Creative Technologies – Synopsis
UdiGitalEdu – University of Girona

The term 'Creative Technologies' is very general and can be approached from different perspectives. In the framework of the **MonTech project**, when we refer to Creative Technologies, we mean **Technologies for Creative Learning**, so what we are proposing is a vision of technology as a medium of creative expression.

To explain this concept, its main ideas, and the methods arising from them, we will introduce six topics, all of them related to creative technologies and interconnected with each other: **Constructionism, Maker Education, Computational Thinking, Creative Computing, STEAM and Tinkering.**

1. Constructionism

To explain **Constructionism**, we first have to take a step back and explain what **Constructivism** is. **Jean Piaget** —well known for his contributions to the field of developmental psychology, his studies on childhood and his theory of cognitive development— is considered the father of Constructivism, a learning theory which, to summarize it as much as possible, states that knowledge acquisition is a process of **continuous self-construction**. The child **builds** his/her knowledge with what is **meaningful** to him/her, making a process of assimilation of what is new with respect to what he/she already knows.

Seymour Papert, a disciple of Piaget and professor at the MIT Media Lab, developed ideas over the years that eventually took the form of a new learning theory: **Constructionism**. Papert stated that humans construct their knowledge especially well when they participate in the construction of shareable **'artifacts'** that are personally meaningful to them. According to him, children (and humans, in general) construct knowledge in their mind while building something with their hands. These 'artifacts' can be anything from a sand castle to a poem to a robot to any tangible object.

Papert and Piaget were adept of the idea that the child builds his knowledge from his interactions with the learning object. However, **for Papert the learning process would be more effective if the student constructed a significant shareable**

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product after his interactions with the object. This is the main difference between Constructivism and Constructionism.

Constructionist learning involves students drawing their own conclusions through creative experimentation and the making of social objects. The constructionist teacher creates conditions for invention, taking on a mediator role rather than adopting an instructional role. Teaching "at" students is replaced by assisting them to understand —and help one another to understand— problems in a hands-on way. The teacher's role is not to be a lecturer but a facilitator who coaches students to attaining their own goals.

Papert's most popular and influential book, *Mindstorms: Children, Computers, And Powerful Ideas* (1980), established the foundations of what we now call **Computational Thinking, Creative Computing and Maker Education**. In this book he also introduced **LOGO**, the first educational programming language for children, which he had designed with some colleagues a few years earlier. But above all, the most important idea on which the whole book revolves is that **the computer, if used well, can be a tool for constructing knowledge and a medium of self-expression.**

Papert anticipated by many years what has come to be known as educational technologies. **His concern was that children would end up using technology only as users and consumers.** With LOGO and his constructionist ideas, he inspired hundreds of teachers and researchers who have later worked to design ways for children to use technology as creators and producers. Ways where they can express themselves creatively, critically and collaboratively.

Among Papert's students and disciples, it is important to mention **Mitchel Resnick**, who is the LEGO Papert Professor of Learning Research at the MIT Media Lab. He is the founder and leader of the **Lifelong Kindergarten research group** (LLK). Its team develops technologies and activities to engage people (especially children). One of them is the Scratch programming software and online community (and evolution of LOGO), the world's leading coding platform for kids. His research group also collaborates with the LEGO Company on the development of new educational ideas and products, including LEGO Mindstorms and LEGO WeDo robotics kits.

The technologies developed by the LLK group have the explicit goal of helping people develop as creative thinkers. They are designed to support what they call the **"creative thinking spiral"** (Figure 1). In this process, people imagine what they want to do, create a project based on their ideas, play with their creations, share their ideas and creations with others, reflect on their experiences – all of which leads them to imagine new ideas and new projects. As students go through this process, over and over, they learn to develop their own ideas, try them out, test the boundaries, experiment with alternatives, get input from others, and generate new ideas based on their experiences. As Resnich (2007) explains, this is the process children in kindergarten

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learn, without the boundaries and restrictions that they find later in traditional school. It's the natural way humans learn and is how learning should be approached during our whole life, hence the name of the **Lifelong Kindergarten** group.

Figure 1. Creative thinking spiral, by Mitchel Resnick (2007).

To learn more:

- Papert, Seymour (1980). *Mindstorms: Children, Computers, and Powerful Ideas*, New York: Basic Books.
- Piaget, J. (1936). *Origins of intelligence in the child*. London: Routledge & Kegan Paul.
- Resnick, Mitchel. (2007). *Sowing the Seeds for a more Creative Society. Learning and Leading with Technology*. 35. 10.1145/1518701.2167142. https://www.researchgate.net/publication/241624003_Sowing_the_Seeds_for_a_more_Creative_Society
- Resnick, Mitchell (2007). *All I really All I Really Need to Know (About Creative Thinking) I Learned (By Studying How Children Learn) in Kindergarten* https://www.researchgate.net/publication/221629475_All_I_really_need_to_know_about_creative_thinking_I_learned_by_studying_how_children_learn_in_kindergarten

2. Maker Education

The **Maker Movement** is a contemporary culture that is based on people's innate desire to make things. It is a movement that has traditionally been inspired by the **culture of DIY (Do It Yourself) or more recently DIWO (Do It With Others)**, but adds to them the power and revolution of digital technologies and Internet. Maker culture empowers people through knowledge and tools, but also promotes the creation in shared spaces (co-creation, co-working), where people come together (physically or virtually) to create, learn, share, play, participate, teach, etc. **The maker movement promotes informal, cooperative and networked learning and proposes the exploration of intersections between traditionally separate disciplines (such as robotics and fine arts)**. In this sense, there might be some confusion from some voices labeling the maker culture as being techno-centric, while, on the contrary, it is precisely a culture where we can see how arts, sciences and technology are integrated.

What makes today's makers different from the inventors or craftsmen of the past, is the power that new digital technologies and the Knowledge Society now offer them. There are almost no limits, and today a group of makers can launch a satellite into space, create an impressive sculpture for their city, or develop a new mobile application that millions of people will download.

Recently this Maker Movement is making a strong entry into education. It is what some have called **Maker Education**, **Educational Making, or Maker-Centered Learning**. In fact, the maker philosophy connects perfectly with active learning pedagogies and project-based learning methodologies. Many schools are currently exploring ways to encourage children to take control of their own learning while they make/build/create/invent within workshops, makerspaces, hackspaces, etc. In some way this connects with what Dewey had imagined and described in his book “School of tomorrow” more than 100 years ago.

Today, studies are now beginning to analyse the maker education phenomenon. Among these, it is important to highlight the analysis being carried out by the prestigious Project ZERO of the Harvard Graduate School of Education. They have arrived at a very interesting conclusion: “Students learn a tremendous amount through maker-centered learning experiences, whether these experiences take place inside or outside of makerspaces and tinkering studios. There is no doubt that students learn new skills and technologies as they build, tinker, re/design, and hack, especially when they do these things together. **However, the most important benefits of maker education are neither STEM skills nor technical preparation for the next industrial revolution. Though these benefits may accrue along the way, the most salient benefits of maker-centered learning for young people have to do with**

developing a sense of self and a sense of community that empower them to engage with and shape the designed dimension of their world".

Inspired by Seymour Papert's work and ideas, Sylvia Martinez and Gary Stager wrote the book *Invent to Learn: Making, Tinkering and Engineering in the classroom*. This book offers some key ideas that are fully related to Maker Education:

- **Idea 1: Learning by Doing!** Learning becomes solidified when the content and pedagogy are authentic and relevant. That is, in order for deep learning to occur, one must interact with the content and knowledge directly. Makerspace allows this to occur for students, by making them the creators and designers of their own knowledge. The same premise is applicable to educators.

- **Idea 2: Learning to Learn!** The educational system that has been in place for the past century has taught students how to be passive learners; sit, listen, and learn as the teacher fills you with knowledge. The constructionists and maker movement takes learning from being a passive event to an active one.

- **Idea 3: You Can't Get It Right Without Getting It Wrong!** It is very important to lose the fear of making a mistake. Error is a necessary requirement in every creative process and every innovation. In the workshops you always learn through trial-and-error methodologies.

- **Idea 4: Taking Time!** In the traditional (non-constructionist) classroom, every minute of the day is scheduled and planned for. Lessons and activities switch often and someone is always telling students what to do. The constructionist movement allows students to develop a plan, implement the plan, perhaps fail at the plan, try again, and at the same time managing the time they have to complete the task. This process encourages persistence, resilience, complex problem solving, and innovation.

- **Idea 5: Hard fun!** The fact that the workshop is fun does not in any way mean that the effort has to disappear, but that it has to be linked to motivating and stimulating practices. Hard fun is a Papert concept that explains that many times something is fun precisely because it is complicated. Effort and fun are not at odds.

- **Idea 6: Objects to think with!** The object-with-what-to-think about is another concept of Papert. In the preface to his book Mindstorms, he himself explains how in his childhood he "fell in love" with gears, and how they allowed him to self-learn many mathematical concepts throughout his life.

- **Idea 7: Do Unto Ourselves What We Do Unto Our Students**. In our classrooms, we tend to have defined the traditional roles of teacher and student. One is the receptor of knowledge and one is the expert and keeper of the knowledge. In a makerspace, we are asked to set aside our traditional understanding of roles and engage in learning as both a teacher and a student. A constructionist educator is a facilitator, guide and inquisitor at the heart of student centered learning.

To learn more:

- *Maker-Centered Learning and the Development of the Self* (2015), Harvard Graduate School of Education. http://www.pz.harvard.edu/
- Martinez, S.L., and G. Stager (2013). *Invent to learn: Making, tinkering, and engineering in the classroom*. Torrance, CA: Constructing Modern Knowledge Press.

3. Computational Thinking

In 1980, Seymour Papert introduced the term "computational thinking" in his book "Mindstorms: Children, computers, and powerful ideas". In 1996, the same Papert, presented the idea in the context of mathematical learning in his article "An Exploration in the Space of Mathematics Education", but it was not until 2006 that Jeannette M. Wing popularized the concept of computational thinking in the field of educational and psychological research, publishing an article in the journal "Communications of the ACM" (2006). Specifically, Wing explains:

"Computational thinking as solving problems, designing systems and understanding human behaviour by drawing on the concepts fundamental to computer science." (Wing, 2006: p 33).

The author suggests that this way of thinking is applicable to the resolution of diverse problems, being a fundamental skill for the whole population and not only for computer scientists and programmers. From this perspective, she emphasizes the need to integrate computational ideas in other disciplines, posing solutions that could also be carried out by humans, and not just by machines.

In the 15 years following Wing's first publication, many authors have focused their attention on the idea of computational thinking, contributing complementary definitions. Berry (2014) and Selby & Woollard (2014) have proposed their own definitions, which in spite of their nuances coincide in understanding computational thinking as the ability to identify problems that can be solved in a way similar to what a programmer would do when giving instructions to a computer using a programming language:

- Divide complex problems into smaller size modules.

- Sequence long and complex processes in “steps”.
- Organize and analyze data recognizing logical patterns.
- Start from specific cases to arrive at abstract and generalizable situations.
- Use algorithms to automate solutions.
- Evaluate the validity of solutions.

There’s the general view that the use and development of computational thinking fosters the development of other skills such as the ability to look for ingenious-creative solutions, the capacity to deal with complexity and the tolerance to ambiguity, essential qualities to tackle projects and learning in general.

To learn more:

- Berry, M. (2014). Computational Thinking in Primary Schools. http://milesberry.net/2014/03/computational-thinking-in-primary-schools/
- Selby, C. & Woollard, J. (2014) Refining and understanding Computational Thinking. https://eprints.soton.ac.uk/372410/1/372410UnderstdCT.pdf
- Wing, J. (2006). Computational Thinking. COMMUNICATIONS OF THE ACM. Vol. 49, No. 3. https://dl.acm.org/citation.cfm?id=1118215

4. Creative Computing

Creative Computing covers the interdisciplinary area at the cross-over of **creativity** and **computing**. Creative Computing is a growing educational trend around the world.

Today, with digital technologies now everywhere, researchers, educators and engineers have created tools that allow kids to construct digital and physical artifacts, with almost no prior programming knowledge or engineering skills. Programming languages such as **Scratch** or electronic boards such as **micro:bit** have transformed the way children and young people use technology to express themselves, create projects and share them in community.

These tools encourage kids to program and to make tangible things (robots, digital stories, simulations, games, art projects, etc.), not as a way of learning programming, computing or electronics per se, but more as an opportunity to create and share their ideas and digital artifacts with other users through the Internet. Most of the current Creative Computing tools combine learning about programming and computing with participation in online communities.

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This is how the **Creative Computing Lab** at the **Harvard Graduate School of Education** describe Creative Computing:

> ***Creative computing is about creativity.*** *Computer science and computing-related fields have long been perceived as being disconnected from young people's interests and values. Creative computing supports the development of personal connections to computing, by drawing upon creativity, imagination, and interests.*
>
> ***Creative computing is about computing.*** *Many young people with access to computers participate as consumers, rather than designers or creators. Creative computing emphasizes the knowledge and practices that young people need to create the types of dynamic and interactive computational media that they enjoy in their daily lives.*
>
> *Engaging in the creation of computational artifacts prepares young people for more than careers as computer scientists or as programmers. It supports young people's development as computational thinkers –individuals who can draw on computational concepts, practices, and perspectives in all aspects of their lives, across disciplines and contexts.*

To learn more:

- *Creative Computing Curriculum*, by members of the Creative Computing Lab at the Harvard Graduate School of Education. https://creativecomputing.gse.harvard.edu/guide/index.html
- Resnick, M. (2017). *Cultivating Creativity through Projects, Passion, Peers, and Play*. MIT Press,

5. STEAM

STEAM Education is an approach to learning that uses **Science, Technology, Engineering, the Arts and Mathematics as access points for promoting project-based learning** through student inquiry, dialogue, and critical thinking. In contrast with traditional approaches, STEAM blurs the boundaries between disciplines, and fosters an inclusive learning environment in which all students are able to engage and contribute.

Some years before the STEAM approach appeared, there was the acronym STEM (the same but without Arts), which was introduced to refer to careers and curriculums centered around Science, Technology, Engineering and Mathematics, which were disciplines that were considered key to the knowledge economy and to future jobs. So many schools and educators began to focus on STEM approaches to help children develop what they called "21st century skills".

After a few years, the term STEAM emerged, with an 'A' that refers to Arts (and sometimes more broadly to the Humanities and Social sciences). The idea is that the integration of the Arts into STEM learning allows educators to expand the benefits of hands-on education and collaboration in several ways, promoting creativity and curiosity at the core. Educators realized that adding Arts it's a way of bringing personal expression, empathy, meaning-making, purpose, etc.

It is not that the Arts add creativity to the other disciplines, since these are already creative in their own right, but that art-practices are complementary and open up interesting paths and intersections with the other disciplines. The disciplines in STEAM are a means, not an end in itself.

To learn more:

- Colucci-Gray, L.; Burnard, P.; Cooke, C.; Davies, R.; Gray, D. and Trowsdale, J. (2017). *Reviewing the potential and challenges of developing STEAM education through creative pedagogies for 21st learning: how can school curricula be broadened towards a more responsive, dynamic, and inclusive form of education?*
  http://oro.open.ac.uk/62156/

6. Tinkering

When we refer to **Tinkering** in the context of education and learning, we mean learning through hands-on experiences, learning from mistakes, toying, messing, and exploring and inventing without following structured steps. Tinkerers build **personally meaningful artifacts**, and "think with their hands" in order to construct meaning and understanding. This of course resonates strongly with Constructionism and Maker Education.

We like to use the definition of Tinkering by Karen Wilkinson, and Mike Petrich, authors of the book "The Art of Tinkering", and members of the Tinkering Studio at the Exploratorium in San Francisco:

> *The word Tinkering was first used in the 1300s to describe tinsmiths who would travel around mending various household gadgets. But in our minds, it's more of a perspective than a vocation. It's fooling around directly with phenomena, tools, and materials. It's thinking with your hands and learning through doing. It's slowing down and getting curious about the mechanics and mysteries of the everyday stuff around you. It's whimsical, enjoyable,*

fraught with dead ends, frustrating, and ultimately about inquiry. It's also about making something, but for us, that thing reveals itself to you as you go. Because when you tinker, you're not following a step-by-step set of directions that leads to a tidy end result. Instead, you're questioning your assumptions about the way something works, and you're investigating it on your own terms. You're giving yourself permission to fiddle with this and dabble with that. And chances are, you're also blowing your own mind.

The Tinkering Studio is undoubtedly the place where this concept has been explored the most, and many artists, engineers, educators and researchers from across the world have visited its Learning Lab. Their proposals and suggestions for activities have been examples for teachers, children and families from all over the world.

Tinkering is important because it **helps kids understand how things are made, how things work, and enables them to have focussed and unstructured time to explore and test their ideas and projects**.

Since its popularisation in educational contexts, tinkering has been used by teachers as a bridge to move between the limits of engineering and education. Through tinkering, we can bring a spirit of play into the classroom.

To learn more:

- *Learning dimensions of making and tinkering*, by Tinkering Studio
  http://192.174.2.50/learning-dimensions-making-and-tinkering
- Wilkinson, K. and Petrich, M. (2014). *The Art of Tinkering*. Weldon Owen Editions.
  http://192.174.2.50/art-tinkering

Creative Technologies and vulnerable communities

Nowadays, there are a lot of initiatives under the umbrella of what is called educational or pedagogical innovation. Most of these attempts to change the educational landscape are focused on promoting an education more active (where students are the protagonists), more connected (collaborative learning), more committed to respect the environment and help the community (service-learning) and more creative. This is supported by educational approaches such as the already mentioned (Constructionism, Maker Education, Computational Thinking, Creative Computing, STEAM and Tinkering). Leaders of these initiatives and approaches are changing education in schools by engaging kids in discovery-based learning from a young age, encouraging them to learn not just by watching, but by doing –to not only consume, but also create.

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The educational sector has noticed these changes, and although they are still few (and generally the richest), some schools are already building out spaces for maker or tinker centered activities, and are moving to embed makers and edtech experts into their programs.

Although this is already happening and promising, the reality is that these changes are not taking place in an inclusive or well-distributed manner. Many children, teachers and schools are being left out of these innovations. This is especially true in vulnerable and underserved communities in both developing and developed countries. Minority groups, newly arrived migrant children and refugees usually attend schools that are left out of these innovations. The approach to these new technologies and methodologies in education has a great socioeconomic bias. Although it is true that in the whole world there are many experiences that bring the maker movement and creative technologies closer to children, successful experiences continue to occur among sectors of the population with a medium-high socio-educational background, further widening the digital divide. Often the spaces and projects in these areas are not permeable to neighbourhoods where there is a high risk of exclusion, where the socioeconomic level of their inhabitants is below the city average and where the results of the educational system require special reinforcement.

How to put Creative Technologies into practice

So far we have presented different concepts and learning approaches related to Creative Technologies, but focusing on their theoretical ideas and perspectives. This section consists of a collection of tools, materials, resources and guides that can be useful for putting them into practice.

Interesting resources:

- Tinkering Studio projects. Experiments with science, art, technology, and delightful ideas.

- Arvind Gupta's website. Toys from trash. Hundreds of short clips on *Making things, Doing Science.*

- Creative Computing Guide (Harvard): The Creative Computing Curriculum, designed by the Creative Computing Lab at the Harvard Graduate School of Education, is a collection of ideas, strategies, and activities for an introductory creative computing experience using Scratch. It contains a lot of lessons and activities related to digital storytelling.

- Family Creative Learning Guide (MIT): This guide provides a basic framework to implement some workshops on Scratch and other creative learning technologies. It is designed for teachers, community center staff, and volunteers interested in engaging young people and their families to become designers and inventors in their community.

- Scratch teacher's community website. ScratchEd is now closed to new members and contributions, but still contains interesting resources and conversations.

- Scratch in practice (SiP) shares ideas and materials from the Scratch Team and educators around the world.

- The LEGO Foundation. Learning Through Play. Different resources and materials. Specially related to MonTech project: Learning through play increasing impact reducing inequality white paper.

- PlayfulCoding Teacher's Guide. Engaging young minds with creative computing.

- PECOFIM guide. Teacher training in Computational Thinking. Teaching guide.

- Instructables: a community for people who like to make things.

- Micro:bit projects. Quick projects in MakeCode, Python & Scratch to help you get the most out of the micro:bit's features

- Rob Ives paper toys and designs. Projects to download and make.

- Paper Crane Lab. Low cost STEM projects.

- Celeste Moreno. Creative learning experiences.