University of Tartu

Faculty of Social Sciences

Institute of Education

Curriculum: Educational Technology

Marwa Seoudy

FROM INSTRUCTIONISM TO CONSTRUCTIONISM: THE ROLE OF TINKERING IN EDUCATIONAL TECHNOLOGY

MA thesis

Supervisor: Emanuele Bardone

Tartu, 2019

Abstract

The aim of this Thesis is to discuss the role of tinkering in education technology starting by tracing the history of tinkering and making while redefining tinkering in education and casting the light on the role of the educational technologist in a tinkering space and time domains. Through this study, we are answering why tinkering is considered an important approach for students to practice next to analytical approaches, how tinkering prepares students to face future uncertainties and invites them to be self-learners.

We are narrating a group of case studies as a sample for cases that helped us to understand tinkering, and comprehend why students seek or leave tinkering activities. We are also arguing if the role of the educational technologist in tinkering/making spaces is limited to technical knowledge or he/she should be able to handle a complex network of relationships. And how we can shift the mindsets of teachers and educational technologists from "Instructors" to "Constructors".

Keywords: tinkering, making, constructionism, education technology, meaningful tinkering.

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Introduction

I started my journey in making and tinkering since I was a school student. During my primary school and high school, I helped my teachers to construct a maker area inside my school. My personal experience was very joyful and helped me to learn beyond the traditional school context. Thrilled by my personal experience, after I graduated from the faculty of Engineering I was curious to see how children respond when they get exposed to digital tools and to use engineering approaches. My personal curiosity and love for tinkering and engineering drove me to start tinkering activities with school students since 2006 on a small scale. In 2011, I decided to open my first constructionist centre in Egypt. Then in 2016 with my team, we opened two more constructionist centres acting as hubs serving different Egyptian cities. Through my journey, I served 1000s of Egyptian students to build and tinker. As an engineer, educational technologist and entrepreneur my work varied from helping students to tinker, build, and understand science to manage, deal with parents, Egyptian media and politics. That made me see educational technology from different viewpoints. The work with the Egyptian schooling community has broadened my horizon. In Egypt, we have various schooling systems such as the American system, the French system, the Dutch system, the governmental system, STEM schools and the British system. In soccer, the coach could be engaged in the player's life for several years. The same happened with the students under my observation who focused on tinkering with digital tools or technology in their learning journey outside the standardized or formal school setup. Thus it is important to highlight that my work as an educational technologist is different from school instructing. In teaching the teacher usually get engaged with a certain student for about a year. In my work, I get engaged and remain in contact with students for several years. Through my long term projects, I got a chance to measure the impact of tinkering on students differently. For example, there are students whom I remain in contact with for 7 years, and that allows us to see the impact that our work has in the long term.

During this journey, the following questions have emerged in the course of my work: how students learn via tinkering? Why there are students who tinker under stress and others don't? How a constructionist learning environment could act as a hub transforming the surrounding community? And how we can prepare students for future uncertainties? Seeking answers to those questions I had to analyse my daily experience and had to look for reasons beyond the use of technology in education. The present thesis came as a result of my need to answer those questions. Through my study, I got inspired by Seymour Papert, the father of constructionism, and Reggio Emilia approach. I consider Papert and Reggio Emilia schools of thinking the nearest to my heart and to what I believe in when we tinker with students.

The thesis is composed of five sections. In the section called 'Theoretical background' I present a timeline for making and tinkering since Dewey till today. I also discuss the current attempts and concerns about involving making in the schooling system. And I give a definition for making, tinkering and engineering and discuss the relation between the three. The 'Methodology' section contains a description of the methodology used, while in the 'Results' section I present three case studies using the narrative approach. The three cases are a sample from my work experience and they helped me to find answers to my questions regarding education technology and tinkering. The 'Discussion' section provides a common thread between the three cases and illustrates the importance of reshaping our current thoughts regarding education technology and the use of tinkering in education. The thesis ends with a conclusion where I highlight the role of the educational technologist in a constructionist environment and a proposed description for meaningful tinkering.

Theoretical Background

As technology advances the rise of new professions and the need for prepared candidates ready for the future is a critical demand all over the world. Those technology advances go hand in hand with the emergence of new practices in education. This need enforces the link between technology and education while it pushes different countries and governments to put design and engineering in the front line with the need for workers to move away from the isolated production modalities of the past (Blikstein, 2018).

Since 2014 with Obama declaration to promote what is called "Maker movement" within the American society, and the marketing campaigns done by Dale Dougherty the publisher of the Maker magazine, the making initiatives started to flourish across the globe (Blikstein, 2018; Vossoughi & Bevan, 2014; Gonzales & Arias, 2018; Halverson & Sheridan, 2014). For instance the maker initiative in the British schools in England in 2016 which was led by BBC with the goal to look for an innovative holy grail (Blikstein, 2018). Practices and initiatives of how making and tinkering can serve to advance the inquiry-based education and STEM education are researched and reported as in (Vossoughi & Bevan, 2014; Halverson & Sheridan, 2014; Blikstein, 2018). However, there are questions that are still open when it comes to tinkering or making in education and the role it plays in education technology such as: how it could be integrated with schools? How it could be linked to a pedagogical framework? How we are going to assess the students? Is it a fad? Is it towards vocational education? Is having a Maker space or Fab Lab inside schools going to change the education and help the future generations?

To answer those questions we need to take a deeper look and provide a multifaceted analysis to the role of making and tinkering in education. More specifically, we need to understand what are the roots of making in education and the educational values that come along with tinkering with technology. Giving a closer look to the relationship of making and tinkering in education we find that not only has this movement been related to education for not less than 100 years since Dewey, but also that the making movement in education is a culmination of a long tradition of educators seeking to put children and youth at the center of the educational process (Blikstein, 2018; Martinez & Stager, 2013). However this fact is unknown to many educators; even most of the 21st-century skills advocates have neglected the connection between those skills like problem-solving skills, critical thinking, and inquiry-based learning, to progressive education and constructive/critical pedagogy theorists.

Progressive Education & Constructionism Vs. Instructionism

The discussion of having making and tinkering within the schooling system reflects a continuous debate between the major two schools of education traditionalists/instructionism and progressive/constructivists. The progressive education re-emerged in different industrial economies in the 1960s and 1970s pioneered by Ivan Illich, Lillian Weber, John Holt, and others was meant to bring practice into the classroom, constructing authentic knowledge through creating and to reject behaviorism (Martinez & Stager, 2013). The importance of constructing authentic knowledge through creating and inventing, which is a current concern in modern education practices, was discussed by the father of constructivism Piaget in the 1970s. Piaget theory which was later on known as constructivism requires every new truth to be learned, rediscovered or at least reconstructed by the student and not simply transferred to him. Constructivism is a theory of learning that doesn't incubate a specific method of teaching. However, constructionism advocated by Seymour Papert is a theory of teaching or, better, *constructivism in action*. According to Martinez and Stager (2013) the difference between instructionists and constructionists is:

> Instructionists rely on a treatment model to explain learning. (I did X and they learned Y.) Constructionists believe that learning results from the experience and then understanding is constructed inside the head of the student, often in a social context. Constructionist teachers look for ways to create the experiences for students that value the student's existing knowledge and have the potential to expose the student to big ideas and (aha) moments. (p.72)

Papert & Constructionism

Seymour Papert is considered the father of the maker movement, and the creator of the constructionism learning theory. Papert was a mathematician, computer scientist, artificial intelligence pioneer, psychologist, educator, inventor, epistemologist, and activist. He started his work in the 1950s as a mathematician in Piaget team researching how children construct mathematical knowledge (Martinez & Stager, 2013). Papert is the genius mind behind Lego Mindstorms, Logo programming, Scratch, MIT Media Lab and One laptop per child. When it comes to technology and education Papert's thoughts are visionary. As Papert (1972) criticizes the common practices when technology is integrated into education by arguing that:

> The phrase, "Technology and education" usually means inventing new gadgets to teach the same old stuff in a thinly disguised version of the same old way. Moreover, if the gadgets are computers, the same old teaching becomes incredibly more expensive and biased towards its dumbest parts, namely the kind of rote learning in which measurable results can be obtained by treating the children like pigeons in a Skinner box. (p.245)

Papert (1987) gives an example of two classrooms using the Logo program, the first classroom used the traditional way which is very common today when it comes to engaging students to any piece of technology. While in the other classroom the teacher used the Logo to unleash the students' creativity. That example given by Papert is important to help many of educators today to sense the difference in the culture of teaching when digital tools are integrated with the classroom. In other words how we need to develop the culture of teaching and education practices instead of looking for a silver bullet using technology.

Making, Tinkering and Engineering

Papert's arguments about why we use the technology in school in a way limiting the student's imagination could be used today to question why the institutionalized "educational technology" community appears so ignorant of the learning affordances created by the making, tinkering and engineering approaches inside school education (Martinez & Stager, 2013). Making, tinkering, and engineering are three words that commonly used when it comes to learning by constructing. According to Martinez and Stager, the three are ways of knowing, that should be inside any classroom regardless of the subject of study. Martinez and Stager (2013) give a loose definition for the three which is:

> Making is about the active role construction plays in learning. The maker has a product in mind when working with tools and materials. Tinkering is a mindset - a playful way to approach and solve the problem through direct experience, experimentation, and discovery. Engineering extracts principles from direct experience. It builds a bridge between intuition and the formal aspects of science by being able to better explain, measure, and predict the world around us. (p.32)

To Martinez and Stager (2013) messing around is the action that we might call tinkering. When it comes to technology Martinez and Stager framed three potential uses of the computer based on Taylor (1980) such as a tutor. Computer displays instructions and conducts the assessment; a tool. The computer allows the student to perform academic tasks easier or more efficiently; a tutee. The student learns by programming (tutoring) the computer. The third use is the closest one to the construction school of learning as the students learn by tinkering a design. According to Edith Ackermann (2010), play and design are similar. "You get started and the ideas will come. You preserve and the ideas will fly."

Banzi (2008) describes tinkering as what happens when we try something we don't quite know how to do, guided by whim, imagination, and curiosity. For Banzi tinkering basically a process that marries play and inquiry. Martinez in (Martinez & Stager, 2013) gives an example from her career life as an engineer about tinkering, engineering and her work environment. What is interesting in her example is it is a real story reflecting the real life of engineers and how they tinker to develop.

More broadly, engineering practices generally involve both making (constructing) and tinkering (creative problem-solving) activities (Vossoughi & Bevan, 2014). And children are born as engineers building houses, toys, and interacting with their environment to craft or make something that makes them enjoy their time.

One of the concerns when it comes to constructing is mixing the making and tinkering with the assembly. The difference between making and assembly must be considered as described by Vossoughi and Bevan (2014) on behalf of Espinoza (2011): "Making seems to be cognitively and socially richer than assembling as it involves more active testing and fitting and less routine following of directions" (p.9). Papert (1987) reported a trial of learning via tinkering inside the classroom when a teacher asked the students to design a tool to measure time. In this trial, each group of students designed a different tool to measure time, from simple sand clocks to the use of the LOGO program. That reflects the diversity of learning and tinkering through technology investigation. As Vossoughi & Bevan (2014) argues:

> Making thus looks and feels different from more traditional open-ended inquiry activities. Its invitational potential may be a part of what is driving so much interest in making as an important innovation in teaching and learning practice, particularly after the predominance of text-based, test-driven, teacher-centered STEM instruction. (p.4)

Most of the research literature represents tinkering as a kind of making activity and not just a mindset. This concept is followed in the presented literature so when we mention making or constructing we don't mean an assembly action of following instructions to build a project, however we mean an activity that includes tinkering and messing around ending by constructing something new to the learner.

Over 8 years of my work with students in a constructionist learning environments and as an engineer, I observed tinkering as: the use of intuition, logic thinking and any type of knowledge inside the self to go from state A to State B, using available resources in hand. To transform from A to B we have to pass by a challenge. The challenge could be due to the environment surrounding us (external challenge) or a need like lack of a human part, a mentor asking you to do something, the need to have fresh air. Or the challenge could be set by the self to discover something new, or to reach a higher mode.

What makes tinkering an educative practice is the students are allowed to explore the world themselves. In comparison with regular ways where the students just watch an assembled experiment, via tinkering they compose the experiment using their knowledge and intuition, they might build a device, and they experience the exploration and uncertainty of results. Moreover when a learner makes and tinkers feelings of accomplishment, confidence and motivation are created inside the learner, which are important in learning (Boakerts, 2011). Hence when we use constructing and tinkering approaches in education we create the chance for the students to be active citizens and for the educators to act as partners in learning with the students, rather than perceiving the students as passive receiving elements.

Makerspaces and the Schooling System

Before the start of the Makerspaces, the hackerspaces started since the 1980s and 1990s in the USA and Europe. The audience were high-end programmers, hackers, and engineers. However, hackerspaces, as reported by Blikstein (2018), weren't suitable for school culture and young learners. In 1985, Seymour Papert with others created MIT Media Lab. The Media Lab embraced polymaths and became a grand center for tinkering across the lines (Martinez & Stager, 2013). One of the Media Lab creations was the born of Fab Lab. The Fab Lab addresses access for tools in design and fabrication, adding to it an environment of collaboration, design, teaching, and learning. As inspired by his book Fab, Greshenfeld expresses this process as can be seen as teaching on demand rather than the more traditional just in case model that covers a fixed curriculum put by a group of adults, hopefully, it will help the students in the future (Martinez & Stager, 2013). In simple words, in making inside a Makerspace or Fab Lab the student is the creator of his/her own future.

In 2014 Mark Hatch founder of Tech Shop proposed a Maker Movement Manifesto that describes nine key ideas that need to be included in a making activity which are: make, share, give, learn, tool-up, play, participate, support and change. It is worth noting the Tech Shop business model was built on membership fees. Tech Shop although was seen by many as a successful commercial Makerspace, closed its branches in the US in 2017 causing problems to small businesses and hobbyists depending on the space (Su, 2017).

Blikstein (2018) stated five social trends that helped in pushing the maker movement and makes making more appealing to schools. The trends are:

- The spread of the social acceptance of progressive education;
- The competition between countries to have an innovation-based economy;
- The growth of sharing mentality;
- The increase of research on Makerspaces;
- The reduction in digital tools costs.

In general, Makerspaces is an output of the maker faires and maker magazines and are less structured places than Fab Lab. As to have a Fab Lab a list of specific machines should exist in the lab and a membership with the Fab Lab global network should be established. The good thing about Makerspaces or Fab Labs is allowing those who are interested to learn from experts to have access to fabrication tools and have a space to make. However, learning happens as a consequence of individuals beginning as legitimate and moving towards full participants (Halverson & Sheridan, 2014). Hence a major weakness point in the Makerspaces or Fab Labs is that learning is not constructed on the individual level. In other words, the unit of analysis is not what an individual learns but what is going on in the space.

Makerspaces or any physical space for making could be seen as a place to practice constructing activities and learn by building something or tinkering your own creation. The importance of having access to constructing tools and learning environment with its relation to educational technology is highlighted by (Eisenberg & Buechelet, 2008). However, another weakness point about Makerspaces is the Make Corporation, the movement and fairs are all sharing the "Make" domination. That brought some confusion to schools and criticism by scholars compared to Fab Labs, despite the flexibility offered by Makespaces over the Fab Labs (Blikstein, 2018).

In 2008 Paulo Blikstein created FabLab@school project. He was teaching MIT Media Lab design courses to graduate students and teachers to enable the design of a new project for K-12 education using a Fab Lab. In 2011 Blikstein hosted the first FabLab@School conference at Stanford. In his chapter Blikstein (2018) discussed three possibilities of how a Makerspace could be integrated with schools. The first possibility is having a Fab Lab inside each school. According to Blikstein, there are concerns and challenges beyond having a proper Fab Lab in all schools due to the lack of funding to have enough equipment. As when it comes to classrooms we should consider the students to tools ratio, which requires more funding. Moreover, we might risk equality as schools with more chances to access funds would have more tools than other schools with fewer chances to access funds. The second possibility is having a system of incentives for innovative teachers and schools to democratize the maker movement in schools. The challenge here is how we can implement a scripted maker curriculum for an entire nation while making is committed to some level of free choice and project-based learning. In that case one of the possible solutions would be to reward innovative teachers and schools. However, we might risk equality as we might have lucky schools with skilled teachers who can lead the Makerspace inside the school while other schools in the same area might miss having a teacher with similar skills.

The third possibility is National Standards rewards the innovative practices and includes making activities inside the curriculum. The problem here is schools will need to redistribute time throughout the school day. It will soon be apparent that there is no way to offer maker activities within the traditional school day. Moreover, the schools will need new teachers with new skills, offering training to the current teachers and the school spaces need to be redesigned. Which is a huge cost making this possibility hard to be implemented. The three possibilities mentioned by Blikstein include the risking of equality and democratization. To Halverson and Sheridan (2014) the greater fear on that part of those deeply invested in the maker movement are those attempts to institutionalize making which might result in killing the democratization and individualization spirit of making.

A model reported by Blikstein (2018) in a San Francisco Bay Area school, was established in 2011. Here the teachers from different fields bring their lesson plans to a Fab Lab instructor who works to design an inquiry-based activity based on the teacher needs. The Fab Lab instructor works to develop assessment, rubrics, evaluation, and technical tutorials. In that model, we fall in the same trap of limiting the freedom of learning by making. As discussed by Martinez and Stager (2013) rubrics may be counterproductive. Rubric effects serendipity makes failure not an option and imposes the teacher's vision. Also, rubric becomes the checklist of the project and students expend minimum effort to receive the desired grade.

What attracts the students to Makerspaces and construction competitions outside schools is what Martinez and Stager (2013) emphasized as the serendipity over the structure. As in most of the school activities structure is valued over serendipity. Understanding is often designed by an adult committee and the learner is not a part of the design process. Hence, the last model reported by Blikstein couldn't be considered the best approach to integrating making within the education system. To harness the benefits and educational values of tinkering and making in education we should be highly sensitive not to use the same traditional schooling system methods with tinkering and making. Martinez and Stager (2013) gave an example when we ask students what are you doing in Math and they answer chapter "12" instead for example saying we are measuring the circle circumference. This example could be reflected also in construction activities when handled in the traditional way. In the start of any Robot activity, I ask the students what do they know about Robotics. Students who have previous experience in educational robots always gave the same answer "Robots are built by LEGO, we connect a wire and download a program". For 8 years I ask this question annually for not less than 200 students per year in Egypt and I hear the same answers from those with previous experience in learning Robots using traditional schooling methods inside Makerspaces or Technology centers either inside schools or as an extracurricular activity. This example reflects how the students are programmed to learn by assembling the building steps and how the students might be confused between the meaning of Robotics as a field of study and the building steps. The problem is much deeper cause for those students LEGO Robots equals Robotics. And when we ask them what are other types of Robots they say "Arduino Robots". So we don't hear Military Robots or entertainment Robots as examples of Robots, instead, they explain the prototype they built and what they used on this prototype.

Reggio Emilia Approach

The mentioned example about robotics reflects the fact that making is not about a space of formal or informal activities in school or outside the school. But to achieve the making educative values the environment of learning, teachers' mindsets and management need to be reshaped as done by Reggio Emilia in Italy. Reggio Emilia approach is the best experience built of constructive learning which fills the gap between achieving the making educative values and schooling. Reggio Emilia is an Italian city where Loris Malaguzzi created municipal infant and toddler centers based on the theories of Dewey, Piaget, and others. The approach is highly sensitive to local culture and community and respects the talents and needs of individual learning. In Reggio Emilia, there are three teachers to the child: Parent, the teacher in charge and the environment. The teacher in charge of the children is a researcher charged with understanding the thinking of each child and preparing the environment for the child's intellectual growth. A wide variety is used to construct the learner's knowledge and the word project is a dynamic learning process. According to Carlina Rinaldi (2006), the president of Reggio Emilia terms as curriculum planning and lesson planning is not suitable for representing the complex and multiple strategies that are necessary for sustaining children's knowledge- building processes.

The success of Reggio Emilia for 50 years compared to the struggle and arguments of integrating making in the school system let us see that the problem is not in technology or making approaches but in the traditional culture of the schooling system which is trying to apply the same traditional management and educational methods on making and tinkering activities.

Maker Movement Concerns

Although making lets a learner feel a sense of control and achievement. Most of the cases reported proving the success of Makerspaces are reported after the participants achieved something (Vossoughi & Bevan, 2014). In other words, the successful cases are reported but not the cases of why students might leave a making activity, as a result the probability of success of making and tinkering approaches inside schools beside the analytical approaches is still unknown.

Blikstein (2018) communicated three concerns for the maker movement to success in schools. The first concern is to make sure that this movement is not an overhyped fad. The second concern is the society look when it comes to making which tends to relate making to vocational education. The third concern is educational technology is always going beyond the demonstration phase. How we ensure democratization and not widening the gap between rich schools and schools who lack funding should be under consideration. Vossoughi and Bevan (2014) discussed other three concerns for involving making activities in schools:

- are the activities relate (or do not relate) to existing curricula and/or lead to the development of conceptual understandings;
- how making can support student engagement in scientific and engineering practices;
- ensuring that making is leveraged to challenge rather than reproduce existing inequities.

To understand Vossoughi's & Bevan's concerns we need a closer look at the trends governing the making and tinkering movement which are reported in (Vossoughi & Bevan, 2014). The first trend is making and entrepreneurship community creativity. Where the community is concerned with creating new startups that can use Makerspaces to develop their business ideas. The second trend is the STEM pipeline and community development. This trend is pushed by technology companies seeking more professional capacities. That lead those companies to create tools and lesson plans for school students, to be embedded in the schooling system with the aim of filling the gap between schools and industries. The third trend is making is an inquiry-based educative practice which is the most reported and popular trend due to the possibility of integrating this trend with the regular school curriculum and learning process.

Due to the trends mentioned above that are controlling the maker movement, we easily track the government's investments in new digital devices with hope to develop the future generations. However, less work is done to develop the schooling culture as Reggio Emilia did. When we are tracking the history of making in education, we expect that making and tinkering as an approach for constructionist learning supposed to be more popular. However, how the educational technology community doesn't give enough attention to the educative values of tinkering and making as Martinez and Stager (2013) argue and Papert (1987) argued more than thirty years ago is still a concern. What we need is to shift our focus to prepare the students to the future by reshaping the education environment and to encourage the students and teachers to face the uncertainty of dynamic projects through tinkering. For Piaget, Papert, Martinez, and others who believe in the educational values of constructionist learning, how we learn by inventing, how we make by tinkering and facing the uncertainties around a certain challenge is the way to develop our humanity. As Papert argues through his work, computers supposed to offers learners' technology instead of teachers' technology. But, many attempts in the past and present are to enforce the role of the teacher as a class manager. The challenge for the teachers and educators is to change their mindsets. As reported by (Belland, 2012) teachers have concerns about their abilities to move out of the structured environment and to work with the students on a project they don't have enough instructions about it. Add to this, the current focus still on standardized testing and the acceptance of teaching to the test as never before. The fundamental question of how we merge the making to the current educational system is considered an abstracted question. The fundamental question should be how we reshape the current education system as Reggio Emilia approach did by building an education system based on constructionism instead of purchasing construction tools and apply the same traditional schooling methods. The fundamental argument needs to be modified to reach beyond the current controlling mentioned trends expectations. The questions should be modified from how we build the same lesson plans and teachers training on how to do the same thing using a piece of technology? to under the future challenges that future generations will face, how we reshape and rebuild the education system based on the constructionist theory? The question of the role of educational technologist needs to be modified from how a teacher could use this piece of digital technology inside the classroom? to what is the role of education technology and educational technologist in a constructionist learning environment? And last but not least we need to focus on how we can shift the teacher and educational technologist mentalities from instructor to constructor? Those questions are discussed and addressed in the following chapters.

Methodology

The aim of this part of the thesis is to create understanding through observing, writing and reflecting. The stories narrated and discussed in this chapter reflect a central concern which is to make connections and identify shared understandings regarding the generation of reflective practice through storying. According to Martinez and Stager (2013), a teacher in a making environment is an ethnographer, documentarian, studio manager and wise leader. Which makes the narrative approach the most suitable one to the present study.

To analyze and understand the role of education technologist - as what I recommend to call the constructor in a constructing learning environment - while making or tinkering with students, and to understand what educative values are gained using making and tinkering, I used the narrative approach. Narrative approach as a reflective practice invites the practitioner to enhance thinking and doing through interrogating, rediscovering and redefining a view of an issue. A story enabled with experience as a medium not only facilitates understanding but also generates new knowledge. Moreover, reflective case narratives are positioned as a powerful learning tool with pedagogical benefits (Chambers, 2003; Becker & Renger, 2017). "Narratives are one of the information sources of a case study; they excel in offering flexibility so that theory and practice are still incorporated. Narrating a story as a reflective practitioner provides special insights into a complex system." (Riley & Hawe, 2005). While Winter et al. (1999) characterized narratives based on Dewey as expressing our experience in order to shape and realize its significance.

I composed the narratives based on, my personal business diary, which I have been keeping since 2011, and internal company reports and records. Since we started the company we kept documentation for all events and students. The diary and internal company reports are a part of my practice as a practitioner. Over the years the diary, reflective meetings, company records, and documentation helped me and my team not only to analyze and observe our practices but also to develop our practices, to raise questions and draw patterns for the students. As an educational technologist constructor, my role varied from coaching, documenting, observing, analyzing events, supervising and above all learning.

My position as a manager and cofounder allows me to see a bigger picture. I had to deal with Egyptian media, politics, parents, schools, teachers, and other actors in the education field. And the moment I am interacting with a student all those experiences are considered and put under consideration. The description of my position is similar to what Papert (1987) described arguing that in education systems it is incompatible to just change one factor in a complex situation as education and learning while keeping everything else outside of the game. Although Papert in his argument was talking about LOGO programming, we can still apply his arguments in education technology or when we start integrating a piece of technology in a learning environment. According to Papert (1987), a LOGO practitioner needs to understand and deal with the political side, pedagogical side, culture building side and the teacher effect of using the LOGO program inside a classroom.

From the narration of the case studies presented, the role of an educational technologist presented by me is expanding from someone who knows about a certain tool or presenting a certain tool, to someone guiding the students through different stages of tinkering or making. While also helping them to discover science theories, reaching a new theory or achieving a sense of accomplishment. What makes the presented stories remarkable is they are a result of a long duration observation and analysis which is still going like an open mission. That way I had the chance to see the deep connections between the role of the educational technologist constructing and tinkering with students and the progress of those students inside and outside the learning space.

Three Cases

In this section, I am narrating three cases. Each case is a source to analyze and answer questions regarding learning in a complex environment as construction learning spaces. To illustrate the purpose of each narration, each narrated story is followed by a brief analysis. The discussion section that follows up is meant to address broader issues.

The first case is about an educational technologist interacting with a complex network of relationships. In this story, I am discussing how the role of the educational technologist goes beyond the reference to how a digital tool works. I do that by presenting the story of a female student who tinkered with LEGO robots for around two years and joined national robot competitions. This story is an example of a set of actions and reactions practiced by her and other students when they are required to tinker for a long time to solve a robot mission.

The second narration is about an educational technologist interacting through an online platform. In this story, I am discussing the role of educational technologist interacting with students using online tools. The story gives us an idea about how an educational technologist helped students to tinker and construct remotely in the online setup which is different from the face to face setup. In the narration, the students were supposed to build, tinker and design science and engineering projects. The story also illustrates the importance of having a constructionist mindset when we are interacting with the students online. Despite the fact that most of the e-learning providers depend on instructing or posting materials without following with the students on individual bases, the narrated case reflects the need of constructing challenges to the students and the effect of constructing a relationship between the educational technologist in charge and the students.

The third narration is about an educational technologist co-creating with organizations. The story discusses the effect of cooperation between teachers and an educational technologist who is a LEGO robot practitioner. The purpose of the narration is to show the need for tinkering as a method of learning, and instruction Vs. tinkering and construction.

First Case: Educational technologist interacting with a complex network of relationships

Usually, in engineering, the number of enrolled female students is smaller than the number of enrolled male students. Such a fact sometimes causes challenges for young female students who need more confidence in that age. In the lines below I discuss the story of one of my female students and her mates from different angles. The main interest lies in trying to understand what allowed them to succeed. Had they used tinkering to face their mission challenges, or their personal challenges held them from tinkering? In the narration, I am using fictional names and calling a female student a smurfette and a male student a smurf. I am referring to the constructionist educational technologist here as a coach.

The case as it unfolded

I met Lolita in 2017 when she was around 12 years old. She started her tinkering journey with LEGO Robots by joining a Robotics camp for 5 days during the 2017 winter vacation. Her coach noticed during the camp that she was so smart but has a problem when she was working in a team. She wanted to do everything alone and wanted to control more than she was willing to share. Her mother was informed about this problem. Lolita continued her work with LEGO robots after the camp until she decided to join the National Robot Competition preparation training in 2017. Once Lolita started preparing for the competition she behaved differently as if she was another one.

In the competition training, Lolita was in a team with a smurf named Fox. Fox wanted to do everything by himself. From the other side, Lolita's mother talked to Lolita about her teamwork attitude privately. As a result, Lolita lost motivation and left the work to her teammate Fox. Fox got disappointed after a while once he perceived that he was carrying the workload alone. The team coach got disappointed as well about how the team performed, and we had to deal with the human learning complexity. So far I was away from coaching and just observing what was going on. However, I interfered at that moment to solve the situation which for me resembled like a dilemma. For addressing such a dilemma, the team and their coach needed to be regrouped and other teammates should be introduced to recreate a sense of purpose that got lost. Which what I did. I had another Smurfette (Farfoura) who was smart and good at programming. Farfoura was in another team with two other male students. One of Farfoura's mates was Mr.Black a Smurf whom Farfoura couldn't cope with him due to gender sensibility issues between both of them and here we got a distinctive challenge as we had to deal with the complexity of teens behavior and cultural barriers.

As a response to Lolita's and Farfoura's challenges, I put Lolita and Farfoura in the same group and I became their new coach while re-grouping the Smurfs in Lolita's team in Farfoura's team. That gave a renewed sense of purpose to everyone and gave an impression of a new beginning. However, for Lolita, Farfoura was so sober. This led Lolita to lose motivation again after a while. The smurfettes team as I called them continued their training with low performance till the National Robot Competition qualifying tournament in 2017 started. As the girls were engaged with their personal problems instead of tinkering with the robots to solve their mission. The team only solved 30% of the robot mission in the qualifying tournament, not because the team required technical skills or technical comprehension, but out of emotional concerns. The team got the third place in the qualifying tournament but wasn't qualified to the national finals due to their score. Although the two girls were thrilled because they got a better rank than the male groups, Lolita decided that she would stop her robotics training.

After a couple of months, Lolita started to get triggered to resume her work with robots. I met her again after 2017 National Robot Finals and she told me that, the competition preparation was troublesome for her, and she missed going to the beach and enjoy the summer vacation - which was a natural concern to a teen in her age - as she had to work on the robots during the summer vacation. However, after the competition was over she yearned those robot preparation moments and she craved the working environment.

In 2018 qualifications Lolita joined a new team with another two male students. The new team was excited at the start. One of her teammates was her teammate at school as well and the team seemed like they had a kind of harmony. During 2018 I took myself out of coaching and I was only observing and supervising. I visited all the enrolled teams after a month from starting their preparation training to check their robots and found a common problem in 5 teams (15 students) they all built a robot similar to the one they built in the year before. That was an indicator that all the 5 teams ceased to learn and adapt to a new mission. As a supervisor, in that case, I was not handling the technical problems of a digital tool but I was dealing with a fixed mindset problem and I had to go beyond the technology box. I began to challenge each team of the 5 teams. I represented to them their technical problems and left them to think, while kept following up with their coaches. After a couple of weeks, the coaches lost command on Lolita and her team. Hence, I had to investigate what was going on. After a conversation with Lolita, I started to understand that Lolita lost motivation as she felt ineffective. One day I asked her to volunteer and to help new Robot camp comers, where by chance one of the newcomers was a male school mate of her. Once she started this volunteering experience, I found her acting as another one as if she retrieved all the coding in the world and she told me (please let me live the moment!). At that moment, it was apparent to me that Lolita's difficulty wasn't about tinkering and making with technology but what tinkering and making with technology meant to her as a student seeking attention from her friends. I communicated this to the coaches, exchanged her team members and asked the coaches to give her responsibility. Every couple of days I got a complaint from Lolita's coaches but I insisted that the coaches should give her the right chance because the girl was clever and what was stopping her from tinkering were personal issues. Until one day I got a call from her coaches that Lolita's performance was getting better and they started to understand her.

During the National Robot Competition qualifying tournament in 2018, Lolita was working so hard because she was afraid to fail. After Lolita passed the tournament hardly with low score she became another one. She took her robot work soberly and in September 2018 with her team she received the bronze medal in the National Robot finals.

Discussion of the case

The Educational Technologist is a dynamic job associated with the quick changes in technology and different technology trends used in education. From my work experience over ten years I tend to agree with the definition mentioned by the Association for Educational Communications and Technology published in 1977, which reads as follows: "Education Technology is a complex, integrated process involving people, procedures, ideas, devices and organization for analyzing problems and devising, implementing, evaluating and managing solutions to those problems involved in all aspects of human learning". Lolita's case is a reflection of the mentioned definition. Going with Selwyn (2011) argument, we shouldn't disregard the cases where the students didn't continue in their making activities. Vossoughi and Bevan (2014) highlighted that most of the evidence presented in the current reports about making and Makerspaces is observed or self-reported during or soon after making experiences, and focus more on the nature and impact of extended participation than on the reasons some people may choose not to continue participating. However, Lolita's case is a sample of a challenge that an educational technologist might face when coaching students to tinker with a digital tool for a long duration. In the described case the digital tool was LEGO EV3 Robots. What I faced as an educational technologist with Lolita's case could be simply explained in the light of the Boekaerts model (Boekaerts, 2011) where the problem is not in the technology or the technical comprehension but the students' complex relationships with emotional challenges caused by parents, mates and work environment. That requires the educational technologist to be aware of those challenges and their effect on the students' performances. For example, in the narrated story the challenges started when Lolita's mother communicated to Lolita that she lacked teamwork skills. That was reflected in Lolita's behavior, so instead of acting in a proactive way, Lolita leaned back. Lolita's reaction could be seen under the light of Behaviorists learning theories within the law of "Associative shifting" for Thorndike, stating the fact "we may get a response, of which a learner is capable, associated with any other situation to which he is sensitive" (Simons, 2018). In Lolita's case, Lolita was sensitive to lead her team, to avoid criticism so instead of acting in a balanced way she went to the extreme side and left the work for her teammates. We can also analyze her behavior as presented in the light of the comparison between the "Fixed Mindset" and the "Growth Mindset" as explained by Carol Dweck. As once Lolita received negative feedback she ignored it and bypassed the work challenges to avoid criticism instead of learning from criticism to enhance her work attitude. Another challenge was the transfer of disappointment feelings among the team members even the coach, which was also demonstration for the difference between the "Fixed Mindset" and the "Growth Mindset", as once the team started to face some challenges in their tasks instead of trying comprising those challenges and persist to solve their own problems, they gave up easily and started to see their effort as fruitless or not worthing. Carol Dweck classified this as an indicator for a fixed mindset where the intelligence and general qualities couldn't be developed. On the other hand, Lolita resumed the training and got back to constructing because she missed the environment. Socio-constructivism here played a major role, as Lolita meant by yearning the work environment was desiring spending time in the presence of other teams from different age groups. The same feelings are reported by Martinez and Stager (2013) and Vossoughi and Bevan (2014) as common feelings in Makerspaces and making activities. Those feelings are in line with broader approaches such as social constructivist as Lolita was seeing herself in the eyes of others and she was mastering skills with the aid of peers which created a good feeling that helped her to return back. Once Lolita returned back she showed her will for self-regulated learning. As the robot activity is not a formal activity. And tinkering with robots for a long time needs a strong will from the participating student. As a conclusion to this situation, the good emotions that Lolita developed during her tinkering journey affected her will to return back. This point is a demonstration to Boekaerts (2011) model and emotions effect on self-regulated learning.

We have come to the end, to sum up: what is that motivated Lolita? The factors that might have been affecting her were seeking attention from a school mate, taking responsibility due to the fear of loss, her inclination to the environment of study. Social Constructivist theories, Carol Dweck and Boekaerts model give us the right framework to interpret Lolita's learning behavior especially when self-regulation is needed. In Lolita's case, she was joining a National Robot Competition which is a non-formal learning activity depending on constructing, making, tinkering and engineering, and away from the school environment. However, solving a mission by building and programming a robot within a limited time frame and with technical constraints is a challenging task. Moreover, it requires teamwork skills and the ability to learn from peers and from mistakes. Here the role of the educational technologist as we see involves educational perception and goes beyond comprehending a piece of technology. The technology is just a tool here to build or to learn, and the human complexity formed by parents, environment, age needs, gender needs, and other constituents, couldn't be underestimated when technology is used. The narrated story gives us a perception of the reason beyond why many students might lose interest in Makerspaces or give up tinkering in the long term. An educational technologist with an instructor mindset in situations similar to the narrated case usually keeps his/her focus on the technical features of a digital tool and keeps his/her concern on the number of technical features comprehended by the student. However, an educational technologist with a constructor mindset goes beyond the technology features, and instead he/she using the technology to allow a student to master his/her life.

Second Case: Educational technologist interacting using online tools

In the following narrated case I was using an online platform to help a group of students to tinker and construct science and engineering projects. The objectives of that project were: helping the students before being nominated to join the National science fair; prepare the students to convert their ideas into scientific research or an engineering project; choose the best 30 science and engineering projects; And nominating students to represent Egypt in the international level.

Regardless of the environment online or face to face, there are fundamental factors between both setups, such as the educational technologist mindset, the culture and learning attitudes of the students. A rule of thumb we need to keep in mind is that by going online we are just changing the learning setup or the learning environment, but we are not changing the learning actors (teacher and students). The project started with an online preparation course for two weeks during the students mid-year vacation (From 27th of January 2019 to 7th of February 2019). Followed by selection for the students' projects abstracts and research plans in March 2019, and ended with the National finals in the 6th of April 2019. During the online training, my role was to put the content, run the webinars (Using Zoom), follow and guide the students through their learning and tinkering processes. That included answering their emails and reading all their submissions. The total number of participated students in the online training was 184 high school students from all over Egypt. It is worth noting that the online training saved us more than 200,000 EGP which is equivalent to 10,000 Euros.

The case as it unfolded

> Students get confused with the new learning environment. However, giving them a new chance while being firm is the key to make them go forth. As Engineers design the satellite missions, educators need to design the students milestones. As a writer writing an open ending story, the educator shall design an open ending mission for his/her students. (A quote from my diary)

I officially started my interaction with the students in the first webinar on 27th of January - where 26 students participated from 184 - during which I asked the students to submit a summary of their projects. The submission deadline was planned to be due by the second webinar, which was supposed to take place two days after the first. Sadly, only 14 students submitted their summaries before the deadline and to my disbelief two students submitted their summary in a voice message format. During the first webinar, I perceived that the students were confused as they thought that the Zoom access link of the first webinar is the (Learning Management System) LMS link. As a response to this, I postponed the second Webinar two more days than was planed and I recorded a video and shared it on google drive explaining the task again. In the video I explained to the students how to work with the LMS (Although there was a video explaining how to work with the LMS but inside the LMS). I added a condition on the LMS so that students couldn't proceed to the next step in the LMS, if they didn't submit the project summary. That way I managed my role as a learning partner to build a relationship with the students by studying every submission and commenting on it.

I also uploaded the webinars so those who couldn't attend it live they could have a chance to see it.
On Thursday 31[st] of January 9:10 am right before the start of the second webinar I had 65 submitted summaries, the students started to be more interactive on the LMS and sending questions investigating their grades. It was apparent to me that in an online setup students might feel disregarded and hence are vulnerable to feelings of loneliness and boredom. Balancing the students' freedom by adding goals or milestones and illustrating to them that they will not pass a milestone except after finishing the first milestone made the students take their online work more seriously. Or in other words, challenged the students to proceed.
To join the science fair the students were asked to find an idea and to start a scientific inquiry, which would involve making, tinkering and testing. To my surprise, the topics of the submitted projects shared by the students reflected the social psychological problems the students were facing. In other words students' culture and environment, altered their way of thinking. The students' main ideas were related to water pollution, air pollution, cancer, Robotics (mainly ideas related to science fiction) and Alzheimer.
The second Webinar took place on Thursday 31[st] of January 2019 and 23 students participated. The students were more interactive asking questions and discussing, and in contrast to the first webinar where students used the online chat feature in zoom to ask questions, in the second webinar 10 students were asking questions using their voice only while one female opened her video camera during the webinar and asked questions. I considered the girl a pioneer as she was the first to ask questions. The girl came from a far city close to upper Egypt and the male students started to interact after she started.
I was thrilled to see the students interacting in the second webinar and after the second webinar 94 students submitted their summaries. While reading all those summaries, I had a concern about what the participating students were thinking about a scientific problem. I had the feeling that this generation is really poor surrounded by cancer, wastes and energy threats. The submitted summaries were like their way to send a scream to save their future. In preparation of the third webinar, which took place on the second week of the course, I asked the students to submit an abstract. At 8 am on the day of the third webinar, the number of abstracts that had been sent off was 30 and the students' performance was visibly better.
My job then consisted in giving all the students comments. The comments varied from stimulating to encouraging. I found that this one sentence comment on the students' summaries and abstracts enhanced the students' interaction. It was apparent to me from the emails I exchanged with them that they were taking my comments seriously and that my comments acted as an icebreaker helping the students to feel supported and not forgotten.

During the two weeks, I wasn't seeing the students' tinkerings or projects, however, the students were requested to share with me their work progress. By the end of the course according to the LMS report, the total number of assigned students was 184, the number of students who passed the course completely was 91 students, the number of students who completed the course partially was 50 students, and the number of non-active students was 43 students.

Discussion of the case

When we use an online setup to construct with students, we need to consider the psychology of the educational technologist and the learner in the e-learning setup. For example, what are the educational technologist feelings when interacting with a screen, dealing with the students panic by emails, and how the educational technologist can be self-motivated and motivates others? For instance, if the educational technologist used to energize by moving inside the classroom how he/she maintains the same energy while sitting during a webinar?

In a review about teachers-students relationships and the effect of this relation on both especially the teacher, Spilt and colleague (2011) highlight the effect of the teacher's relationship with the students on the teacher wellbeing and emotional stability. The review is one of the rare reviews discussing the teacher-student relationship from the teacher's side, as most of the studies usually focus on the students' side of the relation. Although the review is discussing this relation in a regular classroom setup, the bond between the educational technologist and a student should be put into consideration to have a successful online course. From the students' side as reflected in the case narrated, when we go to an online setup the students might develop the feelings of loneliness and boredom. If the educational technologist role here was to set deadlines for the students or to upload materials without giving the needed attention to the students enrolled, the students' interaction would be dropped. However, the educational technologist in the narrated case was someone constructing challenges for the students. The dialogs I built through emails with the students, while setting time constrained challenges helped me to keep the students engaged. Following Neill (2002) the humanized interaction between the educational technologist and a student, is a powerful formula to enhance personal growth. In her book, "Mindset" and the interviews followed her book Carol Dweck discussed the importance of challenging students on the growth of their minds. When designing the online course I put my personal experience into consideration. As I experienced being an e-learner myself where the online courses which I mastered or captured my interest, were the courses whose teachers kept engaging the learner during the course and trying to use different communication channels. However courses I joined that were designed as a series of videos with no invitation from the lecturer side to engage the learners, I was losing interest in the mid of the course.

Continuing with the importance of the humans relationships, comparing the LMS reports with the students' performances, it was apparent to me that spending more time on the LMS doesn't mean more progress, it can mean the student is opening the LMS for a longer time with passive interaction or the student might be struggling with the LMS. This observation reflects the importance of the educational technologist role as someone not just taking the LMS data as an indicator of the student's progress. However, the educational technologist in an online setup should put his/her time to use the technology and personal communication to understand the students and construct with them. To sum up the educational technologist as someone using online tools to help the students to tinker, he/she should put a time to construct challenges and to establish relationships with the students. When we teach to provide students with instructions we lower the gaze on what is going on the students' side but when we teach to construct with students we build challenges and relationships, which enhance the students' learning experience and progress.

Third Case: Educational technologist co-creating with an organization

In this third case, I am discussing some issues, which involved myself as an educational technologist who was co-creating with teachers. This case will show the major challenges faced by teachers when they are called to tinker.

I started giving Robots and Engineering short workshops with my team as a response to external organizations requests since 2011. The workshops had to be short in time, and with high and ambitious learning goals. For example, discovering how robots work, how Ferris wheel works, Faraday's law or other concepts. The workshop duration might usually range from 45 mins to 90 mins. As we started, our main challenge was how to give students adequate information about the tasks that they were supposed to complete, while at the same time giving them enough freedom to tinker and discovery for themselves. The result was that the method that we eventually adopted was itself a product of tinkering, which we created along with the students. I referred to this case as co-creating with organizations to reflect our cooperation with any organization such as NGO, governmental organization, a company, a school or a teacher who was interested to co-create with my team. From 2011 till today, we have been cooperating with many organizations inside and outside Egypt to deliver those types of workshops. We have dealt with thousands of students. At the beginning of every workshop, we asked the organization with which we were collaborating about their goals and what they were expecting the students to learn. Then we designed the workshop so as to enable the students to tinker, discover and learn new concepts.

The case as it unfolded

October 2018, I had the chance to co-create in a country in the North of Europe. My main task was supposed to give a 100 mins robotics workshop to 3rd and 5th-grade students in a governmental school. The school was equipped by LEGO robots as WEDO sets and EV3 sets and iPads to program the sets. I was curious to interact with the students in a different language and to see the students' tinkerings in a different environment. For the privacy of my mission, I am describing here what happened in terms of the work done, and I won't mention the name of the country or the name of the school where I executed my workshops.

Entering the school where I supposed to give my workshops, I got welcomed by female teachers whom I was supposed to work with. Holding a friendly conversation with both I noted that, they knew nothing about robots. As the teachers had no time to use the robots sets or to learn how to use it, however, they showed high interest and curiosity to learn. On my way to the classroom where I was going to give my workshop, I passed by a room that was supposed to be hosting a robot club. Examining the school robot club was out of the scope of my work, however, I had a look over the room, and asked a couple of questions to understand how the robot club was run. Entering the robot club, I found 5 boys and 1 girl from the 5th and 6th grades working with LEGO WEDO sets during their break time. The students were tinkering and no adult was present. To me, the students seemed to be unable to link their observations to the mechanics and physics laws. On the side wall of the room, there was a shelf with ready-constructed EV3 robots. All the robots shared the same design and built by following the same instructions. This observation can be quickly noted by a LEGO Robot practitioner. After a while, I got to know from the teacher managing the robot club that he was the only teacher in the school organizing the robot activity and to my surprise, when I requested from him to disassemble the EV3 ready-constructed robots before my workshop, the teacher refused to disassemble the designs. And I had to use the WEDO robot sets instead. The reason of his refusal according to the teacher's claim was University students helped him assemble the EV3 robots using the EV3 manual, hence he wanted to keep the EV3 robot assembled as it would be hard to assemble those robot sets again. I entered the class for the 3rd-grade students to start my 100 mins workshop with 17 students (10 girls and 7 boys). It was the first time for those students to tinker with LEGO robots and I had a personal challenge which was the language barrier. I was talking in English during the workshop as I am not familiar with the students' native language, but the students weren't familiar with English. However, I got help from the class teacher as she translated what I was saying from English into the students' native language. Interestingly the students got a lot of my comments through my body language and eye contact and they were delighted when I said something in English and they understood it without translation.

I divided the students into groups of their choice. The group was composed of 3 to 4 students. Each group got a WEDO set and an iPad for programming the robot. The robot set was given disassembled to the students. I gave them a 10-mins introduction about robots, their functions and what are the parts in the set. Then I asked them to construct a robot capable of playing tug the war. The students got excited then, as usual, after around 10 mins they asked to get instructions. That was a common reaction that I used to receive from the students whenever I gave this workshop. The classroom teacher wondered if there were instructions or a manual she could use to assist the students, which was also a common reaction I used to receive from teachers as well. As a response, I gave the teacher and students my common reply which was, they had to tinker and follow their intuition and I wouldn't provide them with instructions.

I was supposed to be present inside the classroom for 120 mins with 20 mins lunch break in the middle of the workshop. I was thrilled to see students expressing their excitement and joy while they were tinkering and building. The thrill of excitement was visible when I saw them coming back from lunch as quick as they could to resume their work on the robots. The students kept building, tinkering and constructing through trial and error. And I kept rotating between the groups to regard them and to give them my comments on their constructions. The purpose of my comments was to guide the students without intervention to their tinkerings and to show them how to link their trials to science and engineering concepts.

By the end of the workshop, the classroom teacher gave me the following feedback from the students: "The students liked the session and they asked for more sessions from this type. They enjoyed building and discovering by building. They discovered how to balance objects and how to use motors to move an artifact by experimentation and not by instructions." The teacher enjoyed learning with the students as well. That was her feedback about her own experience. She expressed her joy of comprehending scientific concepts in a short time by practice. I received another comment from a co-teacher who joined later, which was about the type of mission I gave to the students. The mission as mentioned earlier was to design a robot to play tug the war. Consequently, The robot should be able to move forward and backward and I added a constraint that was to use one motor only. I ran conversations with the students and enabled the students to tinker, try and fail until they built the robots. By the end of the workshop, each group built a uniquely different design that was able to move forward and backward in a good way and capable of playing tug the war. For me, each design was an art.

After a couple of days, I gave the same workshop to another group of students inside the same school. The second group was in the fifth grade. I received the same feedback and reached similar results. The co-teacher who attended the first workshop attended the 5th-grade workshop as well. This time he had experience from the first workshop. His first workshop experience inspired him to guide the 5th-grade students and to encourage them to solve the challenge via tinkering.

After a couple of months, I returned back to Egypt and gave a similar workshop on the 30th of March 2019 to 30 high school girls. The workshop was a part of a girls day organized by one of the big Multinational Technology companies in Egypt. The girls were divided into two groups. Each group was divided into 4 subgroups. I used disassembled LEGO EV3 sets and challenged the students to build in 45 mins a robot able to play tug the war. There was a teacher with the girls, who as usual was interested to join the workshop as a learner. In the start of the workshop, I asked the students "what are the type of robots?" , and "what is a robot?" As usual, I received common answers from a couple of students as "there are two types of robots the LEGO EV3 and Arduino" and "a robot is a brain we connect with a wire to the computer and download a program". Those type of answers was commonly received from students who had previous experiences in building robots in Makerspaces in Egypt. In the two main groups, I had two girls who claimed that they joined robotics competitions in Egypt and achieved a high rank. However, the two girls were struggling in building their robots with their team. By the end of the workshop, we got 7 robots (representing 7 subgroups) playing tug the war and we had only one subgroup who couldn't complete the challenge. That group had a problem in teamwork and the girls weren't working in harmony.

I had two female engineers from the organizing Multinational company who were taking photos of the workshop, however, they got engaged in the workshop. Seeing the adults excited to get engaged and use their hands to tinker and build is a common response that I always received during the past 8 years. I used to give the same workshop for 4 years now in the girls day organized by the same Multinational company. The company each year distributed an internal feedback survey between the participating students to evaluate the robot workshop during the girls day. The following feedback was what I received through the company over the 4 years “All students enjoyed the robot workshop. The students enjoyed learning about robots via building and tinkering”.

Discussion of the case

What makes tinkering an educational practice, is how you teach the student to examine facts in comparison with the traditional practiced teaching methods where students just watch or follow an experiment. Giving the students the chance to construct and tinker, we open the chances for the students to experience the exploration and uncertainty of results. As Vossoughi and Bevan (2014) expressed “Making thus looks and feels different from more traditional open-ended inquiry activities” (p.4).

The troubleshooting engaged with constructing always opens the door for tinkering and hence discovering new approaches. One of the common misunderstandings of how constructing and tinkering with tools could be used in education, is looking at the digital tools used in construction as tools limited to technology education. Here the students work mainly on assembly, handled instructions by their teachers and lack proper mentoring to link what they are experiencing with their hands to science, hence depriving the students of achieving better perception and gaining new skills. That fact was reflected in the two high school girls answers, who participated in the girls day when they gave an abstracted definition to what are the types of robots. Categorizing robots by the type of the Microcontroller or defining the robot as a brain which we just connect wires to a laptop to program it, is not only a very abstracted answer but also far away from perceiving robotics. Here as Beer (1973) describes “we mistake the model for the reality” (p.1). As we are engaged with the model which is here the technical details of the tool in hand more than understanding the science and applications of the tool, resulting in minimizing our ability to learn through creation. The girls' answer is a phenomenon which is often seen as a result of getting students engaged with a Makerspace without a mentor or, the mentor in the Makerspace gives the participants instructions to follow.

Under that light, the question what are the goals of education? should be considered. One of the main goals of education is to allow the students to learn and to apply what they are learning. By applying we are examining what we learned and we face uncertainties. Eventually, we discover new approaches or develop new technologies. Which explains the following quote by Pitt (2018):

> I suggested teaching the sciences by teaching the history of science, starting in the first grade. The idea was to have the student's intellectual development parallel the development of science. So, in the first grade, the student is a free agent exploring the world around her, reporting back what she finds. In grade two, they are introduced to the idea that they can improve their exploration by employing some principles, and they start becoming little Aristotles, until the Aristotelian approach and assumptions fail, and they are given some of the tools to figure out a different approach, and so on until they are studying the world in a Newtonian fashion by their final year of high school. One of the ideas here is to let them play with a theoretical framework until it breaks down, and they have to find some other set of principles to guide their explorations. There are several lessons to be taken away here. The first is that science is an ongoing process that changes in many ways over time. The second is that one of the major forces affecting changes in the sciences is the introduction of novel technologies. (p.34)

When we use digital tools or even recycled materials to understand and apply science, eventually the learner is linked to technology and science while the door of innovation and creation starts to be opened to the learner. Under that setting, we can see the role of construction tools as Lego Robots in education technology. Those tools are not only used by students to understand science or by the teacher to communicate science, but also within those tools a strong potential for the students to be creators and constructors of their own experiment and to have their own minilabs. The link between using digital tools in making and education technology opens the need to redefine the role of the educational technologist and what background should the educational technologist have to handle the tinkering environment uncertainties. When the educational technologist or a teacher with a constructor mindset integrates a piece of technology he/she constructs a setup of discovery and not instructing a known experiment.

Hence the students got challenged by not having instructions, and they have no choice except to tinker, explore, try and reach the moment of creation and achievement. Either in the narrated experience or in my other experiences, I perceived similar actions and reactions from students. Students usually after 5mins ask for instructions. If there was a teacher, she would start to worry about the students' abilities to solve the mission. However, once the students tinker, they started to wonder and new doors were opened in their minds. And once they reached this stage they were opened for learning and deep understanding. As much as the students did the effort to pass the given challenge, as much as they were thrilled with the sense of achievement. The same response was reported by Martinez and Stager (2013) and Vossoughi and Bevan (2014) describing why students were attracted to making. As the feelings of achievement and solving a challenge via tinkering amplifies self-confidence.

When it comes to teachers and tinkering there is a concern that most of the teachers lack the technical knowledge concerning a certain tool or they aren't masters of technologies like robots, the Internet of Things, or similar technologies. This fact explains the reasons behind the abstracted way most of the teachers engage a construction technology tool in their classroom.

We can't blame teachers for lacking the needed technical knowledge to tinker with a tool like LEGO EV3. Teachers are already overloaded with other tasks associated with their duty. Educators insisting on the concept of having teachers and schools as the only source of STEM development and tinkering aren't developing a significant change in education. In contrary co-creation and supporting, teachers on their mission could be one of the solutions on how we could integrate tinkering inside the school environment. When an educational technologist is from outside the school environment he/she adds fresh air to the classroom environment, allowing the teacher to take a break from the full responsibility, and hence the teacher has a chance to observe and learn. Many educators are afraid of students' frustration that they might face when getting engaged with undefined tasks, or the troubleshooting associated with those tasks. Simply they are avoiding tinkering. Those feelings could be a projection of the teacher's own fear. However, students when they tinker and pass their frustration they surprise us and they learn new things (Martinez & Stager, 2013).

An educational technologist with a constructor mindset is a supportive agent who knows how to balance between passing a piece of information to students and leaving them dealing with their frustration to learn and discover. The teachers' fear from students' frustration is restraining the students' tinkerings, as reflected in the narrated story of the school when the teacher brought University students to construct the EV3 sets based on the LEGO basic design manual and refusing to disassemble the kits. This way he limited the school students' experiences by directing them to program basic functions on the EV3 platform hence depriving the students for instance from co-relating the effect of different designs to the robot actions. In other words, we teach the students to deal with linear situations by directing the students' attention to add a piece of code and watch a known response for the robot, instead of teaching the students to face complex situations as the effect of a student's tinkered design on the robot response.

During short workshops, I used to rely on the human brain curiosity while pushing the students to act naturally as Aristotle during the workshop. I gave limited information and 10 mins discussion about the nature of the mission and the tools or resources in hand, then let the participants explore and do the rest. The narrated story is a sample of the response pattern. It's not a single case but a group of experiences entangled in one narrated story. It is worth noting that one of the main limitations in short time co-creating workshops is continuity. Most of the times the students come with new creations and designs, that we need to give a deeper look and study more. In other words, we need to develop the students' tinkerings. This fact emphasizes the importance of construction environments separated from the traditional schooling system.

Discussion

Following the timeline from Dewey to Papert, the current schooling system is supposed to embrace, constructing and tinkering with digital tools, in order to prepare the future generations. However, we often see the use of digital tools inside the schooling system to support the teacher's role as an instructor and a class manager. When it comes to engineering, constructing and tinkering activities, K-12 education is facing a challenge that belongs to the second half of the 20th century, where less expensive theoretical classes prevailed over engineering labs or design work. Over time, this resulted in the removal of the engineering design experience from not only the college curriculum but also from K-12 education. Hands-on work started to be for vocational education and seen as unserious work, or seen as a type of work for those who have less mathematical and analysis skills. After a couple of decades, faculties and employers started to witness the fact that engineering graduates are not qualified enough in any real engineering design work, and there is a lack of interest in STEM fields (Blikstein, 2013). In light of this fact, the calls and worldwide actions asking for integrating design and engineering work in the K-12 studies are flourishing.

From my experience in co-creating with teachers, in many cases, the digital tools are forced in the classroom, while teachers might not be in need to use those tools. Other times teachers are in continuous pressure of learning about new tools, which consumes them in technical details instead of serving educational purposes. The problem is within the current educational technology business which focuses on introducing a digital tool in the schooling system and raising the expectations for a positive change in the education outcomes (such as encouraging more students to be inventors, creators, or digital citizens). However, as Papert argued looking for a single factor such as using a digital tool in the classroom to change a complex system as the education system while keeping everything else the same, is reducing the effect of humans and culture. According to Papert (1987):

> The context for human development is always a culture, never an isolated technology. In the presence of computers, cultures might change and with them people's ways of learning and thinking. But if you want to understand (or influence) the change, you have to center your attention on the culture -- not on the computer. (P.2)

The Education system is a complex system, in which many factors are playing an important role as we discussed in the narrated cases. Taking a look at the cases we can understand the relation between Papert's argument and what is going on in the education technology debates. We can list dozens of studies talking about the importance of using Smartboards, iPads, Smartphones and other digital devices in the classroom, and at the same time, we can list dozens of studies talking about the concerns and failures of those same devices in the classroom. The problem is when we introduce technology, we think that we introduced technology X and that will automatically yield Y, which is what we are looking for, and we overlook the complexity of the education system. However the higher the level of complexity of a system is, the higher the level uncertainty is as to the success of our interventions. Dakers (2017) argues:

> that there is much more to technology education than the mastering of technological know-how and the techniques associated with the fabrication of artifacts. Considered thus, technology cannot be autonomous, it is, rather, part of a more complex network of

> relationships that include social, economic, political, cultural, and philosophical discourses that both affect human beings and is affected by human beings.(p.5)

In other words, to be certain about the results of any digital tool and its effect on education, we should be able to control all the variables of the system and certain of the actions and reactions caused by each variable. For instance, we should be able to control the physical state of the students when exposed to digital screens, we should be able to control the politics, we should be able to control the teacher's mental state and so on. In their article "Education technology research in VUCA world" (VUCA: Volatility, Uncertainty, Complexity and Ambiguity) , Revees and Revees (2015) discussed the possible consequences, if we continued to focus our education technology research on the latest hype in the tech industry rather than the important educational issues or problems faced by practitioners. For example, we are at risk of losing any meaningful impact on the fundamental challenges of teaching and learning that will emerge in the coming decades than we have over the past 60 years.

Table 1: Education technology research focused on things vs. problems as presented in (Revees & Revees, 2015)

Research focused on *things* is what we do	**Research focused on *problems* is what we should do**
• Learning Analytics • Mobile Learning • Online Learning • 3D Printing • Games and Simulations • Wearable Technology • Clickers and SmartBoards • Machine Learning • Virtual Assistants • Immersive Learning	• Ineffective teaching • Inadequate higher order learning • Poor learner motivation • Failure to engage • Little preparation for real world • Lack of intellectual curiosity • Undeveloped creativity • Weak communication skills • Insufficient time-on-task • Declining value of degrees

When looking to education technology and education as a complex system associated with uncertainties, we can see the importance of reconstructing the education system to embrace making and tinkering as reflected in figure (1). Making and tinkering put both teachers and students into a position of partners, despite they are still characterized by different levels of experience. Instead of providing students with instructions to follow, when we invite students to tinker, we are more open to whatever useful may emerge in the process of making. The teacher in that mindset is prepared to face challenges and not stressed by the continuous demand of following a set of instructions that should yield a specific outcome. Taking climate changes and challenges as a living example and a threat to future generations. Can we say to students that the reason for climate change and the threats associated with climate change are a result of the high level of Carbon dioxide only? Looking to the climate change problem that way looks simple and naive. The students need to know the complexity associated with climate change. There are industries beyond it, culture beyond it, politics beyond it and other factors. In other words, students need to know that there is a network of complex relationships playing an active role in climate change.

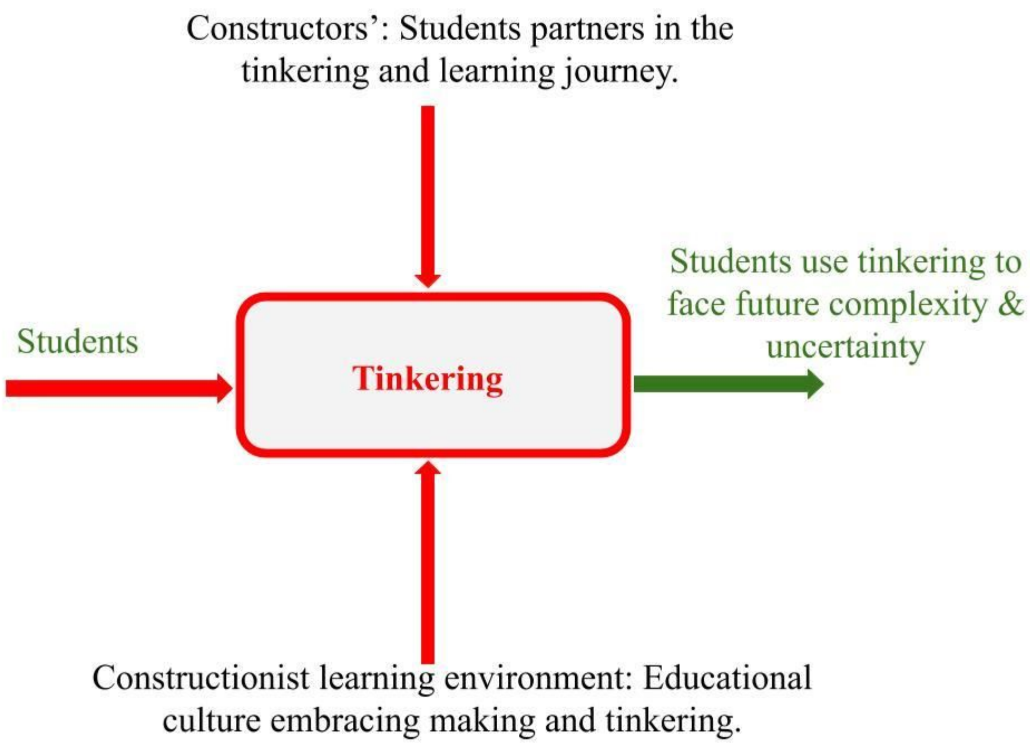

Figure 1. The elements of an education system based on tinkering

From the above discussion, we can highlight an important educative value when we build education systems with constructionism and tinkering in the core of those systems, which is, tinkering and constructing with digital tools, are tools for the students to face future uncertainties, or to face a VUCA world.

Tinkering ignites students' imaginations and ideas while promoting self-regulation skills among students. Tinkering allows a student to take control of his/her life, be more active and be responsible for his/her own learning. It liberates learners from their dependency of being instructed, creates serendipity over the structure and breaks the role of a teacher as a classroom manager, thus opening the door for students to feel safe by acknowledging that there is an alternate answer. We usually assess students by assessing problem-solving using a traditional step by step model, while non-linear, collaborative, or more artistic problem-solving styles are called messy, intuitive and considered unreliable. However when using tinkering we allow all students to learn in their own way, at their own pace and we value effort and creativity (Martinez & Stager, 2013). This fact is what made many students across the world get attracted to the Makerspaces, maker faires, robot competitions, or any kind of making events and spaces. As, students are searching for better recognition and a sense of achievement away from the traditional school system. This pure fact illustrates the need of either rebuilding the current educational systems as Reggio Emilia did or, based on my practical experience building a constructionist learning environment that can act as a hub, serving a certain area. When building a constructionist learning system, we should consider that, first, it is a part of students' education and not an extracurricular activity, and, secondly, educational technologists working as constructors are an important active element in this system. For example, if we run a constructionist learning system as a hub inside a city for school students, not only will the students practice tinkering and learn via tinkering, but also they will have access to a constant place where they are guided and developing their projects. Students can have the choice to learn about a certain topic inside the school or go to the hub and learn by pure doing or do both. And when it comes to assessment, the time, effort and creativity of the projects developed by the students in the hub add points to their school score. The concept of a shared hub minimizes the expenses that a city might need to cover each school, opens the door to students to exchange experiences with each other regardless of age or school. Blikstein (2013) explained the motives beyond starting Fablab@school as he saw how students' tinkerings and projects are constrained by 50 mins session. While students need sustainable access to constructing space to develop their projects. That makes the constructionist hub an attractive place for students to develop their learning and tinkerings, and at the same time overcoming the concerns we raised in the theoretical background related to Makerspaces inside schools. Figure (2) illustrates the principles of the constructionist learning hub.

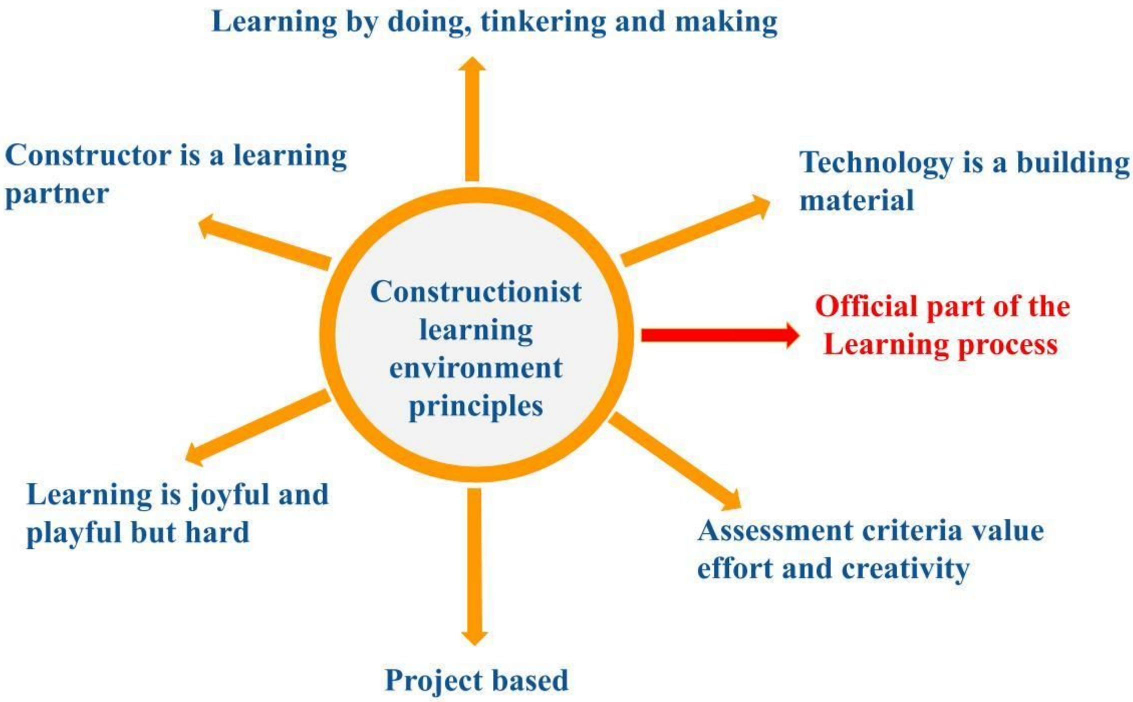

Figure 2 . Constructionist learning environment principles

Conclusion

From my work experience reflected in the described cases, the theoretical background and discussion presented in this thesis we can articulate the role of the educational technologist as a constructor instead of instructor. An educational technologist as a constructor listens carefully to the student's needs and problems beyond formalities, communicates with different parties as parents and others to understand deeply the challenges a student is facing and have the ability to put himself/herself in the student's place. Care, patience and ability to perform a conversation and a dialog with the students are skills that an educational technologist as a constructor should have or should gain as a partner to students. An educational technologist self-awareness is a success factor helping him/her to overcome depression and to help the students to overcome their own obstacles. Hence, the educational technologist as a constructor needs to prepare a suitable environment that encourages constructive learning and be aware of the factors affecting the student's behaviors and to be aware with the pedagogical side, cultural side, political side and the school teacher side when using a digital tool. Last but not least the educational technologist as a constructor is an ethnographer, documentarian, studio manager and wise leader.

The educational technologist acting as constructor need to be engaged with meaningful tinkering and train the students about how to face the future challenges, motivate students to learn by doing, unleashing students' creativity and to make education an attractive journey. What we call meaningful tinkering isn't a learning approach suitable for top-scoring students at schools only, but also meaningful tinkering is a learning approach to discover the creativity of students who get bored, lost, and underestimated in the traditional schooling system. As shown in figure (3), what we mean by meaningful tinkering is: building communities, by building constructionist learning environments, with educational technologists as constructors supporting the students' tinkerings, linking those tinkerings to science, opening the chances for those students to develop their tinkerings and preparing students for future uncertainties.

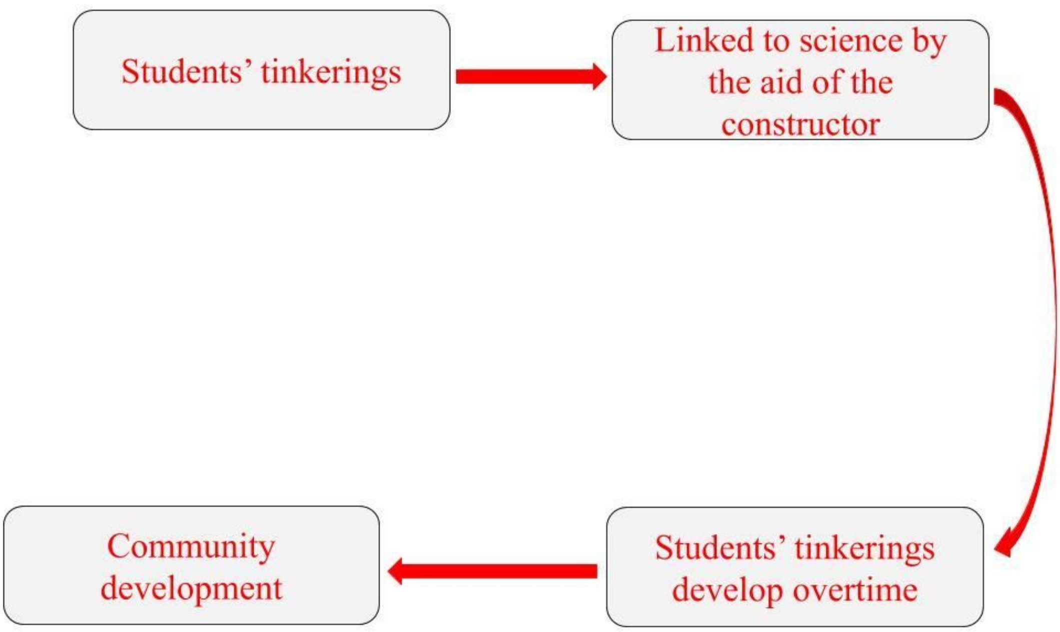

Figure 3. Meaningful tinkering in a construction learning environment

Acknowledgements

I would like to thank my supervisor Prof. Emanuele Bardone for his guidance, support and mentoring. Special thanks to my husband Yasser and my daughter Malak for standing beside me during my work journey. Last but not least I would like to thank my sister Esraa, my friend Manal, my students and Ideas Gym team. Without you all I couldn't make it.

Author's declaration

I hereby declare that I have written this thesis independently and that all contributions of other authors and supporters have been referenced. The thesis has been written in accordance with the requirements for graduation theses of the Institute of Education of the University of Tartu and is in compliance with good academic practices.

Marwa Seoudy

--------------------------(Signature)
27.05.2019

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