cars don't have enormous wheels?" This set James off into a new experiment looking into the effect of wheel mass on speed.*

Now I ask you, was this Science? Or maybe Math? Or could this be a technological project? Engineering?

Was it all of the above?

This is interdisciplinary STEM.

And how can this bring more love?

Easy. And to illustrate it, I bring before you a short story I hold dear:

*"**T**wo mothers are walking down the street. As a homeless person passes by, one mother says to her child with a harsh look on her face, 'if you won't study hard, you'll end up like him' (can you smell the fear?) The second mother looked at her child and said with compassion 'if you'll study hard and do your best, you may be able to help him and others like him'".*

In STEM education students work together to solve problems and provide solutions for real world problems. The key is to focus on social problems that can be solved through Science, Technology, Engineering and Math, and not math problems or engineering challenges. Bringing out the social needs, while evoking compassion and empathy in our children is, in my view, is the heart of STEM.

There are many ways to go about STEM, make sure you use it to bring love into your students' hearts. Let your students find ways of helping others, their friends, families, communities, or even countries. Looking for inspiration? Then check out "Just Spirulina" – an incredible STEM project that started at the Hebrew Gymnasium of Tel Aviv in Israel, and is now making this world a better place.

The Makerspace is the 21st century classroom

Roni Arkush

Director of Activities, XLN – Israel

What will be the occupations of the future?

The work world is changing at a dizzying pace – with many secure occupations, among them bookkeeping and travel agents, currently in danger of extinction. Concepts such as artificial intelligence, machine learning, Internet of Things and data mining signal the need for a fundamental conceptual change in Man vs Machine relations and abilities. The Internet is no longer just an endless source of knowledge that cuts across geographic, language and cultural boundaries, but rather a smart network that combines knowledge, calculation abilities and conclusion and insight capabilities – of both humans and autonomous machines.

Learning dedicated exclusively to the acquisition of knowledge is no longer sufficient for today's pupils and separate subjects can and should be combined to create multi-disciplinary learning processes. The main challenge today is in fact developing the ability to ask questions and providing access to meta-skills, first and foremost the ability to learn how to learn and acquiring tools to address real-life problems, even in unfamiliar areas.

Pedagogic Innovation is the Name of the Game

Even world-renowned experts cannot confidently predict the effect technological changes will have on our daily life in all areas, among them – employment, social life and urbanism. At this point in time there is huge potential to change the role of teachers, schools and pupils. The education system is a primary arena for creating fundamental and significant change in learning and socialization processes. This is where the Z generation is exposed to today's complex and intricate reality and the system charged with preparing pupils for tomorrow's employment market.

"Making" is the underlying concept of a new culture based on creating projects that combine 21st-century skills. The "makers" are no longer just the technology-loving geeks or artistic creators attracted to DIY. So what distinguishes pupils from Makers? What are in fact the skills that pupils need in this age?

Soft Skills Drive Progress

If you think of well-known entrepreneurs, Steve Jobs and Mark Zuckerberg probably come to mind – role models usually described as revolutionary and singular trailblazers, as soloist entrepreneurs. Today we know that entrepreneurship and innovative endeavors are deeply-rooted in teamwork and collaboration. Work processes in industry take place in work teams comprised of developers, designers, content people and product managers, all working together in iterations on the development of innovative products and services in a variety of content worlds.

Multi-disciplinary undertakings and peer learning are now the building blocks of research units and innovative laboratories that have become integral parts of leading institutions and universities such as Harvard and MIT. Numerous studies have shown that real learning takes place by doing and through experiencing trial and error processes. In light of the accelerated pace of change, teaching agile skills, among them rapid prototyping, is vital for dealing with the challenges we face.

Project based learning (PBL) is fertile ground for teamwork, peer learning and multi-disciplinary learning processes. This methodology presents pupils with frequent situations in which they must operate in unknown areas. Pupils must initiate and explore new content worlds on their own, and perhaps most importantly – contend with fear of failure and acquire the ability to learn from mistakes. How do we strengthen pupils' sense of competency in their ability to create? What helps them develop a sense of responsibility for their learning?

Radical Change or the Current Curriculum

A group of 12th grade pupils from the city of Netanya worked on its matriculation exam project in the mechatronics track last year. In contrast to standard matriculation exams, they would be evaluated on a unique project, in this case building a musical instrument for pupils with disabilities from another school. They were accompanied by two XLN instructors – an industrial designer and an electronic engineer, and closely assisted by the subject coordinator.

The pupils went through all the product development stages – from choosing the idea to final execution. They used Arduino laser cutter technology to design the musical instruments and programmed the playing keys. As part of the matriculation exam they presented their project to the evaluators who faced a challenge: evaluating the pupils in keeping with accepted measures in the education system. The pupils did not demonstrate sufficient knowledge of the required material for the matriculation exam, however in terms of their initiative and creativity and the project's educational value – their work was significant and impressive. Think about this for a minute – what grade would you give these pupils? What measures would you use to evaluate the project?

This is an excellent example of the existing tension in education in the 21st century – can such undertakings exist alongside the existing curriculum or is a radical change needed in schools structure and pedagogic contents?

The School for Future Professions, established by Dror Educational Centers (Drornet) in kibbutz Ravid near the Sea of Galilee, is planned to represent a new model, a radical change in the education world. The aim is to create a meeting place of industry and pedagogy, "to develop the world of education, employment and economy in the Galilee" in their words, while forging a significant partnership between area youth from varied backgrounds. The subjects that will be studied are not found in the familiar curriculum. Instead, they address real life challenges, among them – life-enhancing products, agriculture of the future and urban planning.

The Teacher as Guide

Remember Robin Williams in the Dead Poets Society, or Michelle Pfeiffer in Dangerous Minds? The image of the highly motivated charismatic teacher has been showcased by Hollywood in many films. The image is usually that of a non-conventional teacher, the kind that does not follow in the tradition of the conservative and old-fashioned system. The 21st century offers a significant opportunity to redefine the teacher's role. Teachers are no longer the sole source of knowledge to which the pupils look up to, but rather guides that accompany them, helping them ask the right questions and acquire investigation and project management skills.

In the unique XLN project in cooperation with Danor (the Association for Education Advancement in memory of Shai Danor), junior high schools are selected to participate in a 3D modeling and printing program. As part of the program, the teachers participate in comprehensive XLN training, where they learn to use 3D modeling and printing software for teaching purposes. The teachers then integrate the technology into their lesson plans, creating a different learning experience for their pupils who experience a trial and error process, as well as teamwork and individual work and in-depth feedback about the entire process. The range of outputs is vast and fascinating: from modeling letters in a foreign language, through designing an historical building to demonstrating mathematical principles using printed games.

The Classroom as a Hybrid Laboratory

Makerspace is an innovative learning space, a hybrid between the traditional artisan workshop and innovative laboratories with cutting edge technologies. Carpentry tools, sewing machines and manual lathes meet 3D printers, laser cutting machines, CNC and Arduino based sensors. The hybridization characterizing the projects, along with thee variety of tools requires an innovative learning environment featuring modular furniture and areas for "dirty" work alongside quiet and clean areas for thinking and contemplation. Work processes are also addressed, facilitated by sticky notes, inspiration boards, thinking maps and displays of the pupil's outputs.

Pupils no longer specialize in one skill, instead developing an array of skills – for using tools and for ways of thinking in characterizing and solving problems. One of the leading methods used is Design Thinking which covers the full range of steps involved in problem solving – from a sketch to the completed product, taking into consideration usability and ergonomics, creativity, originality and the aesthetic dimension.

So what will schools look like in 10 or 20 years, and how will learning take place? While it appears to be too early to know for sure, Makerspaces and pedagogies that integrate Making will undoubtedly be a vital part of this future.

Established in 2011, XLN is the first and leading entity in Israel that sets up and operates Makerspaces. We have since set up a network of 3D laboratories in Israel and the US. Two projects that grew out of our laboratories are TOM that develops solutions for individuals with disabilities throughout the world, and the highly successful project by Danit Peleg who designed the first 3D printed dresses in the world. Our current focus is on using Makerspaces as platforms for innovation in the education and health systems. We are involved in planning, accompanying and establishing innovative learning centers, and in developing content and training programs for teachers and center managers in varied Making content worlds and adapting them to the learning needs of the 21st century.

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