eCraft2Learn

Digital Fabrication and Maker Movement in Education
Making Computer – supported Artefacts from Scratch

Deliverable D2.1

Enabling maker innovations in education: Barriers and drivers

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 731345.

PROJECT DESCRIPTION

Acronym:	**eCraft2Learn**
Title:	Digital Fabrication and Maker Movement in Education: Making Computer-supported Artefacts from Scratch
Coordinator:	University of Eastern Finland
Reference:	731345
Type:	RIA
Program:	HORIZON 2020
Theme:	Technologies for Learning and Skills
Start:	01. January 2017
Duration:	24 months
Website:	http://www.project.ecraft2learn.eu/
E-Mail:	office@ecraft2learn.eu

Consortium:

University of Eastern Finland, Finland, (UEF), Coordinator

Edumotiva, Greece (EDUMOTIVA)

Mälardalen University of Sweden, Sweden (MDH)

Zentrum für Soziale Innovation, Austria, (ZSI)

The University of Oxford, United Kingdom, (UOXF)

SYNYO GmbH, Austria, (SYNYO)

Linnéuniversitetet, Sweden, (LNU)

University of Padua, Italy, (UNIPD)

Technopolis City of Athens, Greece (TECHNOPOLIS)

Evothings, Sweden (EVOTHINGS)

Arduino, Sweden (ARD)

Ultimaker, United Kingdom (ULTIMAKER)

DELIVERABLE DESCRIPTION

Number:	**D2.1**
Title:	Enabling maker innovations in education: Barriers and drivers
Lead beneficiary:	Zentrum für Soziale Innovation (ZSI)
Work package:	WP2
Dissemination level:	Public (PU)
Type	Report (R)
Due date:	August 2017
Submission date:	September 2017
Authors:	Christian Voigt, Margit Hofer, Johannes Simon, ZSI
Contributors:	all Partners
Reviewers:	SYNYO and LNU

Version Control

Version	Date	Person in charge (Organization)	Changes
1	March 2017	Voigt, Simon and Hofer (ZSI)	First Draft
2	June –August 2017	All partners	Contributions in form of comments or interviews
3	September	Voigt and Hofer (ZSI)	Final Draft

Acknowledgement: This project has received funding from the European Union's Horizon 2020 Research and Innovation Action under Grant Agreement No 731345.

TABLE OF CONTENT

1 EXECUTIVE SUMMARY 6

2 INTRODUCTION 7

3 INNOVATION MANAGEMENT IN EDUCATION 7

3.1. TYPES OF INNOVATION 9

3.2. INNOVATIONS IN EDUCATIONAL QUASI-MARKETS 10

4 INNOVATION MANAGEMENT METHODS: FROM IDEAS TO IMPLEMENTATIONS 10

4.1. IDENTIFYING IDEAS 11

4.2. EVALUATING AND SELECTING IDEAS 12

4.3. IMPLEMENTING AND SCALING IDEAS 13

5 ANALYSIS 15

5.1. INTERVIEW PARTICIPANTS 15

5.2. DEFINING INNOVATION IN SCHOOLS AND INDUSTRY 18

5.2.1. Innovation components, needs and outcomes 18

5.2.2. Concrete examples 20

5.2.3. How innovation is understood outside schools 22

5.3. BARRIERS 24

5.3.1. Knowledge gaps 25

5.3.2. Markets 27

5.3.3. Funding 28

5.4. ENABLERS AND COMPETENCIES 28

5.5. EXISTING INNOVATION MANAGEMENT PRACTICES IN SCHOOLS 30

6 CONCLUDING RECOMMENDATIONS 31

6.1. A STRATEGIC APPROACH TO OPEN INNOVATION 31

6.2. DESIGN PATTERNS AND PRINCIPLES 32

6.3. PLATFORM INNOVATION 33

7 ANNEX – INTERVIEW QUESTIONS 35

8 REFERENCES 42

TABLE OF FIGURES

Figure 1: Balance score card (Source: Kaplan & Norton, 1996) 12
Figure 2: The innovation chasm 13
Figure 3: Stage model of participation (Von Unger, 2012) 14
Figure 4: Interviewees' nationality and professional background 16
Figure 5: Interviewees' age and gender distribution 16
Figure 6: Number of interviews per country 17
Figure 7: Average student – teacher ratios 17
Figure 8: Collaboration within the triple and quadruple helix 22
Figure 9: Innovation management tools in schools 31
Figure 10: Degrees of user involvement (Source: Arnkil et al., 2010) 32
Figure 11: Arduino online programming 34
Figure 12: Arduino platform features 34
Figure 13: Tinkercad Browser-based 3D design platform 35

1 EXECUTIVE SUMMARY

This deliverable explores pedagogical innovations as embedded actions in a wider ecosystem. Innovations are generally described as the exploitation of new ideas; hence innovations imply novelty and use (i.e. the adoption of the solution by a relevant user group) (H. W. Chesbrough, 2003). The deliverable discusses the role of appropriate funding, national regulations, curricular flexibility, technologies ready to use and adequate training opportunities for teachers, on the basis of 25 interviews from 9 European countries.

The deliverable starts with a conceptual overview of innovation types (disruptive, radical and incremental) and highlights the special situation of educational quasi-markets, where innovation management cannot follow the same rules as innovation management in fully competitive markets, such as in the hardware and software industry. A brief overview of selected innovation management tools introduces main innovation management stages such as 'identifying, 'evaluating', 'selecting' and 'scaling' ideas.

Barriers and drivers of educational innovations, together with an overview of existing innovation management tools are at the core of the deliverable. Barriers are discussed in terms of 'lack of time', 'lack of a supportive culture', 'lack of understanding market conditions' and 'lack of funding'. Enablers of innovation were discussed in terms of technical competences, organisational competences and human resources competences (e.g. hiring processes, incentives and professional development opportunities). Looking at existing innovation management activities within the interviewees' schools, we found the top five tools focusing on teachers' networking capabilities.

We conclude the deliverable with three strategic recommendations: (a) the strategic planning of open innovations; (b) the use of design principles to capture and transfer knowledge related to a project-driven, crafts-based learning methodology and (c) the critical examination of platforms innovations sharing development costs and possible leveraging major benefits through the analysis of vast collections of individual projects in central repositories.

2 INTRODUCTION

> "Old versus new. That battle is nothing new. As Machiavelli wrote in The Prince: Innovation makes enemies of all those who prospered under the old regime, and only lukewarm support is forthcoming from those who would prosper under the new. Their support is indifferent partly from fear and partly because they are generally incredulous, never really trusting new things unless they have tested them by experience."
>
> (Lessig, 2002, p. 6)

The objective of this deliverable is to analyse **pedagogical innovations as embedded actions** in a wider ecosystem. Innovations are generally described as the exploitation of new ideas; hence innovations **imply novelty and use** (i.e. the adoption of the solution by a relevant user group) (H. W. Chesbrough, 2003). To what degree the innovating organisation is enabled or supported by its surroundings is part of the following discussion. As will be discussed, such support form the outside can relate to appropriate funding, regulations, curricular flexibility, technologies ready to use, adequate training opportunities for teachers as well as people with relevant roles outside formal educational institutions (e.g. science shops, libraries or maker spaces).

This deliverable will adopt two perspectives (a) outside conditions as mentioned above and (b) conditions inside the organisation such as barriers and drivers including a place's culture (e.g. freedom to experiment, embracing failure as learning opportunities etc.), strategic decisions (e.g. the teaching of innovation and entrepreneurship competencies) or evaluation standards. Evaluation and formal acknowledgement of teaching practices are critical elements. If the significant learning that can be enabled through 'making' is to become a sustainable component of our learning landscape, without depending too much of the often-volunteered enthusiasm of teachers, teacher evaluation has to change accordingly.
The deliverable is structured into the following sections:

- *section 3* ('Innovation Management in Education') establishes some conceptual foundation, zooming in on innovations in an educational context;
- *section 4* ('Innovation Management Tools) reflects state of the art research in innovation management;
- *section 5* ('Analysing Interviews') presents the discussion of 25 interviews, analysing respondents views on barrier, enablers and support of innovation management;
- *section 6* ('Recommendations for the future') concludes with three, strategic final recommendations in support of an innovative, crafts-based learning framework.

3 INNOVATION MANAGEMENT IN EDUCATION

Enriching the educational landscape by new technologies has a long tradition and discussions about technological features frequently dominate the debate. Even today, when technology and the use of software is commonplace in many if not most areas of life, the role of pedagogy has gained in im-

portance, but the embedded nature of educational technology is still neglected. Changes in educational systems are always ‘changes of a running system', hence the management of innovations seems a much-needed ingredient to ensure the efficient usage of the already scarce time resources of teachers and learners alike.

More than 10 years ago, Watson (2006) analysed educational research and its relationship with technology, listing a number of enduring issues:

- ***Should it be 'learning with' or 'learning about' technology?***
  Since we can certainly sustain that it should be both, the real question is one of resources and the need to prioritize learning objectives and learning strategies. Watson observes a tendency that ICT is primarily used for 'lower order thinking', and 'how to' tasks; whereas context-driven problem solving including simulations ect. are on the decline.
- ***Are teacher innovators or conservators of the status quo?***
  This plays into teacher education as well as on-going professional development for teachers. A challenge here is the lack of 'proof' that a given technology 'pays off', i.e. is worth the up-front investment in time and motivational energy. An open approach to organisational barriers is mentioned as paramount if teachers are expected to change their practices, fine-tuned with the liabilities of the current system. A typical roadblock, many ICT projects run into are old forms of assessment applied to new styles of learning (Meek, Blakemore, & Marks, 2016).
- ***Can we balance technocentric enthusiasm and reflective implementations of ICT in education?***
  As in other areas, there might be a tendency to techno-solutionism (Morozov, 2013). That is, the believe that unprecedented networking effects (e.g. Facebook) or the spreading of generative software or maker technology is changing societies for the better. Arguably, large scale effects can be seen by 'disruptive innovations' (e.g. mobile, ubiquitous devices), yet, whether these changes are for the better or worse is not centrally controlled and likely to differ depending on the target group observed.

That these issues are still partially true is accounted for by Resnick and Rosenbaum (2013): “The tinkering approach is characterized by a playful, experimental, iterative style of engagement, in which makers are continually reassessing their goals, exploring new paths, and imagining new possibilities. Tinkering is undervalued (and even discouraged) in many educational settings today, but it is well aligned with the goals and spirit of the progressive-constructionist tradition—and, in our view, it is exactly what is needed to help young people prepare for life in today’s society”. The quote shows how existing preferences in the educational system, e.g. emphasizing content delivery and quantitative assessment, run counter to a pluralism of learning paths including the bottom up experiences of creating tangible objects, the notion of adapting solutions to changing conditions and an essentially different way of accessing STEM problems. Resnick and Rosenbaum (ibid) highlight that making and tinkering requires not only a rethinking of students’ interactions with specific topics but also the rethinking of STEM curricula and assessment methods.

3.1. TYPES OF INNOVATION

The area of innovation research is very broad. Innovation research can be conducted concerning (a) the diffusion of innovation, (b) the adoption[1] of innovation or (c) the innovativeness of organisations.

Fitting with the wide range of scenarios where innovations can be researched, a suitable working definition is "An innovation can be a new product or service, a new production process technology, a new structure or administrative system, or a new plan or program pertaining to organizational members. … Innovation is a means of changing an organization, whether as a response to changes in its internal or external environment or as a pre-emptive action taken to influence an environment." (Damanpour, 1991).

Different principles for organizing innovations are suggested by (Granig & Perusch, 2012):

Differentiation element ...	**Characteristics**
Area of Innovation	▪ product ▪ process ▪ cultural / social innovation ▪ organizational / structural innovation
Trigger of Innovation	▪ pull (innovation as a means to an end) ▪ push (innovation as a consequence of a new means)
Domain of innovation	▪ manufacturing vs. service industries ▪ private vs. public sector
Degree of Innovation	▪ incremental vs. radical ▪ sustaining vs. disruptive

Whereas all dimension of the above structuration of innovations seem applicable to educational innovations, 'degree of innovations' is of salient importance, if we consider the size of education systems with thousands of schools involved. The 'degree of innovation' refers to the amount of change required (Tidd, 2001). Tidd (2001) suggests the following categorization in order to distinguish between different aspects such as 'What is changing?' and also 'How fast is it changing?'.

- *Disruptive Innovations*: re-writing the rules, reframing the problem
- *Radical Innovations*: novel, unique service / product
- *Incremental Innovations:* day-to-day innovations, sustaining existing services

We will revisit the degree of innovations during the discussion in section 5, when we ask teachers about their definitions of innovations. Disruptive innovations were generally seen more critical, due to difficulties around estimating the benefits they would bring to learning (implying that an effect would need to appear on standard evaluation instruments) as well as the effort the innovation would require from the teacher.

[1] 'Adoption' refers to the stage in which a technology is selected for use by an individual or an organization. 'Diffusion' refers to the stage in which the technology spreads to general use and application.

3.2. INNOVATIONS IN EDUCATIONAL QUASI-MARKETS

Calling for innovation management in schools is often related to a perceived inability of the educational sector to innovate effectively. Lubienski (2009) shows that simply offering students and parents the choice of which schools they want to join, does not yet create a market where innovation is a differentiator and wherefore innovations become desirable per se. Lubienski makes the argument that educational systems are quasi-markets[2]: "schools are in an ambiguous position for sensing and responding to market-style signals. Particularly when bound by obligations such as open access, equity, etc., schools often do a poor job of acting like private providers" (ibid). Put differently, schools don't show the business-like approach to innovation where profitable innovations are extended and less profitable practices are abandoned; and given their mission to provide a service to a wider society that is desirable. Hence, quasi- markets are different in that (Lubienski, 2003):

- providers are not necessarily profit-maximising firms (they may be state-owned or charitable organisations);
- choice may be exercised on behalf of the user;
- users 'spending power' is determined by the value of a voucher or earmarked budget, rather than their wealth.

Still, providing proper incentive structures for teachers remains a critical point in scaling innovative practices. Moreover, even though the eCraft2learn project is primarily involved with developing crafts-based learning methods and technologies, innovative practices can be as broad as: introducing an arts focus, having non-graded classes, using portfolios in formative assessments, supporting smaller class size, emphasizing academic rigour, multi-age grouping, offering after-school-programs, introducing a school-to-work focus, establishing community service projects, initiating team teaching and multidisciplinary learning (Lubienski, 2003).

4 INNOVATION MANAGEMENT METHODS: FROM IDEAS TO IMPLEMENTATIONS

The following three sections are derived from the classical innovation development model (Oke, 2004):

1) Strategy development: identify requirements
2) idea generation: what meets the requirements
3) Screening and evaluation
4) Business check: economic viability
5) Actual product development
6) Testing, commercial experiments
7) Commercialisation

However, the list above requires a note of caution. Service organisations such as schools often use less formal processes for innovating and therefore screening, testing and commercialisation techniques may be less known and / or used (Martin Jr & Horne, 1993).

[2] The term quasi-market was coined by Le Grand to describe public service reforms introduced in the late 1980s. The resulting services were market-like because they split purchaser and providers of public services, and because they introduced competition between providers. However, they are not like conventional markets, hence 'quasi' because they are not necessarily profit-maximising firms. (Source: http://go.shr.lc/2waAuML)

4.1. IDENTIFYING IDEAS

Innovation method(s): Vision workshops, Creativity workshops, Lead-user workshops

Innovation starts with a vision, wrapped in a strategy detailing how the vision can be achieved over the next years. Although the information management vocabulary has emerged from a business context, the interviews analysed in chapter 5 demonstrate that a principal's vision for the future of the school plays an important part in how teachers understand and prioritize their work.
Rather than following main stream developments, a shared vision within the school has the potential to implement an ambitious understanding of how 21st century should look like. Moreover, with national policies shifting more and more decision-making powers to local school management, schools have more possibilities to shape their own unique profile.
For example, although many schools use robotics or other maker technologies like 3D scanning and printing, it's not always clear what the overall strategy behind having these technologies at school could be. This seems like a missed opportunity, as Chu et al. (Chu, Quek, Bhangaonkar, Ging, & Sridharamurthy, 2015) argue, when saying that making activities in schools can achieve much more than just supporting the understanding of specific STEM concepts. The authors point out that making should lead to a 'maker mindset', a frame of thinking about themselves as "technology- and science-capable" (ibid). In such a scenario, making becomes a means-to-an-ends approach, where the ends are driven by students' interests. Developing an interest, then, becomes more important than covering a maximum number of topics foreseen in the curriculum. As we can see, the same educational innovation (e.g. making in schools) takes on different characteristics, depending on the vision of the people behind the innovation.

Example method: Vision Workshop

Visions need to build upon the best in an organisation, set a direction and provide a firm ground for the transformation the organisation should go through: "*Truly great companies understand the difference between what should never change and what should be open for change, between what is genuinely sacred and what is not. This rare ability to manage continuity and change – requiring a consciously practiced discipline – is closely linked to*
the ability to develop a vision. Vision provides guidance about what core to preserve and what future to stimulate progress toward." (Collins & Porras, 1996)

Some standard activities to be used in a vision workshop[3]:

Setting the stage
Who is the beneficiary of the vision? How will it be used? A vision statement is often a one- or two-page word picture of what you want to create. It is a story written in the present tense as if that envisioned reality were already occurring. There is no fixed formula for writing vision statements.

Imagining

[3] https://www.rickmaurer.com/wp/wp-content/uploads/2011/01/CreatingVision.pdf

Create some ideal picture of the future. Explore these images in detail. Who appears in these images, what are they doing and saying. Let the image go and imagine a new one.

Pair discussion
Pairs discuss their visions with a pair. The other person asks questions to clarify the vision without evaluating the vision.

4.2. EVALUATING AND SELECTING IDEAS

Innovation method(s): Balance Score Card, evaluation & selection criteria (user demand, cost estimate, skills required), selection matrix, benchmarking

Once a vision has been formulated and first ideas about novel technologies and methods emerge, it might be necessary to select and prioritize ideas since it is unlikely that there are sufficient financial and personnel resources to implement them all. Criteria driven scoring imply that every vision represents a target system (where the organisation desires to be in 3-5 years) (Gassmann & Granig, 2013). How much an organisation has progressed towards that target system is then measured by indicators (e.g. number of students in projects, participation in STEM competitions or public relations events, promoting students STEM achievements).

Example method: Balance Score Card

A systemic scoring method is the Balance Score Card (BSC) approach developed by Norton and Kaplan (1995). The approach is centred around an organisation's ability to learn, including all aspects of the value chain (innovations in combination with finance, client engagement and internal operational excellence) (Figure 1).

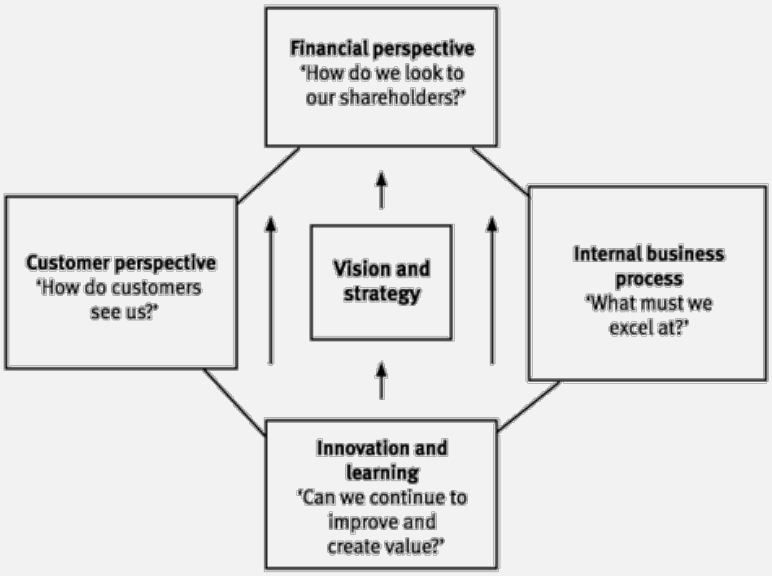

Figure 1: Balance score card (Source: Kaplan & Norton, 1996)

At the core of the scoring process are root-cause analyses, shedding light on issues such as 'the best innovation might fail to become sustainable if they are not communicated to management and parents' likewise is it important to compare the price of an innovation and make sure that alternatives have been tested, in order to identify more cost-efficient solutions where needed.

4.3. IMPLEMENTING AND SCALING IDEAS

Innovation method(s): Participatory design, knowledge management, networking, business development, prototyping, observing beta-users, iterations

Early on, Rogers (2003) established four elements determining the dissemination capacity of an innovation:

- characteristics of the innovation itself,
- communication channels used,
- time spent and
- social systems involved.

Again, innovations in schools may happen in less strategic ways relying more on the reflective nature of teachers than on centralized actions, hence for sustainable change – innovation needs as much bottom up creativity as it needs top down management (Schön, 1995). The figure below is a combination of Rogers' (2003) adopter categories (i.e. innovators, early adopters, early majority etc.) and Moore's et al. (1999) model of adoption of innovations (inflated expectations, enlightenment, productivity).

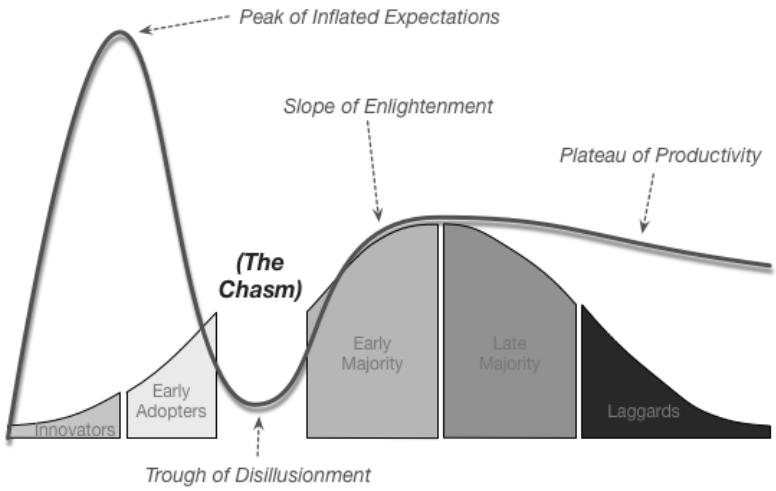

Figure 2: The innovation chasm[4]

Figure 2 shows the importance of managing teachers' expectations about what an innovation can achieve and what not, as well as what sort of effort needs to be made in order to get the innovation working.

A typical approach here is to involve the more experienced teachers (i.e. the early adopters) which can help to win over the majority of teachers more easily, mostly because they can do that expecta-

[4] http://weblog.tetradian.com/2015/09/16/big-consultancies-and-bridging-the-chasm/

tion management very well since they know the local condition under which innovations are meant to function. Such conditions need to be addressed first, if they are as fundamental as lack of preparation time, insufficient number of devices per class or dedicated physical spaces for project work. One of the underlying motivations for participatory design (PD) is the need to align the design of ICT applications with the skills and conceptual models of the people who should not only use them but be effectively supported in their activities.

Example: The participatory research and design mindset

When participatory research originated in Scandinavia in the 1970s, it emphasized the need of users' perspectives, not only to increase the efficiency of systems[5] but also to make the software 'work' in people's overall life context (Kensing & Blomberg, 1998). Participatory design was to overcome the efficiency paradigm and include factors such as people's motivations, their carrier plans or their ideals of teamwork. These goals were new in times when workers had little influence on the technologies they should use afterwards. Paternalistic attitudes towards users of technology who were deemed unfit to understand the workings of technology characterized the introduction process of new technologies (Spinuzzi, 2005). Recognizing the crucial importance of users' practice-based knowledge, PD put forward the argument that involving teachers early on, in fact taking teachers' interests as starting points, was good design practice if changes were to be sustainable.

The stage model of participation (Von Unger, 2012) defines levels of participation on the basis of decision making authority with the highest level of empowerment as one of self-organisation, where the individual or community are able to act autonomously (Figure below).

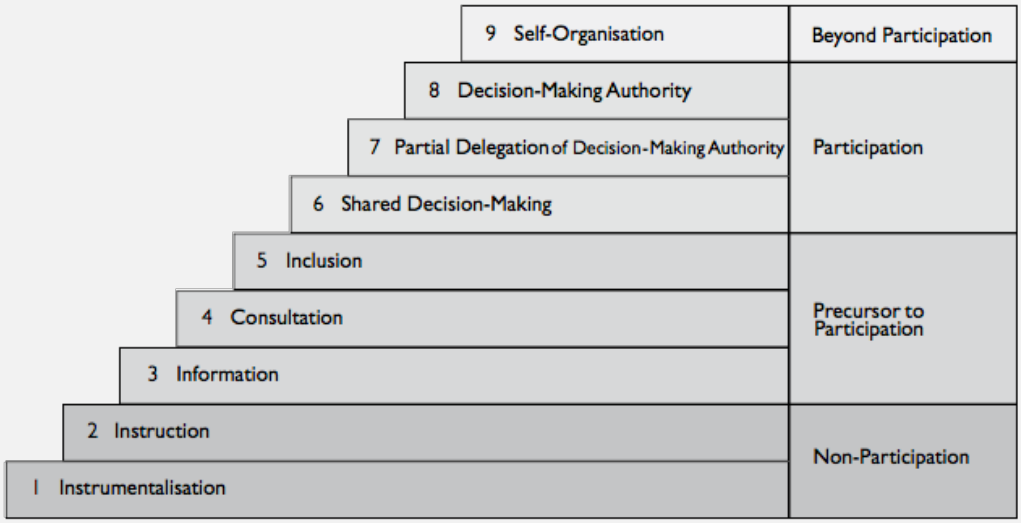

Figure 3: Stage model of participation (Von Unger, 2012)

[5] The participatory research methodology was developed as workplace innovation, meant to empower employees.

5 ANALYSIS

The main purpose of this first deliverable is the analysis of the current situation in schools and businesses related to educational technology through qualitative interviews.

Two different interview guidelines were developed for the two groups: one for teachers and one for businesses. Criteria for the development of the questions were the following (c.f. Hussy, Schreier, & Echterhoff, 2013):

- *Simple:* The questions should be formulated in a simple manner avoiding technical terms (where it could not be avoided they needed to be explained). The interpretation of the questions should be the same for all interviewees.
- *Short questions:* Questions should have an appropriate length in order not to overstrain the perception capacity of the interviewee.
- *No redundant questions:* Avoid overlaps of questions.
- *Avoid leading questions:* Questions that are leading to an answer are not valuable from a data information perspective.
- *Open questions* are favoured: Questions that can be answered with a simple 'yes' or 'no' do not contain a lot of information.

The questions were developed as part of the two separate guidelines for the semi-structured interviews (see **Annex 7**). Semi-structured interviews allow for more flexibility in contrast to fully standardised interview methods (Froschauer & Lueger, 2003). While all the questions of the guideline are mandatory, the sequence of the questions can be changed. Also, ad-hoc questions are possible in case it is reasonable to explore an issue in more details.

In short, the interviews addressed 5 topics:

- defining innovations (Questions: 2-5)
- innovation barriers, incl. knowledge, markets, costs (Questions: 6-14, 22)
- innovation enablers (Questions: 15 - 17)
- existing innovation management activities (Questions: 18)
- innovation measurement (Questions: 19-21)

The following sections introduce the interviewees first, and discuss subsequently the topics mentioned above. Interview responses are referenced as closely as possible to the original answer, although we refrained from verbatim quotes, with few exceptions. The source of the answer is indicated in brackets with a **country acronym and a number**, e.g. SI4 would stand for interview number 4 of a Slovenian teacher.

5.1. INTERVIEW PARTICIPANTS

Interviews were organized and implemented in 9 countries (see Figure 3). Interviews were done over skype or face to face. All interviews took place in the months between June and August 2017. In some instances, interviewees decided to fill in answers in writing, so that there was an individual reflection phases prior to the interview. Selection criteria for interviewees included a focus on

teachers in schools, primarily schools which could benefit from eCraft2learn innovations later on, secondly we were aiming to include R&D companies as well as university departments participating in the development of eCraft2learn innovations. However, we also opened up the interviewing process to organisations outside the network of eCraft2learn partners, in order to reflect the diversity of stakeholders in the educational sector. The high percentage of teachers is justified by the fact that most educational systems show national idiosyncrasies and even within a country, there are often substantial differences among schools according to type and geographical location of the school (i.e. rural versus city schools).

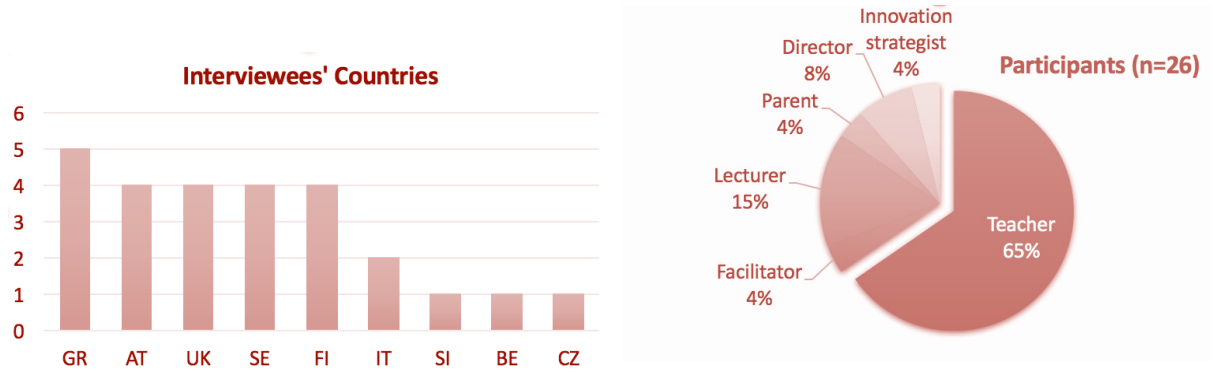

Figure 4: Interviewees' nationality and professional background

In terms of age, 44% of interviewees were between 31 and 40 years and concerning interviewees gender, we achieved a fair balance between male and female respondents (see Figure 4).

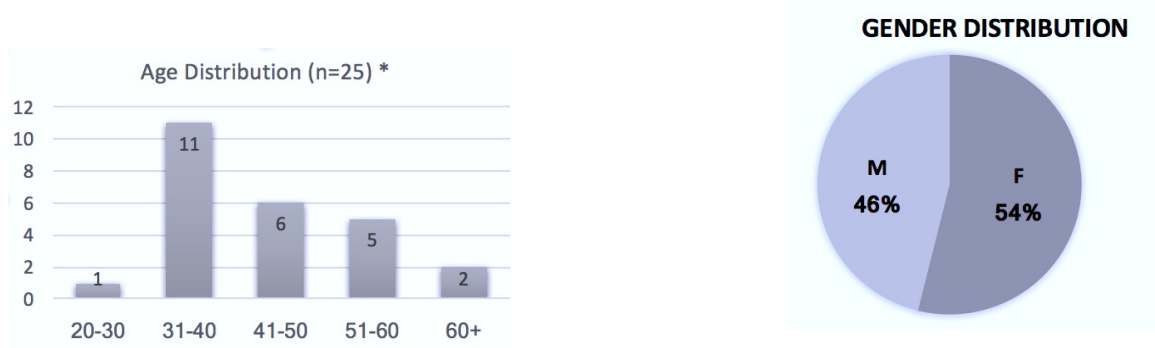

Figure 5: Interviewees' age and gender distribution

The discussion of barriers and enablers of innovation is mostly based on teacher interviews (n=15), with a country distribution as indicated in figure 5.

	Interviews
AT	3
CZ	1
FI	4
GR	2
IT	2
SI	1
UK	2

Figure 6: Number of interviews per country

Lastly, teacher – student ratios were also seen as a determining factor, in that a low ratio indicated either a higher number of part time teachers, a greater variety of choice subjects or a strategic decision for team-teaching.[6] As shown in figure 6, the highest average student – teacher ratio was reported by our UK interviewees (with 13.6 – 15.5 students).

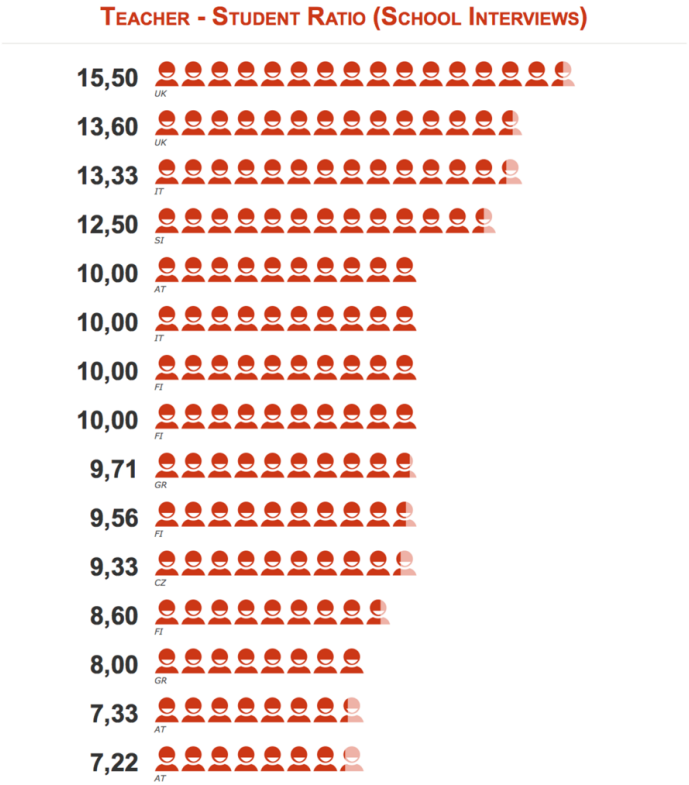

Figure 7: Average student – teacher ratios

[6] A more precise indicator would have been average teaching load, normalized by weekly working hours.

Ratios below 9, however, were the result of curricular innovations such as the 'new middle schools' in Austria, or the recent introduction of a 'project-driven, cross-disciplinary, new curriculum' in Finland. In both cases, the new pedagogy featured team teaching (e.g. 2 teachers per class) in order to allow for a more responsive and individualized teaching style.

5.2. DEFINING INNOVATION IN SCHOOLS AND INDUSTRY

A first question when researching the innovation capacity of the educational sector is 'how do we define innovation?'. Innovations are generally described as the exploitation of new ideas; hence innovations imply novelty and usage (i.e. the adoption of the solution by a relevant user group) (H. W. Chesbrough, 2003).
As highlighted in section 3.1, innovations can be incremental or radical. However, a common denominator of innovations is their reliance on systematic change.

Lubienski (2003) notes three different notions of how innovation in schools can be understood:

- Practices are innovative if they are **new within their local context**. This interpretation goes counter to the idea that innovation has to be 'new' in general. This is an important distinction, since, as previously discussed, a defining characteristic of innovation is acceptance and uptake of 'new practices' by relevant groups (Rogers, 2003). In the context of eCraft2Learn this means that an *innovation seen locally* could consist of a smooth process description for managing a class using raspberry pi, whereas a '*general innovation'* in that area would be a learning analytics infrastructure, capturing and analysing pupils interactions with the RPis.
- A second interpretation of 'innovation in schools' refers to '**novel combinations** of approaches and/ or technologies'. This means that no approach or technology is novel per se, but that novelty emerges when things are combined and applied in a specific context where they can create a positive impact. So, even for learning analytics applied to RPis, we may find multiple tools and processes, which then require adaptation but not necessarily new developments of core functionalities.
- Lastly, a third perspective, sees **innovation materialized as a set of choices**. That is, pupils can choose to engage in different learning formats, using a diverse range of technologies. This might be a problematic interpretation in so far as it strains the resources of the educational provider and there might be justified cases for offering choice only after learners have demonstrated that they understand the various options.

5.2.1. INNOVATION COMPONENTS, NEEDS AND OUTCOMES

This section provides an overview of respondents' definitions of innovations as well as their perceptions oh why their schools should innovate and what they would expect from an innovation as outcome.

ID	Defining Innovation	Innovation needs, Innovation outcomes
AT1	Project-driven classes, use of new media, related professional development	There is a need to be on top of current developments. This is also an expectation society and ministry have towards schools. However, there is a di-

ID	Defining Innovation	Innovation needs, Innovation outcomes
		lemma in that we need to experiment with innovative products but also demonstrate evidence for improved learning.
AT2	There are projects in physic classes, but all in all no clear specifications of what is considered an innovation.	Is mainly teacher driven, though there is little time for innovation since many topics need to be covered. For teachers, outcomes of innovation shouldn't imply major disruptions but there should be a way to connect with existing practices.
AT3	Innovations have a strong technology focus (e.g. Smartboards, document cameras).	Innovation is an important factor to be different, especially since there are schools competing for the same students in the area. Once you have too few students there is a risk to be combined with another school in which case you lose sovereignty about the way you structure your teaching. All in all, innovation should make things easier.
SI4	Project-driven classes involving more than one subject (e.g. combining chemistry, biology and computer science). Using electronics such as Arduinos or Raspberry Pi.	Innovation is a major attractor. Students from other cities apply to the school. However, funding is largely depending on external donors and parents council. The major outcome is that student can try things in order to understand them better.
AT5	Good Information Technology (IT) as well as courses that teach programming and robotics, but not yet connected with other science subjects.	Schools should concentrate on applying 'innovative methods'. Schools are not the place to invent innovations.
GR6	Innovation should inspire students to be creative and to create new things.	Innovation, as one of the outcomes, should raise students' interests in STEM and make them more open minded about the potential uses of computers and smartphones.
GR7	Innovations are expressions of open-minded teachers and students.	Innovations imply change, which in turn can lead to stress. So whatever the innovation, it's important to include teachers and students early on.
UK11	Innovations should help to get the best out of students and teachers.	Innovations are a necessity to spark students interest in the subject. Innovations should lead to questions and the urge to experiment, make mistakes and therefore learn.
UK12	Innovation means addressing new challenges through new subjects and new technologies.	Innovation keeps learning fresh and relevant. Should be meaningful to future workplaces.
IT15	Innovations involve a mandate to focus activities, new technologies and new didactic methods.	Since we are a technical school, innovation is inherent to teachers' individual preparation. For example, recently we started teaching about Industry 4.0.

ID	Defining Innovation	Innovation needs, Innovation outcomes
IT16	Innovation is mainly about new pedagogical methods.	Schools need to involve students in shaping their education, using the tools typical for a given generation.
CZ18	Innovation is mainly presented by new technologies used in teaching. But networking with other schools (e.g. for language teaching) is also an innovation.	Innovative teaching helps to attract more students. Innovation should be defined by its objectives and not by tools. So, the Internet would be only a tool, but the overall objective must be to learn how to use a variety of information sources.
FI23	Innovations are to reform the idea of teaching and learning.	We need innovations as motivators for students. The expected outcome is still 'learning'. What did the student achieve.
FI24	Innovation is about openness and diversity.	Innovation is already triggered by the new curriculum we are implementing. Innovation should establish a certain state-of-mind: seeing how things are connected.
Fi25	Innovations can be changing things we do all the time, if someone finds a way to do it better.	Innovations could be primarily for those who are not motivated or interested. Or the ones with bad grades.
Fi26	Innovation is not explicitly defined but appears in many contexts of the new curriculum.	Teachers need to see the usefulness of an innovation in order to adopt it. Student need to have a more satisfactory learning experience.

However, there were also voices of concern: "The term innovation is scary for many teachers because it is the term that is constantly being talked about and teachers in the Czech Republic are often pushed into it, whatever it means. It is often understood negatively. For many teachers, innovations mean only watching movies or visiting exhibitions, using computers and a projector. … I would not define 'innovation' in teaching as a necessity to change the way of teaching or the necessity to use new aids or play games, but as an opportunity to include cooperation with specialized workplaces or using the Internet as a search tool." (SI4)

5.2.2. CONCRETE EXAMPLES

Last in this section of the interview we asked teachers about concrete examples of innovations, which they either experienced or participated in. In case they had difficulties in identifying such examples, we highlighted again that innovations can happen in very different areas:

- Products (e.g. adapting a video sharing platform for a school)
- Processes (e.g. a new teaching method, peer learning, use of learning analytics)
- Cultural / social innovations (e.g. democratic decision making, idea crowdsourcing)
- Organisational / structural innovations (e.g. a new employee evaluation scheme, a new budget category)

AT1:

- Learning spaces / schools made of wood. Studies have shown that the potential for in-class conflicts is lower compared to traditional buildings using concrete[7].
- A mobile laboratory with equipment and smartphones where students could explore the basics of programming, using their own ideas.

AT2:

- Students need to develop, market and sell a product. This exercise is part of a business course at school.
- The school aims for teachers offering development opportunities for other teachers (similar to having champions per topic).

AT3:

- Development of new curricula to implement a new school type (NMS – Neue Mittel-Schule)[8]. The novelties characterizing this new school type include team teaching (2 teachers), a focus on individual needs, the avoidance of under- or over-challenging students. This has an important consequence for students whose educational paths was often already defined at age 10, now they obtain the 'Mittlere Reife'[9] and can continue with another school allowing them to matriculate at a university.

SI4:

- Two students invented a chip for a washing machine and are now collaborating with the German company Bosch, integrating the chip into actual products.
- Another student invented a mechanism to safe the cold water in the shower that is wasted until the right temperature is reached.

AT5:

- Our students repaired a donated car together with a mechanic. The students could see the parts and make video clips explaining certain parts. The repaired car was then sold and the money went to the school's garden.

GR6:

- Students revised experiments in physics, exploring different ways of measuring things like volume and temperature. Thereby we discussed the need for calibration and how different measurement conditions impact the accuracy of the values obtained.

UK12:

- We use 3D printing and microcontrollers to teach high level engineering.

IT15:

- As an institutional response to promoting innovations in school, we introduced the role of 'digital animation teachers'. Their role is to involve other teachers with the concepts of 3D printing or coding.

IT16:

- I organize a robotics club. To me it's important that students' attitude towards science changes and that they can showcase what they do (scratch days, exhibitions for parents)

FI23:

- From a technological point of view, we introduced iPads and Laptops to the classroom.

[7] http://www.proholz-kaernten.at/fileadmin/user_upload/download/Unterlage_SOS_Studie.pdf
[8] https://www.bmb.gv.at/schulen/bw/nms/index.html
[9] https://en.wikipedia.org/wiki/Mittlere_Reife

- In secondary school, we also started 'digi-tutoring', i.e. two teachers have been nominated to guide others with their digitalisation efforts.

FI25:

- For example, leaving the desk was innovative and motivated the students. Changing the environment made them more receptive.

FI26:

- We had a project around cleaning polluted nature and building the required infrastructure for that.

5.2.3. HOW INNOVATION IS UNDERSTOOD OUTSIDE SCHOOLS

Following the notion of a triple or quadruple helix (Leydesdorff, 2000), this section will link schools' notions of innovation to what universities, businesses and civil society organisations think about innovation. To better understand the helix principle, it is good to remember that early research on innovation started with a linear notion of the innovation process, where science enables new technologies which are transferred into markets (Arnkil, Järvensivu, Koski, & Piirainen, 2010). The idea of markets or end-users informing research was not part of the linear model. Indeed, early on, the fact that further innovation might be needed upon market introduction was not accounted for. As a result, innovation research shifted towards interactive, non-linear innovation processes in multi-actor innovation networks. The figure below illustrates the resulting participation space, here in the context of designing a 'smart city' (Figure 8). No single academic discipline would suffice to offer a complete picture of what the future smart city should entail. The figure shows the emergence of a participatory space, including all stakeholders in order to cover the various dimension of innovations needed (social, organisational, technological and sometimes even political and regulatory innovations). Eventually, a working network of interacting innovations at a systemic level is emerging.

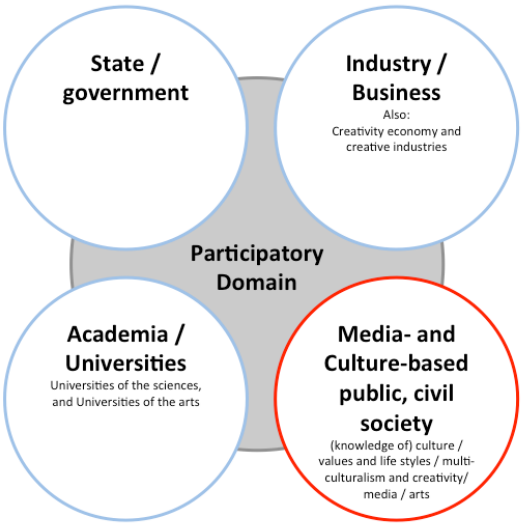

Figure 8: Collaboration within the triple and quadruple helix[10]

Translating figure 8 into the stakeholder groups in eCraft2Learn,

- schools as public organisations represent the government,

[10] (Van Waart, Mulder, & De Bont, 2015)

- companies such as Ultimaker and Arduino, which have long-standing educational programs running, such as '*create education*'[11] or '*creative technologies in the classroom*'[12] represent business,
- teachers from universities such as Cambridge (UK) or Mälardalen University represent academia,
- places for informal learning (The Industrial Gas Museum[13]), since out-of-school learning becomes an ever more important part of the students' individual learning ecologies – represented the view of a civil society organisation. The latter was enriched by an interview of a parent planning to start a parent-organized educational initiative.

After the discussion of teachers' views on innovation in section 5.2, following a summary of comments from companies (including civil societies which in our context were non-profit companies) and universities.

Companies' views on innovation

A. A state-owned, consulting company facilitating networking among different organisations who might not have the full research capacity needed to address a specific problem. For them, innovation covers the entire chain from idea to market introduction. Their special focus is on Needs Analysis "where we today often jump the gun by starting solving identified problems directly, implementing solutions because we have such great tools for doing so, rather than looking at the needs and allowing the corresponding questions to be properly formed. We'd also like more of tools developed purposely for structured, inventive problem solving (e.g. like TRIZ, www.triz.co.uk)." (SE22)
B. A for-profit, open source hardware company sees innovation as paramount to their survival. The idea is that a huge upfront investment leads to an innovation, which, if repeated more often renders a profit. The company has won the innovation radar in the past year In the area of IoT (a Internet of Things platform). However, the company is also very active in the educational sector, using creative technologies. Their programs have demonstrable success, with the latest offering being attended by 4,500 children learning the basics of electronics and programming.
C. Another for-profit organisation, developing and selling 3d-printing solutions emphasizes the importance of 'open innovation' (UK14). Similar to the previous interviewee, innovation is all about translating ideas into outcomes, but market feedback makes all the difference. What sort of innovation is needed is best decided upon receiving comments from those who use your product. Even better is it if you make your components open source and users can prototype their own solutions because they can plug into the existing systems whose specifications are known. So a big part of the company's innovation culture is their supportive user community. Whereby the user community serves a double purpose, not only is the product itself improved but also new application scenarios are discovered, such as scanning and printing an arthritic knee which is then used for doctors – patient communication as well as medical education or exploring various treatment options by a group of experts.

[11] https://www.createeducation.com/
[12] http://verkstad.cc/ctc/
[13] https://www.athens-museums.com/guide/science-nature/223-industrial-gas-museum

Universities' views on innovation

A. The interviewee works at a technology institute, being part of a university. For him, innovation is what comes after a proof-of-concept stage (SE21). However since the university is active in two areas: teaching and research, he is also aware that there are different areas for innovation. So that educational technology seems to be the most agile area, whereas innovations in the administration is very 'play it safe', and the introduction of new ideas is even frowned upon at times.
B. Also working at a technical university, the interviewee sees innovation as an omnipresent theme at the university which strives to constantly improve teaching and learning methods (SE20). He is frequently inquiring his students about their use of TV or landline phones, which is declining year by year. He then raises the question of how universities' ways of teaching and assessing students have changed and argues that innovations in education need to be in tune with the life-worlds of those being educated. Another area that calls his attention is the lack of open-source technologies used for educational innovations: "*Sadly, I've found that they [external providers] don't always have the students best interest in mind, as they primarily need to make money for shareholders and owners. Openness, ease-of-use, interoperability with other systems, importing learning objects and exporting data to and from various platforms are lacking as a bit of lock-in often is preferred*." (SE20)
C. An interviewee from a manufacturing department, emphasizes the importance of understanding 'how something is used' and not only 'how something can be done better in the abstract' (UK13).

5.3. BARRIERS

There is rarely an organisation that would say innovation is not important to them, still, many organisations do not consider themselves effective innovators (Loewe & Dominiquini, 2006). The barriers brought forward frequently include 'perceived riskiness' or 'short term objectives such as saving costs'; which stop organisations following through with their innovations strategies. Loewe & Dominiquini list the top six barriers to innovation based on a survey of 550 large companies. However as the ensuing discussion will show, in one form or another, these barriers can also be found in schools. These are the top six obstacles (ibid):

1. Short-term focus.
2. Lack of time, resources or staff.
3. Leadership expects payoff sooner than is realistic.
4. Management incentives are not structured to reward innovation.
5. Lack of a systematic innovation process.
6. Belief that innovation is inherently risky.

One of the key enablers of effective innovations according to the authors is visionary leadership behaviour, which in turn requires a common definition or a shared understanding of what innovation is or why it matters to the organisation. One of the reasons we included this point in the interview guide and discussed it in the previous section.

Talking about 'barriers to innovation' is not an easy task for organisations. Not only because it implies to engage in critical self-reflection[14], but also because organisations' perception of barriers strongly depends on their propensity to innovative. This is described by D'Este and colleagues as the difference between revealed and deterring barriers (D'Este, Iammarino, Savona, & von Tunzelmann, 2012). Revealed barriers are those, organisations encounter when they actually engage in innovation processes and need to overcome these barriers, meaning that organisations who innovate less, likewise see less problems in their innovation processes. Deterring barriers, are a distinct set of barriers experienced by less-innovative organisations and include things like path dependencies, market regulations or costs, etc. This is also closely related to the importance attached to each barrier – a perspective not discussed in this report – but essentially there is also a difference between the perceived importance of barriers and the actual impact these barriers can have (Iammarino, Sanna-Randaccio, & Savona, 2009).

The interview guide addressed three different areas of barriers:

1. **Knowledge / Skills:** Knowing about latest innovations in the field, having the skills to preselect potentially applicable technologies (Chase, 1997);
2. **Markets**: Knowing which products / markets are relevant, dependencies on market conditions (offerings, educational focus) (D'Este et al., 2012);
3. **Funding**: An organisation's ability to make the necessary investments, including financial and man power resources.

5.3.1. KNOWLEDGE GAPS

In this section we asked teachers about their ways to keep up with the growing amount of information related to innovative technologies relevant to their respective subjects. We also asked them what they found particularly important to boost innovations in their schools.

Teachers attempt to be on top of their subjects as well as related educational technologies by

- Accessing the Internet (SI4, GR6)
- Reading relevant journal and magazines (AT1,GR7)
- Attending open days, fairs and exhibitions (AT2, GR6, CZ18)
- Having local interest groups for exchanging experiences (AT2, GR6, Fi23)
- Using information channels provided by the education ministries, e.g. 'IT at school in Austria'. Unfortunately, filtering and keeping an overview of what is offered as part of the initiative is a challenge (AT3)
- Exploiting personal contact to the computer department of the local university (SI4, UK11)
- Following e-learning classes (GR7).
- Organizing professional development sessions at the school (UK11)
- Joining Facebook groups (Fi23, FI25)
- Making an e-Book (FI26)

An open question at the end of the interview section about the role of knowledge, asked whether there are other factors they consider important to support innovations at their schools. For this question we got mostly answers that hinted at the cultural dimension of an organisation, including

[14] One interviewee addressed this by saying „If you ask our principle she would say everybody is innovative, but there is a big mass of teachers that don't have a lot motivation, they are not really brave enough to go totally a different way, they also have children of their own, but innovation comes with extra time and extra meetings." (AT5)

not only what is communicated, but also how it is communicated (e.g. passionate and compelling champions). After reading through all the answers we could see two main areas emerging: (a) the importance of freeing up / being granted enough time to explore innovations and (b) – probably related – getting support from the school's management and principal.

Time

- There were also some references to keeping particular life phases in mind, e.g. teachers with young kids cannot spend as much of their free-time on extracurricular innovations as teachers whose children are already grown ups (SI4). Or the fact that senior teachers have less foundational skills they can build upon as younger teachers, who grew up with tablets and smart phones, hence a one size fits all training is not adequate. Time needed to become acquainted and fluent with educational innovations needs to be addressed openly, a first step needs to be the integration of project work and the use of innovative technologies into the official state curricula (SI4).
- There is no shortage of resources (mainly commercial support materials supplied by publishing companies), but we also need the time to review these materials (AT1)
- Given the shortage of time for exploring innovative products, teachers stressed the importance of 'ready-to-use' products, where own developments are minimal (AT2). On the other side, even 'ready-to-use' products require experience in order to apply them under different conditions (e.g. deciding about the most appropriate size of a group, when working on a robots experiment) (IT15).
- In some instances, obtaining the knowledge is the smaller problem, acquiring the technology can be more time consuming as we experienced this when searching for some particular sensors (SI4).
- Many teachers think they have to stick to the curriculum, no matter what. However I think they should cut-off some topics and be more flexible in the way they implement it and allocate more or less time to topics if they use innovative methods which require more time. (AT5)

Supportive, collaborative culture:

- Open minded colleagues (AT1, GR6)
- Thinking about incentives is extremely important. There is no performance or innovation bonus to teachers' payments (AT3). Hence, it's about personal interests.
- The management of schools needs to be won over (IT17). This requires good presentation skills (AT3), it should be the other way around – management should present innovations to teachers (GR7). Principals need to provide resources and support, they need to be positive about it (FI24).
- We also have to think about sharing good examples, for teachers and students alike. We could also have prizes or competitions at school for innovative practices (GR6). We need effective ways of sharing, if time for reading up on a topic is limited we could use Friday Morning sessions, during which one teacher presents to the others what he or she is currently focusing on (UK11). Equally we could use informal talks during coffee breaks to talk about our innovations (FI25).

5.3.2. MARKETS

In this section, we aimed to explore the relationship between teachers, planning innovations, and schools' decision making processes, given a 'market of opportunities'. Firstly, we wanted to know, whether teachers felt like they were up to date with what the market had to offer. Secondly, we wanted to know how decisions about acquiring novel technologies are made and whether some limiting factors were at play (e.g. proprietary systems, maintenance contracts or hardware dependencies). However, with hindsight we can say that these questions seemed too removed from teachers daily experience.

Market offerings

- We don't have a lot of contact in that area. Some of the technologies really need to be presented, so that we can get a better impression of what the innovation is all about (AT1). Similarly another teacher commented, that yes the information is there, but once a product is purchased, it's quite cumbersome to get it running. The latter involves a lot of Google searches (AT2)
- Most teachers understood the question in terms of whether they knew about specific technologies such as 3D-printing, virtual reality and microcontrollers in general.

Decision making

- On one side we have some quite rigid structures and on the other side there are no 'extra' financial resources. So schools need to collect money from parents, donors or do things like 'Sponsor Runs' – basically running for money (AT2).
- It's not only about the decision to do something different, it's equally important to fit you plans into existing structures, which impose a lot of limitations (lesson plans, bus time tables).
- If innovative technologies are used in the classroom, it is important to have a sufficient quantity of those. After all, most groups are heterogeneous and if all students need to participate in the activity I need enough devices to allow for groups that advance at different speeds (AT3). We only have one lab for 1,300 students where we can use 3D printer, Lego robotics or Arduinos (AT5).
- Our decision making is constrained by the Ministry of Education. If they are not interested in a particular innovation, it cannot become part of the formal curriculum. Also on one occasion we got a national product, even if this was far removed from the current state of art (SI4). The kind of innovations that a teacher is allowed to introduce is limited to what the government proposes, since that's the reason why the funds were assigned to the school in the first place. If a teacher has a good idea, he's not allowed to put it into practice because he does not have enough funds. (IT15)
- For me, the decisive things are to make students aware of the social implications of their actions. From a PSHE perspective[15], getting children to have more compassion with each other and a better understanding of whether they can start thinking about how 3D Printing can improve society and help others. (UK11)

[15] Personal, social, health and economic (PSHE) education

5.3.3. FUNDING

In this section, we were primarily interested in finding out how teachers perceived the level of investment their schools put into learning and technological infrastructures. Interviewees associated costs mostly with the acquisition of technologies, wherefore we had some overlap with the previous question, which included answers about the approval of funding for innovations.

There were two main arguments driving the discussion about funding:

(a) **Type of school**: private or public, or in Finland we had a research-oriented school, or in Austria we had the 'new middle schools' which had a somewhat better funding than other school types.

(b) **Source of funding**: there will be national differences, but some parts of the school's cost are covered by a national budget, other costs are covered by the local community (municipality) and then there is some extra money coming in from parents or donors. Although the latter depends on the network the school has as well as the general socio-economic situation where the school is located.

But even if different sources can be combined, it seems like the teacher needs to develop quite some fund-raising qualities if he or she wants to get a project of the ground: "*Funding is absolutely a big problem, the school budged sounds quite big, but there are lots of big costs. The primary cost is the teachers, the building and then very little is left. About 30.000 is like nothing for a school of around 1300 studying. The whole budget has been frozen for 3 years now and no inflation adjustments were made. You always have to pay the teachers and the building first, and it always get less and less left. It's is really hard to get even 100 EUR for something, you have to ask for 10-20 € things, and don't get any money. In our school, parents have a strong organisation any they continuously contribute, but not all teachers want to go to ask parents. You need to have a budget from the school*." (AT5)

Then there is the economic situation of a country, which determines how much budget is made available for education: "*Funding is very low. Our Ministry of Education is not funding neither schools nor researchers in the academia. And this is the major obstacle. Almost all we do is through external contributions.*" (SI4) Or similarly Greece: "*Finally, innovation is traditionally related with paying extra for acquiring the necessary new equipment and that is a real barrier in a country under financial crisis like Greece. But, judging by my experience, innovation is not an expensive thing and people in charge should know about it.*"(GR6) Interesting about the last comment is the statement that innovation doesn't have to cost much. Of course, there is a difference in wanting to use Arduinos and stepper motors of about 50 € or a Lego Mindstorm Robot that can cost anything between 200 € and 500 €. In contrast to these statements, we also have schools which are facing no difficulties in getting the necessary resources – at least as far as the technology is concerned: "*We have a pretty good situation with the technology. Our high school is a pilot school in technology area and in our secondary school we get quite good support for investing in new technology (for example Drones and the equipment for programming*)." (FI23)

5.4. ENABLERS AND COMPETENCIES

Whereas the previous section discussed impediments of innovations, this section is focusing on competencies and skills needed to create and sustain innovations. Given the importance of innova-

tion in all sectors (public or private), having a better understanding of those factors is of great value to academics and practitioners alike. On the one side competencies can be real competitive advantages and on the other side they can lead to path dependencies (organisations do what they have always done, because this is where they have the best provisions).
On a higher level there is a quasi-consensus on four areas, which organisations need to manage in order to become more innovative (Souitaris, 2002):

- technical competence
- market competence
- human resources competence
- organisational competence

In the interview, we operationalised these areas by asking about how schools obtain information about educational innovations (from a *technical* as well as *market* perspective). The organisational dimension will be covered by discussing '*existing innovation management'* activities in the next section. Lastly, the main focus of this section is on the 'human resources' dimension and here more specifically on 'professional development opportunities' and 'hiring for innovation practices'.

Professional development opportunities

- We have one day per year, where we can choose trainings and then we have seminars during holidays. Occasionally there are also mandatory trainings, however I don't think it's appreciated a lot. (AT2) The latter was seen differently by an interviewee who reported that school management likes to see teachers taking advantages of professional development offerings (AT1). So it seems that here the individual attitude of a school's management plays an important role.
- Professional development depends a lot of teacher's individual decisions. Apart from the time it can also be a geographical problem, if your school is in a rural area and all courses are in the major cities. (AT1, AT3)
- There are courses that teach how to assist students with disabilities, bit no training is available for teaching computer skills, etc. (SI4)
- There are development sessions in the afternoon, but funding is always an issue because the school is very small (UK11).
- We have a local innovation group, with 6 weekly meetings, exchanging ideas and listening to each other (UK12). Apart from that we can attend training days at Manchester University.
- There aren't many options. Most development opportunities are organised internally (IT16)
- We have tutor teachers, who go to trainings and share what they learnt with their colleagues (i.e. train-the-trainer system). We also have 2 hrs a week support from two teachers showing how to use tablets in class (FI25). There are plenty of offerings but it depends on teachers' own will and activity (FI24).

Hiring practices

- In the past, teachers applied for a region and were send to whatever school had the need. However, this has changed over the last years and now many teacher candidates introduce themselves directly to the principal (AT2). However, the main selection criteria are the sub-

jects and less teacher's innovative ideas (AT1). The first selection criteria are the combination of subjects a teacher offers, then, what counts is the overall personality (AT5).

- Teachers' innovation capacities usually don't play a role for hiring, which is a pity. This way we run the risk of hiring blinkered specialist (SI4)
- There are state laws that regulate the hiring of teachers, e.g. years of service, age, family etc. so that 'innovation capacity' doesn't play a huge role, though it would be welcome (GR6)
- In my case I could see that the school was dilapidated [interviewee just started working there], so I was partly hired to make a difference there, improving teaching quality (UK11)
- Hiring happens through a centralized process, so the local needs of a school can't be taken into account (IT15, FI25). In the past, my school could hire teachers able to develop innovative ways of teaching (IT16).
- Hiring happens through the municipality, so I don't know if innovation plays a role (FI25). With the new curriculum, I do think that ICT competences and the ability to integrate different subjects and have peer teaching influences the hiring of new people (FI23)

5.5. EXISTING INNOVATION MANAGEMENT PRACTICES IN SCHOOLS

Typical innovation management methods include establishing a personal responsibility for knowledge, knowledge management as business strategy, assessing external knowledge, knowledge management trainings, reward systems for knowledge sharing and establishing best practices (Chase, 1997).

However, current conceptions of innovations have changed from a product or outcome perspective to a process or network perspective. By now, innovation management standard applications (Tidd, 2001) emphasizes the importance of networks for

- sharing information,
- sharing infrastructures and
- co-specialization.

The tools and methods needed to effectively manage innovation are as varied as intranet applications, groupware, conferencing tools, internal experts list, CRM, ect. Nonetheless, the networking aspect of innovation management has pushed a few 'unusual suspects' to the forefront such as Facebook Groups or WhatsUp Groups. The figure below lists tools and organisational arrangement interviewees mentioned in the context of their schools. In some instance networking platforms were not confined to the limits of the school but connected teachers at a regional or national level, like the use of peda.net[16] in Finland or bildung.at[17] in Austria.

[16] Peda.net is a social networking platform with personal profiles and discussion forums. There are different ways of using it and teachers, students and parents can sign in and check or comment what has been done at the school or at the day-care. However, it is primarily the schools and teachers, who decide how they are using it.

[17] Bildungt.at is a sharing platform for services, content and initiatives, including online materials supplementing school books or specifications of and recommendations for learning management systems (LMS). (Source: https://www.bildung.at/index.php?id=10)

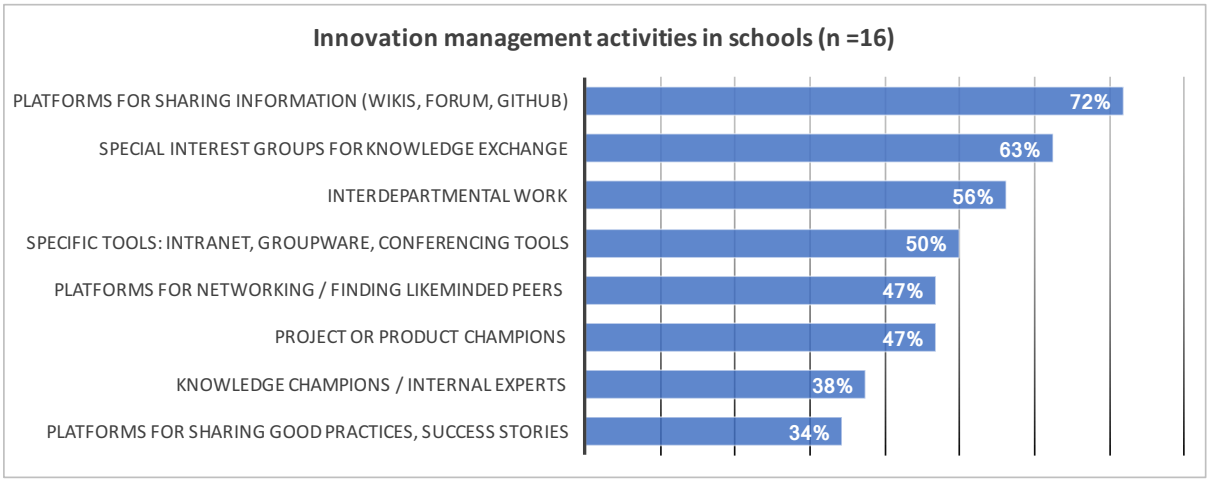

Figure 9: Innovation management tools in schools

Knowledge-based innovation management requires two types of tools (Hidalgo & Albors, 2008):

a) **technical tools** related to the acquisition and use of new information and
b) **relational tools** related to the exchange of knowledge, internally as well as externally.

Although the differentiation is not always clear cut and depends on how a technology is used, we can see that the top 5 tools include some networking capability and the last three tools represent mainly knowledge-push strategies.

However, there is no technological determinism in innovation management, which leads Tidd (Tidd, 2001) to remark that several decades of research on innovation management have failed to create a comprehensive framework to guide innovation management. The author's main argument is related to researchers' neglect of environmental contingencies: speed of change of technologies, changing demands for services and innovations in general or access to relevant research communities (since not all changes can be covered in-house). In some instance some very fine-grained factors might also play a role as we could see that the same technology (Moodle in this case) was used with great enthusiasm for a variety of innovation management tasks (SI4) whereas another organisation made less positive experiences, so that the tool wasn't used much (AT5).

6 Concluding Recommendations

Taking into consideration barriers and enablers discussed in the previous section, we are now suggesting some possible supportive actions which are meant to support the implementation of eCraft2learn pilots.

6.1. A strategic approach to open innovation

Open innovation implies that it is not dedicated R&D departments, operating behind closed doors and releasing innovations from time to time, that determine the innovation capacity of an organisation. Rather, it's teacher internal network and their links with external knowledge organisations that make for innovative practices in a school (H. Chesbrough, Vanhaverbeke, & West, 2006). Open innovation strongly aligns with the network definition of innovation put forward in section 5.2.3 and is also reflected in the strong presence of networking platforms among the interviewed teachers (see Figure 8).

However, at the moment it seems that networked innovations are primarily pushed by enthusiastic teachers working more or less in isolation. Comments in the barriers as well as in the enablers section (5.3 and 5.4) suggest that a school wide strategy for how to promote innovations, to make them more pervasive and ensuring that more students get their benefits, such strategies are largely missing.

A strategic approach could help to clearly communicate how emerging trends are screened and tested, which collaboration opportunities are pursued, how promising ideas are piloted at the school and finally, what financial and professional development resources are needed in order to achieve large scale uptake of the innovation (Igartua, Garrig, & Hervas-Oliver, 2010) within a school.

However, open innovation goes beyond working with other teachers and schools and suggest a stronger focus on involving the actual end-user of the innovation, the students. In this respect, a differentiation between user-centred innovation (lower involvement of user) and user-driven innovation (higher involvement of user) is put forward by (Arnkil et al., 2010).

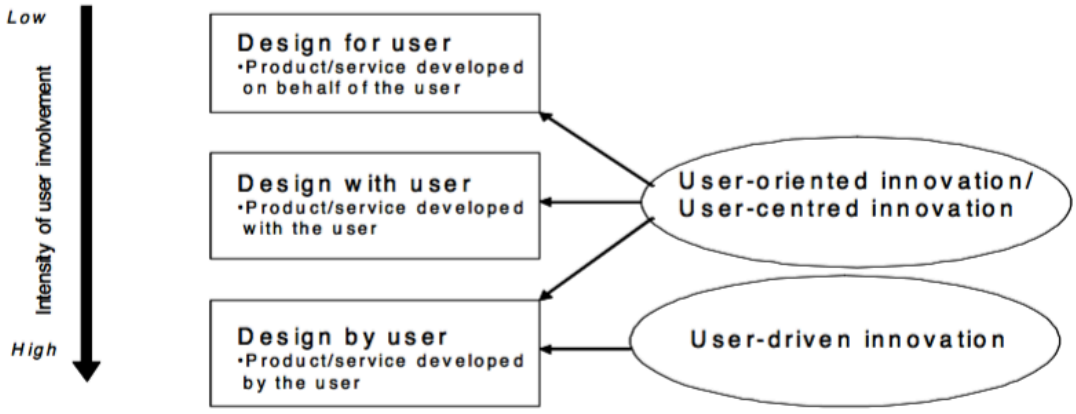

Figure 10: Degrees of user involvement (Source: Arnkil et al., 2010)

The participatory approach already figures strongly in the eCraft2learn project, however a conscious choice of what level of teacher involvement is most adequate given the barriers and enablers we have seen in the various schools seems recommendable.

6.2. DESIGN RECOMMENDATIONS

Observing innovation or starting collaborations to improve an innovation, e.g. making it more robust to work with increasingly heterogeneous groups, sounds straight forward in principle. However, in practice it is often tacit knowledge[18] which determines whether and how good an innovation works out on the ground: "Unlike a theoretical statement, which strives to become as context-independent as possible, the strength of a design pattern lies in its combination of abstract design ideas elucidated by concrete examples. The latter allow the user of a pattern to reconstruct the complex relation-

[18] From a business point of view, tacit knowledge is also a competitive advantage, 'protecting' open innovations from copy cats: "Your competitors will have a harder time copying your innovations. Because they are based in part on tacit knowledge, they are hard to copy. Because you have included your customers directly in your innovation, these customers will have invested their own time and self-generated content, making them less likely to abandon you at a moment's notice should another company try to lure them away." (H. Chesbrough, 2010)

ships inherent to educational designs." (Voigt, 2010). A number of design recommendations have been suggested for the area of crafts-based education such as envisioned in eCraft2learn.

Emphasizing the importance of student-driven, experiential learning, **design principles for tinkerability** in education have been suggested by (Resnick & Rosenbaum, 2013):

- immediate feedback,
- fluid experimentation and
- open exploration oppirtunities.

Similarly, but shifting the focus to learners developing their do-it-yourself identity, **principles to develop a 'maker mindset'** have been suggested by Katterfeldt, Dittert, & Schelhowe (2015):

- Be-greifbarkeit, i.e. being 'graspable' and connecting the virtual and the physical world;
- Imagineering, inventing and imagining a different future;
- Self-efficacy, being confident of ones' own mastery of tools, methods and materials.

6.3. PLATFORM INNOVATION

Open Innovation can have many benefits, such as accelerating underlying processes, improving surrounding services, and reducing costs and risks of innovations. Platform innovations are one category of such services, which share the benefits (and possibly costs) of one innovation among many users. One of the most well-known platforms is the Apple's iPhone, hundreds of thousands of developers create 'Apps' for Smartphones, increasing the smartphone's value and having an income for themselves: "App Store customers have now downloaded more than 180 billion apps and Apple has paid out over $70 billion to developers since the store launched in 2008, making it the most vibrant software marketplace in the world."[19]

[19] https://www.apple.com/ne/newsroom/2017/06/apple-unveils-all-new-app-store/

Educational innovations are unlikely to enter these dimensions anytime soon, nonetheless, the idea of platforms can also be found in the DIY sector, including specialised offers for education providers. For example, 'Create Arduino'[20] is an online platform, that allows user to program online, having their programs, their libraries and the most up-to-date IDE available from any computer they wish.

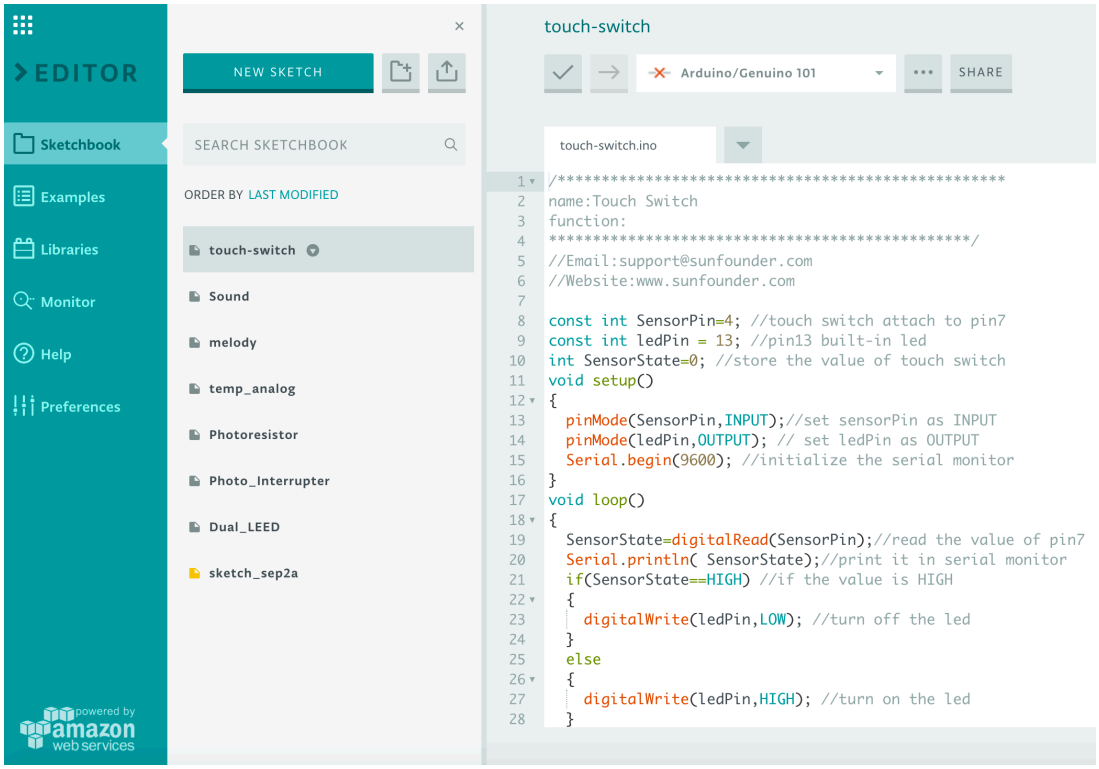

Figure 11: Arduino online programming

However, the online programming is only one feature of the entire platform. Other features include, among many things, introductions to programming, tutorials, support discussion groups and a store for Arduino hardware products.

Figure 12: Arduino platform features [21]

[20] https://create.arduino.cc
[21] https://create.arduino.cc/

A similar model can be found for 3D-Printing with TinkerCad[22], which offers an online version only, for those who want to use its 3D-Modelling and circuitry-testing capabilities.

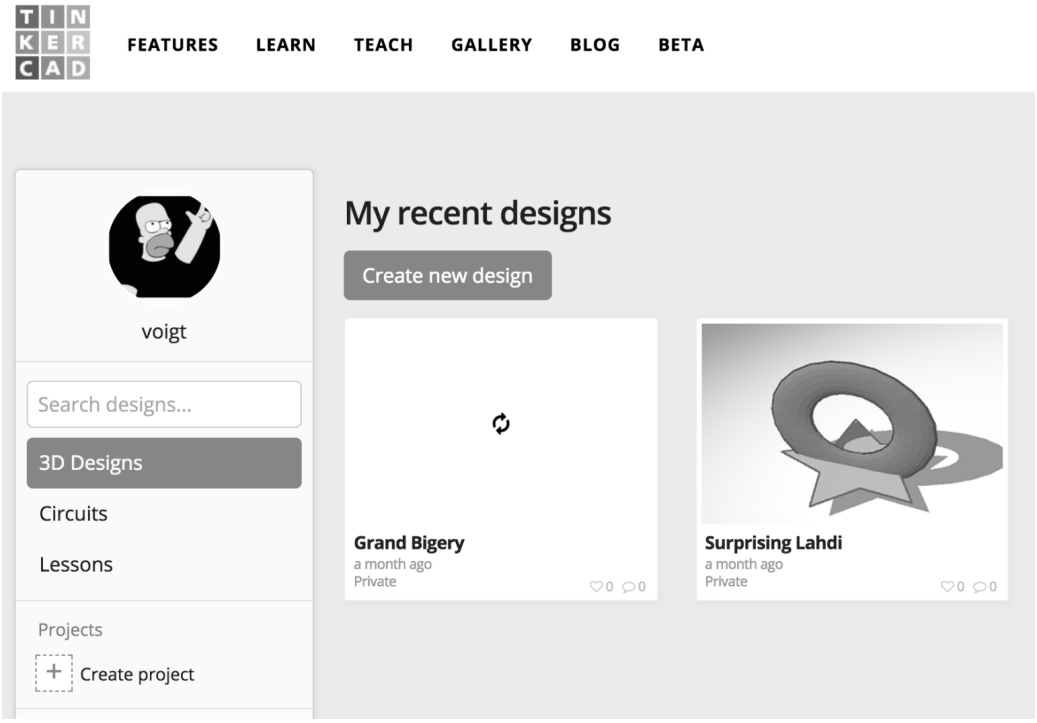

Figure 13: Tinkercad Browser-based 3D design platform

Again, we can find design and modelling features, together with support options and a lead to commercial services, integrating the platform with "leading third party printing services"[23]

7 ANNEX – INTERVIEW QUESTIONS

Following the text of the interview guide for teachers, interview guides for non-school organisations (e.g. companies, maker spaces, museums) were slightly adapted in the wording but contained essentially the same questions. The interview started with some background information about the project and what can be expected during the interview.
Instead of using an empty survey guide, we decided to include a version where some of the answers were already captured, including some follow up questions of the interviewer (highlighted in italics), in order to illustrate the conversational nature of the interview.

INFORMATION FOR THE INTERVIEWEE

Our project plans a series of interviews to better understand ways in which innovative practices around learning technologies are developed, implemented and scaled. We interview teachers, tutors, managers, tech developers, organizers of workshops etc. and are fully aware that some of the following questions might be more or less relevant in your context depending on your role.
Five broad topics will be addressed:

- innovation barriers

[22] https://www.tinkercad.com/
[23] https://www.tinkercad.com/about/features

- innovation enablers
- existing innovation mgmt. activities
- innovation measurement
- desired input from our eCarft2learn project

To what degree individual innovators are enabled by their schools, or respectively to what degree the innovating school is enabled by its own ecosystem are the core questions to be addressed in this interview. More concretely, things like appropriate funding, regulations, curricular flexibility, technologies ready to use or technologies likely to emerge, adequate training opportunities etc. can and should be part of the interview conversation.

The interviews follow a semi-structured format, hence it is totally OK to elaborate on points, include questions not mentioned in this guide or provide explanations. In this regard, it's quite different to a survey.

INFORMATION FOR THE INTERVIEWEE

Our project plans a series of interviews to better understand ways in which innovative practices around learning technologies are developed, implemented and scaled. We interview teachers, tutors, managers, tech developers, organizers of workshops etc. and are fully aware that some of the following questions might be more or less relevant in your context depending on your role.
Five broad topics will be addressed:

- innovation barriers
- innovation enablers
- existing innovation mgmt. activities
- innovation measurement
- desired input from our eCarft2learn project

To what degree individual innovators are enabled by their schools, or respectively to what degree the innovating school is enabled by its own ecosystem are the core questions to be addressed in this interview. More concretely, things like appropriate funding, regulations, curricular flexibility, technologies ready to use or technologies likely to emerge, adequate training opportunities etc. can and should be part of the interview conversation.

The interviews follow a semi-structured format, hence it is totally OK to elaborate on points, include questions not mentioned in this guide or provide explanations. In this regard, it's quite different to a survey.

QUESTIONS RELATED TO THE INTERVIEWEE'S CONTEXT AND UNDERSTANDING OF INNOVAITON

1. **Please tell uswhere you workplace, your positionand your typical tasks (teaching, managing, IT support, etc.).**

I'm working as a teacher of computer science (maths and technology as well) to students aging from 13 to 17 in a school in .. deleted …

How would you describe your teaching versus research in projects activities? About 70% Teaching and 30 % research.

Additionally, I'm supporting the computers' lab of my school and I also perform various tech related tasks in this school, whenever needed.

Is that informally ?

… no it's a formal part of the job

Apart from teaching, I'm working as senior researcher in technology & education related projects.

What are your background studies ?

Computing & engineering, additional seminars in education …

2. **What is your school's definition of innovation (if applicable)?**

Assisting the young students discover new things, be inspired and create.

Is that officially communicated?

… yes there is a lot of talk, but there could be more action ..

3. In what ways are innovations important to your school?

In my school, special time and resources are allocated (during the weekly schedule) for actions of innovation. But, as things are not ideal, not the perfect arrangement of resources is achieved.

Could you be specific? Is it one hour a week – e.g. the innovation hour ?

… formally we can take 2-3 hrs per week for innovative practices, but that needs a formal application at the beginning of the year, including information such as What should be done and

4. **How would you describe the term 'innovation'? What outcomes do you expect from an innovation?**

In my opinion, innovation is to think / design / create something that never existed before or combine things / ideas (not necessarily new) together a way that never existed before or make the others to do so.

5. **Can you talk about two or three examples of innovations within your school? Please let us know if you were involved yourself. And in what ways did your school benefit from the innovations.**

With a group of students we created mobile phone driven robots and artefacts responding to light and sound changes. We also reformed a series of conventional experiments of Physics using arduino uno boards.

What was the link to the actual curriculum (age / topic)? Please give 2 or 3 examples?

… age was between 14-16, i.e. how to accurately measure the amount of water in a bottle

.. we also did measuring temperature, e.g. and were looking at traditional ways vs digital tools. This leads to discussing measurement errors and the need for calibrations of measurement instruments in general.

.. one objective is to form an understanding the importance of measurement conditions (e.g. some electronics cannot measure temperatures above 60 degrees otherwise the components get damaged)

Actions like this made more (and younger) students to be interested for STEAM projects and made them more open minded when about computers / networks / mobile phones. Students – creators

became more self-confident and sociable and more parents agreed to assist in buying extra equipment for the school labs.

An estimate would be enough, what sort of contribution from parents are we talking about?

.. it was voluntary and mainly the initiative of the parents themselves, about 5 € for electronics and sensors

INNOVATION BARRIERS

Knowledge

6. **How many people have the necessary skills to support the innovations you would like to see within your school? (you can also provide percentages)**

I think at about 3 over 30 (10%)

Which skills did you have in mind when estimating 10%?

.. mainly skills related to technological innovations, e.g. computer skills, robotics, connecting things

.. teachers form other disciplines (art, language) might not have these skills

7. **How many people in your school push and support innovative ideas? (you can also provide percentages)**

I think at about 3 over 30 (10%)

How do you notice their support?

.. e.g. proactive suggestions such as 'let's organise an exhibition'

.. again I was thinking of technology related educational innovations. If I apply a broader definition I get up to 25%.

8. **To what degree are you aware of ongoing technological developments in your field? How do you keep up?**

If a have to quantify it, I would say about 80%. For the rest I'm not really interested or I can't catch up with. I manage to keep pace with the technological developments by using the Internet to find answers, by participating in conferences/seminars or by discussing with other teachers/students.

9. **Are there other things beside skills, supportive people and awareness of opportunities, you find important to boost innovations in your school?**

People have to be open-minded at new things, practices and persons. To boost innovation both students and teachers should be informed about successful examples or practices of other persons / schools and establish a mechanism of giving prizes for any good practice/artefact being done.

Markets

10. **To what degree are you familiar with the possibilities to include educational technologies related to making in your teaching? (e.g. Virtual Reality, 3D Printing, Micro Controllers)**

If a have to quantify it, I would say about 90%.

What makes a technology (e.g. VR) to an educational technology?

.. the difficulty is the process of adapting the technology to students interests and current skills (it's not the knowledge about the technology itself)
.. in the classroom, you definitely need an approach that delivers quick results
Can students handle the Arduino scripts if they are 14 yrs old ?
Yes, often they had course in programming already
And then we take existing examples which are adapted, reading data from a photo resistors / temperature via an Arduino can take less than 10 lines.

11. **In your opinion, are there practices in your school that make innovations more difficult? (e.g. by avoiding choice and variety of educational technologies)**

In public schools, people that are working as teachers are public employees and public employees often don't like changes. Sometimes some colleagues are somehow being suspicious of anyone who wants to do something new, to stop saying that he does it to get a promotion, to satisfy its big ego or to offend anybody else who doesn't do so.
Apart from the abovementioned reason, the weekly schedule is quite "heavy" and "inelastic" for both teachers and students and thus it is very difficult the necessary time and human resources to be found.
Finally, innovation is traditionally related with paying extra for acquiring the necessary new equipment and that is a real barrier in a country … deleted …
You made a positive comment about the financial implications of innovation. How about the cultural aspect of innovations? How could we scale the acceptance of more innovative practices?
.. it's important to not keep it private
.. the best is if you can ask colleagues to help and participate

Costs

12. **How would you describe the level of investment your school puts into technological and learning infrastructures?**

I would say is highly dependent on governmental decisions and funding. Additional help is offered by parents of students, former students and the headmaster.
What was the last innovation that has been funded – given you past experiences? (could be technology or a professional development course)..
.. officially there is a team of parents in charge for some investments. Others you need to apply for with the ministry.

13. **How does your school deal with the economic risk of investing in the 'wrong' innovation? 'Wrong' in the sense that it doesn't produce the desired impact either in terms of learners success or a company's turn over.**

The reusability of equipment, the use of recycled materials for artefact creation and keeping low the initial amount of investment are good practices. The good thing about failures is that you get informed about what not to do in the future.
Reply: Yes reusability is a good aspect, avoiding that things become obsolete too quickly ..

Regulations

14. **In your opinion, which European, national or local regulations could conflict with some of the innovative practices you would like to see?**

Specific care should be taken while creating video / photo material involving students in order not to publish sensitive personal information.

- Licences yes!

Furthermore the use of smart phones and the Internet itself under carries similar risks.

Which risks do you see here?

.. posting harmful photos during class, accepting calls during class

.. actually tablets without 3G connections are a better solution, this way we can control access to the Internet during classtime

Finally, while doing things like connecting electrical wires or cutting parts there is a potential danger of getting injured.

- Health issues

It is difficult to take all the necessary for the above precautions / measures and thus we have to leave apart some "ambitious" but "more risky" projects.

Do you feel you are taking a too big risk here as an individual teacher ?

.. I try to find a trade-off between accepting a slight risk (that can never be ruled out) and doing things that would be too simple if I maximize safety

INNOVATION ENABLERS

15. **How does your school collect information about latest educational technologies / innovations? Is this information regularly offered to all interested members of the school?**

Emails coming from central educational bureaus or other schools are the main source of information. Additionally, it happen colleagues to announce important things at monthly prolonged school meetings.

16. **What sort of development options are available to the workforce at your school?**

We have some arduinos / raspberry pi units and similar equipment, conventional computers, traditional hardware tools and an active laboratory of Physics and Chemistry. We also have a piano, a theatre scene, and relevant audio visual equipment. So, we can run STEM/STEAM projects. No 3D printer is available at the moment.

How about courses for teachers and teaching materials?

.. there isn't that much

.. some internal meetings take place

.. and there are some relevant seminars, but these are not mandatory

17. **To what extend do the innovation needs of your school influence the hiring of new teachers? (e.g. a person with eCraft experience brings a benefit to the place)**

Such an option would be very welcome but hiring teachers in schools is something that rarely happens due to financial crisis reasons. According to state's law other criteria are very important as well like the years of teaching experience or the number of members in teacher's family and so on.

Reply: Yes it's a multi-criteria process …

EXISTING INNOVATION MANAGEMENT ACTIVITIES

18. **How is your school promoting innovations at an organisational level? If one of the following applies, please elaborate briefly in what ways this supports innovations!**

a) special interest groups for knowledge exchange,
b) interdepartmental work,
c) project or product champions,
d) knowledge champions / internal experts,
e) platforms for sharing information (wikis, forum, github),
f) platforms for sharing good practices, success stories,
g) platforms for networking / finding likeminded peers
h) specific tools: intranet, groupware, conferencing tools
i) other: please specify ..

[highlighted the methods applied in the school]

INNOVATION MEASUREMENT

19. **How does your school capture the number of innovations in total as well as how many of these become a success?**

They organise exhibitions and special days for promoting innovation being achieved and they participate to similar events or conferences.

Can you describe one of those exhibitions / events ?

.. at the end of the school year, objects and activities are displayed ordered by multidisciplinary categories

The border between something successful or unsuccessful is difficult to tell when talking about young students. Different students tend to like different things in general.

20. **How does your school capture the effort needed to make an innovation a success?**

Difficult to tell what is successful or not in a school project, in any case, questionnaires are filled by the students participating to innovative activities and the pattern of their answers is taken into account to capture the effort needed for the success.

21. **And if so, what would be the criteria to decide whether the innovation is successful or not?**

As mentioned above, the border between something successful or unsuccessful is difficult to tell when talking about young students. Different students tend to like different things in general. But if we see more students to be interested in a specific topic or if people involved in a topic get better marks then this topic can be classified as a success.

SUPPPORT FOR THE INTERVIEWED PERSON'S SCHOOL

22. **What do you think should change first, to make your school more innovative than it is today?**

Better funding, better attitude between colleagues/teachers, stronger and bigger team to publish work being done to the Internet community.

8 REFERENCES

Arnkil, R., Järvensivu, A., Koski, P., & Piirainen, T. (2010). Exploring quadruple helix outlining user-oriented innovation models.

Chase, R. L. (1997). The knowledge-based organization: an international survey. *Journal of Knowledge Management*, *1*(1), 38–49.

Chesbrough, H. (2010). *Open services innovation: Rethinking your business to grow and compete in a new era*. John Wiley & Sons.

Chesbrough, H., Vanhaverbeke, W., & West, J. (2006). *Open innovation: Researching a new paradigm*. OUP Oxford.

Chesbrough, H. W. (2003). The Era of Open Innovation. *MIT Sloan Management Review*, *44*(3), 35.

Chu, S. L., Quek, F., Bhangaonkar, S., Ging, A. B., & Sridharamurthy, K. (2015). Making the Maker: A Means-to-an-Ends approach to nurturing the Maker mindset in elementary-aged children. *International Journal of Child-Computer Interaction*, *5*, 11–19.

Collins, J. C., & Porras, J. I. (1996). Building your company's vision. *Harvard Business Review*, *74*(5), 65-.

Damanpour, F. (1991). Organizational innovation: A meta-analysis of effects of determinants and moderators. *Academy of Management Journal*, *34*(3), 555–590.

D'Este, P., Iammarino, S., Savona, M., & von Tunzelmann, N. (2012). What hampers innovation? Revealed barriers versus deterring barriers. *Research Policy*, *41*(2), 482–488.

Froschauer, U., & Lueger, M. (2003). *Das qualitative Interview: Zur Praxis interpretativer Analyse sozialer Systeme* (Vol. 2418). UTB.

Gassmann, O., & Granig, P. (2013). *Innovationsmanagement–12 Erfolgsstrategien für KMU*. Carl Hanser Verlag GmbH Co KG.

Granig, P., & Perusch, S. (2012). *Innovationsrisikomanagement im Krankenhaus: Identifikation, Bewertung und Strategien*. Springer-Verlag.

Hidalgo, A., & Albors, J. (2008). Innovation management techniques and tools: a review from theory and practice. *R&D Management*, *38*, 113–127.

Hussy, W., Schreier, M., & Echterhoff, G. (2013). *Forschungsmethoden in Psychologie und Sozialwissenschaften für Bachelor*. Springer-Verlag.

Iammarino, S., Sanna-Randaccio, F., & Savona, M. (2009). The perception of obstacles to innovation. Foreign multinationals and domestic firms in Italy. *Revue d'économie Industrielle*, (125), 75–104.

Igartua, J. I., Garrig, J. A., & Hervas-Oliver, J. L. (2010). How Innovation Management Techniques Support an Open Innovation Strategy. *Research-Technology Management*, *53*, 41–52.

Kaplan, R. S., & Norton, D. P. (1995). Putting the balanced scorecard to work. *Performance Measurement, Management, and Appraisal Sourcebook*, *66*, 17511.

Kaplan, R. S., & Norton, D. P. (1996). *Using the balanced scorecard as a strategic management system*. Harvard business review Boston.

Katterfeldt, E.-S., Dittert, N., & Schelhowe, H. (2015). Designing digital fabrication learning environments for Bildung: Implications from ten years of physical computing workshops. *International Journal of Child-Computer Interaction*, *5*, 3–10.

Kensing, F., & Blomberg, J. (1998). Participatory design: Issues and concerns. *Computer Supported Cooperative Work (CSCW)*, *7*(3–4), 167–185.

Lessig, L. (2002). *The future of ideas: The fate of the commons in a connected world*. Vintage.

Leydesdorff, L. (2000). The triple helix: an evolutionary model of innovations. *Research Policy*, *29*, 243–255.

Loewe, P., & Dominiquini, J. (2006). Overcoming the barriers to effective innovation. *Strategy & Leadership*, *34*(1), 24–31.

Lubienski, C. (2003). Innovation in education markets: Theory and evidence on the impact of competition and choice in charter schools. *American Educational Research Journal*, *40*(2), 395–443.

Lubienski, C. (2009). Do quasi-markets foster innovation in education? A comparative perspective. *OECD Education Working Papers*, (25), 0_1.

Martin Jr, C. R., & Horne, D. A. (1993). Services innovation: successful versus unsuccessful firms. *International Journal of Service Industry Management*, *4*(1), 49–65.

Meek, S. E., Blakemore, L., & Marks, L. (2016). Is peer review an appropriate form of assessment in a MOOC? Student participation and performance in formative peer review. *Assessment & Evaluation in Higher Education*, 1–14.

Moore, G. A., & McKenna, R. (1999). *Crossing the Chasm: Marketing and selling high-tech products to mainstream customers*.

Morozov, E. (2013). *To Save Everything, Click Here: Technology, Solutionism, and the Urge to Fix Problems that Don't Exist*. Penguin UK.

Oke, A. (2004). Barriers to innovation management in service companies. *Journal of Change Management*, *4*(1), 31–44.

Resnick, M., & Rosenbaum, E. (2013). Designing for tinkerability. *Design, Make, Play: Growing the next Generation of STEM Innovators*, 163–181.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.

Schön, D. A. (1995). *The reflective practitioner : how professionals think in action*. Aldershot, England: Arena.

Souitaris, V. (2002). Firm–specific competencies determining technological innovation: A survey in Greece. *R&D Management*, *32*(1), 61–77.

Spinuzzi, C. (2005). The methodology of participatory design. *Technical Communication*, *52*(2), 163–174.

Tidd, J. (2001). Innovation management in context: environment, organization and performance. *International Journal of Management Reviews*, *3*(3), 169–183.

Van Waart, P., Mulder, I. J., & De Bont, C. (2015). Participatory prototyping for future cities. In *PIN-C 2015: Proceedings of the 4th Participatory Innovation Conference 2015: Reframing design, The Hague, The Netherlands, 18-20 May, 2015. Eds.: Rianne Valkenburg, Coen Dekkers and Janneke Sluijs*. The Hague University of Applied Sciences.

Voigt, C. (2010). A Pattern in the making: The contextual analysis of electronic case-based learning. In P. Goodyear & S. Retalis (Eds.), *Technology-enhanced learning: Design Patterns and Pattern Languages* (pp. 107–122). Rotterdam: Sense Publishers.

Von Unger, H. (2012). Partizipative Gesundheitsforschung: Wer partizipiert woran. In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research* (Vol. 13).

Watson, D. (2006). Understanding the relationship between ICT and education means exploring innovation and change. *Education and Information Technologies*, *11*(3–4), 199–216.