ICT Tools for STEM Teaching and Learning
Transformation Framework
Research on the use of a diversity of ICT tools in STEM education shows that these technologies are effective in developing key skills and better learning for students. Technology is increasingly accessible, intuitive, reliable, and diverse in its application, and it is becoming possible for each child to be educated in a way and at a pace which suits his or her abilities, interests and needs. As explained by Barak (2014): “The development of ICTs in the form of mobile devices, such as laptop computers, electronic pads, and smart phones, together with the development of interactive Web 2.0 and cloud applications, can enhance both teaching and learning” (Barak and Ziv 2013). ICTs can also serve as tools for creating learning communities (Berenfeld and Yazijian 2010), for enhancing conceptual understanding (Barak and Dori 2005), and for promoting higher-order thinking skills among students (Barak and Dori 2009).

In this report we address the question of how ICT can promote teaching and learning (T&L) in the STEM area. Sample available tools are selected as examples. We also provide evidence for the impact of ICT tools and some recommendations for use.
About the STEM Alliance

This publication has come about due to Microsoft’s engagement in the STEM Alliance. It brings together industries, Ministries of Education and education stakeholders to promote STEM education and careers to young Europeans and address anticipated future skills gaps within the European Union. The STEM Alliance builds on the success of the inGenious initiative (2011-2014) to increase the links between STEM education and careers, by involving schools throughout Europe. With the support of major industries and private partners, the STEM Alliance activities promote STEM jobs in all industrial sectors and contribute to build a STEM-skilled workforce. The STEM Alliance will improve and promote existing industry-education STEM initiatives (at national, European and global levels) and contribute to innovation in STEM teaching at all levels of education. More information: http://www.stemalliance.eu/

The STEM Alliance is working on a series of publications on STEM Education. This paper follows up on these publications and has been produced with additional support from Microsoft.

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Fostering innovative thinking

ICT Tools and STEM education

Technology is an important component of all the T&L processes involved in education. This is especially true if we seek "holistic transformation of education in a digital era".1

Classroom practices influence student learning2, thus it is important to study and understand how ICT can improve STEM education.2 Benefits of ICT for students can be unlimited, especially if they become active producers, able to take part in the learning process.

ICT tools can have a major impact in the many facets of STEM education, such as adding to teacher competencies, diversifying the learning resources, increasing student and teacher motivation.

In this report we look into six types of tools, namely: collaborative technologies, online learning, software (including apps), digital and adaptive content, devices and hardware, and further promising technologies.

For each of these categories we share a few examples of tools, explain their use in STEM education, their effects on students and teachers alike and, finally, provide some recommendations or examples of good practices.

An important caveat to take into account: much of what can be said about ICT in STEM education applies also to education in any other curricular field. For instance, take the use of graphing software or spreadsheets: they have obvious applications in many areas like economics, geography, etc. And many of the educational experiments done with technology in any other field, like music or history, for instance, surely have elements of potential applicability in the STEM subjects. A clear example is the use of students’ or teachers’ collaborative tools. The same lack of disambiguation occurs, cum grano salis, when describing the application of ICT tools in Primary, Secondary and Higher education.

Collaborative tools

“Collaborative learning” is an umbrella term for a variety of educational approaches involving joint intellectual effort by students, or students and teachers together.4

Teachers’ beliefs and worldview have a great influence on the teaching methods and strategies they use.5 ICT-enhanced learning is conceptualized as the consequence of ICT support in education, when engaging students in active, interactive, and collaborative learning, which results in students’ more meaningful and deep learning.

From the point of view of learning and interest, the use of ICT adds motivational learning features for students who engage in collaborative work.6 These tools allow students wider choices of resources, facilitate planning and evaluating ones’ activities, as well as offer choice of tasks; technologies can be used to participate in collaborative learning events, co-planning and other activities which help students feel close to peers.

1 Langworthy, 2014
2 Jaquith et al., 2010
3 Dawson, 2012
4 Smith & MacGregor, 1992
5 Davis, 2003
Finally, collaborative tools also enable the collaboration with experts at a distance.

**Examples of tools**

Large scale tools with the possibility to share documents, create documents, spreadsheets and more: Microsoft Office 365, Google Docs, and Microsoft OneDrive.

On a smaller scale and concentrating on “live” collaboration for specific projects, e.g. Padlet.

Cloud computing technology can assist teachers’ and students’ collaborative work and facilitate worldwide interactions.

Skype video sessions over Internet, for instance, may be used for presentations and demonstrations, and enable interactive collaborative learning. The Skype in the Classroom website helps teachers to set up virtual field trips, schedule online expert discussions and distance lessons.

A number of tele-collaborative projects, like GLOBE, the Global Learning and Observations to Benefit the Environment, links primary and secondary students and teachers in conducting earth science research.

Examples from Microsoft

- Dog-Tastic Mystery Skype Adventure
  [https://www.youtube.com/watch?v=ZqCdfC5BaoE](https://www.youtube.com/watch?v=ZqCdfC5BaoE)

- Finland Meets Florida | Corinth Classroom and Yammer
  [https://www.youtube.com/watch?v=HTlgfI7g7Q4](https://www.youtube.com/watch?v=HTlgfI7g7Q4)
Online Learning

The scope of online learning in education is quite wide, ranging from student quiz-taking in particularly hard topics, to for instance students following formal or informal courses online on a particular STEM subject. The same diversity applies to teachers.

According to UNESCO, “professional learning” corresponds to the additional skills and knowledge which teachers acquire in their work, beyond what they learnt to become qualified teachers.7

Digital skills for teachers and students that can be developed using online learning include:

• Digital citizenship – having the ICT equipment and skills to participate in a digital society, for example to access government information online, to use social networking sites, and to use a mobile phone.
• Digital literacy – basic computer skills such as being able to do word-processing or go online.

And increasingly, digital competence requirements are going beyond digital citizenship and literacy to encompass computational thinking and higher level computer science skills.

Examples of tools

Digital professional development resources: Platforms such as TeachScape and KDS are personalizing development by providing relevant digital courses to teachers.

Technology fosters collaboration and coaching among teachers. Edconnective and Edthena, for example, allow teachers to upload video-recorded lectures for discussion.

Technologies like Innova work in closed-loop system in a blended learning approach, in which individual computer-based learning is combined with teacher-led collaborative learning sessions.

Institutional digital MOOC platforms like the European Schoolnet Academy are used to organize STEM courses to provide teachers, school counsellors and career advisers with resources and ideas to increase pupils’ interest in STEM subjects and careers. Students can also be directly engaged via MOOC or other online platforms offering courses on STEM topics.

The Microsoft Imagine Academy brings together both online and face to face training to enable learning not only on fundamental technology skills, but also technical courses for students, faculty and staff who are interested in pursuing a career in IT after graduation.

Digital competence requirements are going beyond digital citizenship and literacy to encompass computational thinking and higher level computer science skills.

Examples from Microsoft

Renton Prep uses Docs.com to Blend Content
https://www.youtube.com/watch?v=M1ysBdqr_WM

Omaha Public Schools Turn to Office 365 to Streamline Professional Development
https://www.youtube.com/watch?v=VZ3fv3n9RFs
The terms software, software package, computer program, and application are often treated as synonyms. A program is “the set of instructions loaded into a computer which enable it to provide specific functions such as word-processing, spreadsheets, presentations, databases, and image editing.”

Examples of tools

One can use tools like simulations and 3D virtual worlds in Immersive Learning Environments, such as Minecraft: Education Edition, to construct scenarios that mimic realistic situations, and allow individuals to train and practice their skills.

Learning analytics is an educational application of “big data” with the aim of improving student retention and providing a high quality, personalized experience for learners.

Mobile apps are ubiquitous and students and teachers are able to access them with their tablets, OneNote notebooks or many other devices, anywhere and at any time.

Digital and adaptive content

By its very nature, elemental digital instructional materials are easily adaptive. A trivial example of an adaptive digital resource is a problem set created by the teacher with a word-processing program. But according to UNESCO “off-the-shelf educational software – educational programs which are ready to be used with students without the teacher having to do anything to them” are usually closed and not adaptive.9

T&L methods, and not only contents, are adaptive thanks to educational technology. ICT can “complement existing and emerging pedagogical approaches such as project-based, experiential, inquiry-based and adaptive learning methods.”10

Software

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8 UNESCO, 2011
9 Ibid.
10 WEF & BCG, 2015
Over the last decade, our studies and those of others have repeatedly shown that when students solved science and maths problems, performance improved significantly when they used a stylus interface rather than a keyboard.

Oviatt, 2013
Devices and hardware

Hardware and software are basic components of digital technologies, and are constantly diversifying and becoming more accessible “through the availability of new low cost Windows-based devices.” Although, generally, “the investment to hardware and software tools for science education at a high level do not automatically lead to noticeable progress in quality of science education”, ICT enables students with special needs or difficulties. Students also assume responsibilities when they use ICT to organize their work through digital portfolios or projects.

Examples of tools

Mobile Learning is based on smartphones and tablets, and innumerable apps with institutional- and company-produced educational resources and tools. They enable teachers and students to go outside of the classroom and carry out in situ STEM experiments in the wider world.

Robotics and construction bricks, combined with ICT play and interactive technologies, help children develop creativity and scientific thinking skills.

Wearable technology, like the Surface Band can, in combination with tablets, conveniently integrate tools that track movement, location, etc. Wearable devices allow to easily document an experiment, or make observations, and can be valuable input for science classes (Physics and Biology, for instance).

Wireless sensors and data loggers can profit from the vast experience of use in STEM T&L. Many companies offer these products at present. An example is the BBC micro:bit, a programmable development board including onboard sensors. A second is Lab4U, a science curriculum that uses a devices sensors to engage students in real-time data collection and analysis.

Electronic inking in tablet-based technology affords enhanced learning experiences like note taking and sharing in real-time distributed conversation, and has proven impact on student accuracy and creativity for STEM diagrams, models and schematics.
Further promising technologies

Although some education research on current technologies is already available, as we have seen, many of the tools mentioned so far are in the early stages of technology adoption by STEM teachers, and according to WEF & BCG “its full potential to have an impact on student learning in primary and secondary education has yet to be realized.”

However, the accelerated generation of novel initiatives in the education technology field, also mentioned in the introduction, yields a plethora of promising technologies. The selection below is therefore incomplete and biased.

Some innovations are valuable extensions of well-known technologies. For instance, an interesting expansion of the very useful sensors used in STEM experiments of all educational levels and curricular subjects are wireless sensors. Another “old technology” that gains momentum is that of virtual and remote laboratories, especially interesting for STEM high school students who “become familiar with instruments, components, manuals, data sheets, circuit wiring, and other laboratory work.” These labs increase teacher’s options and improve practice at secondary schools considerably.

Other technologies mentioned below are either starting to make their way into the STEM classrooms (like 3D printing) or undergoing fast development, like the Internet of Things. While we are still trying to figure out how to extract the educational potential of 3D printers in our STEM classrooms, 4D printing is on the stove, with an interesting time component put into the equation that resonates well in STEM media.

Examples of tools

The Internet of Things may use embedded chips, sensors, or tiny processors attached to an object that allow to extract helpful information about the object, such as cost, age, temperature, colour, pressure, or humidity to be transmitted over the Internet. According to Correll, “Although Wi-Fi is the most recognized form of wireless technology, IoT leverages other connectivity technologies including Zigbee, NFC, RFID and Bluetooth.” And still with Correll, “The technology exists to add wireless sensor capabilities to virtually any device, including wearables, books, small sensors, fixed structures and even people”. It is very easy to envision how IoT capabilities can be used in STEM programs, robotics and projects having to do with gathering specific data. All these capabilities are in the potential of IoT, which can simplify and automate access to information. This saves teachers and students valuable time and effort.

Flexible displays are currently mass-produced and allow researchers, inventors, and developers to experiment applications for T&L. Portability calls also for applications in science experimentation.

3D printing technologies allows to construct physical objects such as modelling software and computer-aided design tools, as well as many laboratory items, for instance.

“Physics students learned significantly more when using Minecraft than students who did not.”
Wang & Towey, 2013

Examples from Microsoft

PowerBI gives students and teachers the ability to create incredible visualizations and analyse data in new ways to provide insights.

Corinth Classroom enables students to print 3D models of phenomena they study virtually through the app.
Adoption of available and forthcoming ICT tools requires also that teachers change their way of thinking about the application of ICT in education, and continuous professional development on the use of ICT in education is facilitated by various ICT tools.
Conclusions and recommendations

Educational technologies are nowadays inseparable companions of STEM education, and teachers’ creativity will continue to expand the possibilities of use of ICT in order to achieve the many T&L objectives of their profession. Further exploitation of ICT potential requires an adequate mix of resources, technical support and classroom management strategies. Adoption of available and forthcoming ICT tools requires also that teachers change their way of thinking about the application of ICT in education, and continuous professional development on the use of ICT in education is facilitated by various ICT tools. By way of conclusions, we offer five targets of ICT in STEM education:

STEM Education

- Technology can impact on STEM education in deep form; in particular, it can contribute to rethinking STEM pedagogy.
- STEM skills like collaboration, argumentation, experimentation, collection of data, presentation of results, etc., can be facilitated by ICT tools.
- An increasing variety of available APPs requires from the students initiative, creativity and original thought, understanding and application, all of them basic objectives of STEM education.

Technologies

- There are numerous technological tools at hand and in perspective for the STEM teachers and students.
- Collaborative and online learning technologies pose great opportunities to students and teachers for lifelong learning.
- The number of ICT tools available and the many decades of experience with ICT, in general, cannot be covered by any report or even a series of books.

Educational Research

- Research into the applicability and impact of ICT in STEM education is growing and producing solid data.
- Critical reports on experiences and repositories of good practices of teachers using technology to support and complement their teaching are increasingly available.
- Large scale longitudinal (time) studies on the effects of ICT use in STEM subjects are desirable.

Finally, when looking into ICT tools in STEM education, it is recommended to:

- Provide STEM teachers with STEM pedagogical training that integrates use of ICT for pedagogy;
- Ensure students have sufficient access to appropriate technology tools to support STEM learning;
- Think about what the tech component needs to look like, when building new STEM labs;
- Give teachers and students autonomy to select the most appropriate ICT based tools for STEM to suit their own teaching and learning styles.

Examples from Microsoft Case Study: Sammamish High School

- 20% increase in AP pass rates, especially in STEM content areas (Biology, Chemistry, Statistics, Calculus AB/BC, Physics, Environmental Science);
- 20% increase in students with disabilities (SWD) and limited English proficient students;
- (LEPS) enrolling in AP STEM classes;
- 10% annual improvement on the state science test for all students.

These outcomes were the result of a new Problem Based Learning approach in STEM at Sammamish High School, where teachers collaborated in OneNote to redesign the curriculum and pedagogy over 5 years.

See more at http://wwwbsd405.org/2016/03/sammamish-gains-ground-from-investing-in-innovation-i3-grant/
Microsoft in STEM

Microsoft focuses on the T in STEM, with two focus areas:

1. Technology enables – with platforms, environments, and infrastructure that enables a better teaching and learning experience.
2. Technology empowers – through tools, network, and scaffolding such as curriculum that all empower students to create new solutions, change the world, and improve their employability.

Minecraft: Education Edition


Computer Science

We believe that every child has the right to learn code. As such, we put Computer Science (CS) education at the center of our efforts to kindle a passion among students, teachers, and parents. We do this in four ways:

1. Build capacity of teachers, trainers and nonprofit organizations to create computer science opportunities for all youth, with a priority focus on underserved youth, young women and racial & ethnic minorities.
2. Inspire young people to pursue a career enabled by technology, connect them to opportunities, and empower them to achieve more.
3. Drive educational change in a long-term, systemic way.
4. Sponsor research in K-12 CS education.

Imagine Academy

Through Imagine Academy, a program for all levels, we offer technology and computer science curriculum for students to gain industry-standard certifications to help them be college and career ready. Learn more at https://www.microsoft.com/en-us/education/imagine-academy/default.aspx.

Our partnership with EdX and openEdX has allowed us to offer leadership courses on system change as well as Computer Science curriculum. Learn more at https://www.edx.org/school/microsoft.

What is the Education Transformation Framework?

The Microsoft Education Transformation Framework helps fast track system-wide transformation by summarizing decades of quality research. It includes a library of supporting materials for ten components of transformation, each underpinned by an executive summary and an academic whitepaper detailing global evidence. This provides a short cut to best practice, speeding up transformation and avoiding the mistakes of the past. Microsoft also offers technology architectures and collaborative workshops to suit your needs.

Interested in taking the next step on your transformation journey?

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