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RESEARCH

Teachers' Collaborative Pattern Language Design

Ola Knutsson* and Robert Ramberg†

Teachers in their practice make choices grounded in their teaching experience resulting in what could be labelled design solutions. An identified problem is that these design solutions stay at the level of individual solutions and do not reach the teaching community. The aim of this article is to study how teachers´ design solutions can be systematically captured, organized, and communicated through design patterns and a pattern language. Building on participatory design we have together with teachers used and adapted the concept of design patterns and pattern languages as a way of capturing, documenting and communicating design problems and solutions to these. This structured approach led to the teachers seeing connections and interrelations between problems, and that a solution to one of these also helped in alleviating other problems. The formulation of design patterns and proposed pattern languages thus gave the teachers an overview of their practice that would otherwise be difficult to obtain. The content of the design patterns show what problems that are dealt with by the teachers through their design solutions. The structure of the final pattern language shows how problems and solutions are connected to larger goals for the teachers, such as improving the communication with students, as well as the importance of sharing good examples between colleagues.

Keywords: Teachers' design solutions; design pattern; pattern language; participatory design; designs for learning

Introduction

Technology of today has penetrated the everyday life of people and promises of the use of these in teaching and learning are being echoed in the research community. Teachers are in their practice and preparation of learning activities engaged in what could be characterized as designing for learning (Selander, 2008). Teachers make choices grounded in their teaching experience often resulting in what could be labelled design solutions. A design solution here means a solution to a 'problem' that a teacher has, and includes making choices regarding didactics and the use of artefacts for solving the problem (Jahnke & Kumar, 2014). In Sweden and the other Scandinavian countries, most pupils have easy access to computers, tablets and the internet (EUN, 2013; Åkerfeldt, 2014), meaning there are a lot of technology available for the teachers that want to use it in their teaching.

To come to good use of technology in teaching could for instance be to initiate a design-based research approach building on the use of reliable design methods, with the aim to conduct interventions with a new better and more adapted technical solution (Wang & Hannafin, 2005). However, questions pertaining to appropriation and sustainability of these tools can be formulated, and more specifically if and to what extent these research artefacts are appropriated into everyday practice once a research project has ended, which has been identified as a problem (Cerratto-Pargman & Milrad, 2016; Ramberg, 2013). Another concern is to which degree design solutions for teaching scale beyond the context of the immediate design project and those participating in it (Halverson & Halverson, 2011). An additional question that can be raised is how teachers can come to good use of these technologies when many of them are struggling with basic issues of the technical infrastructure (Jahnke, Svendsen, Johansen & Zander, 2014).

Teachers in their practice of course strive towards overcoming difficulties and solving problems related to their teaching. It could thus be claimed that many problems encountered by teachers already have a good design solution, but these solutions are not represented in such a way that these become visible and inspectable to other teachers (Laurillard, 2008). This tacit knowledge of the teachers runs the risk of becoming inaccessible to colleagues and the teaching community at large and thus taps into questions of sustainability of design solutions. Inaccessibility to representations of existing design solutions to problems that teachers encounter in their practice makes the re-use of and continued development and refinement of existing solutions problematic. One way to represent problems, their contexts and working solutions is to use design patterns. In our work we follow

* Stockholm University, SE

† DSV – Computer- and Systems Sciences, Stockholm University, SE

Corresponding author: Robert Ramberg (robban@dsv.su.se)

the definition of both a design pattern and a pattern language made by Dearden & Finlay (2006: 50): "A design pattern may be defined as a structured description of an invariant solution to a recurrent problem within a context. A pattern language is a collection of such patterns organized in a meaningful way".

The aim of this article is to study, through Scandinavian participatory design, how teachers' design solutions can be systematically captured, organized, and communicated through design patterns and a pattern language.

The teacher as a designer in participatory design

Work and research within participatory design (PD) use a range of techniques, methods and practices including different types of workshops, design games, multimodal narratives, and constructions (co-created languages, descriptive artefacts, prototypes) as well as developing a mutual understanding between designers and participants by interacting and learning in each other's contexts (Muller, 2003). The field origins from the Scandinavian tradition of workplace democracy and collaborative technological development (cooperative design), but have nowadays emerged into many different areas with different purposes, including commercial companies (Sanders & Strappers, 2008). Gregory (2003: 62) points out three main characteristics of Scandinavian approaches to PD:

- *deep commitments to democracy and democratisation;*
- *discussions of values in design and imagined futures; and*
- *how conflict and contradictions are regarded as resources in design.*

In a school context this means that the teachers should be supported to take control over technology, and it involves the design not only of the computer tools but also the workplace as such. The Scandinavian participatory design tradition is not only about design of new technology, but also change and development of human's' thinking, organizations and communities ways to work and deal with problems (Gregory, 2003).

Cross (1982) discussed what specific skills and knowledge a designer has: designers are solution-oriented and are not seeking underlying rules for what optimally works for a given problem, and they combine knowledge from both science and humanities. A question can be raised as to what degree these skills and this knowledge are specific to designers. Kress & Selander (2012) for instance argue that in the era of available digital tools, teachers and even learners are designers. New digital tools and what these afford are not only something for designers to work and play with; everybody could do this (Kress & Selander, 2012). From the perspective of the teacher, the teacher designs for certain interactions and activities to take place. However, there is not an exclusive focus on the object per se, for instance the interface of a digital artefact or its internal workings. This is central to participatory design where the idea is to get people involved in design of processes that concern them and form their future uses of what is designed (Muller, 2003; Bannon & Ehn, 2013). However, it should be noted that the teacher should not be seen as a professional designer (cf. Buxton, 2010). Rather, from our point of view, design methods and techniques can also be introduced and used to develop the teachers' designerly-like competences.

Design patterns and pattern languages

Design patterns were originally introduced by Christopher Alexander to capture and communicate recurring design solutions within the field of architecture (Alexander, Ishikawa, Silverstad, Jacobson, Fiksdahl-King & Angel, 1977). This work has gained a lot of attention from other fields than that of architecture, and has come to good use for instance within software engineering and interaction design. Design patterns within these fields vary between a focus on smaller things (the placement of windows in rooms) to larger things such as how whole cities could be planned. The level of abstraction expressed in a pattern can serve different purposes and thus invite to different use of these. A detailed and specific pattern presents the specifics that can come in handy in implementing a particular solution to a problem. Whereas more abstract patterns describe and communicate guiding principles. Many design pattern collections now exist and much effort is put into creating so called pattern languages in which relations and dependencies between design patterns are made visible. What a pattern language thus introduces as compared to collections or libraries of design patterns is structure, hierarchy and sequence among design patterns where the syntagmatic and paradigmatic relations between patterns is clarified and made visible to the users of the patterns. Dearden et al (2002) describe how the structure of a pattern language make users of it to focus on different things and aspects of a design problem, from more abstract aspects such as content to detailed layout decisions.

Different approaches to the use of design patterns and pattern languages for learning and how these can support the use of technology in schools is reported in the literature (Goodyear & Retalis, 2010; Mor & Winters, 2008). As proposed by Erickson (2000), design patterns could be used as a lingua franca for design and for capturing and structuring how technology is currently used (cf. Dearden & Finlay, 2006), and how it could be used in new ways. Other research pointing at the importance and potential benefits to teaching of collaborative production and design of patterns has for instance been reported in (Laurillard, 2008; Karlgren & Ramberg, 2012). In research of design patterns to support teaching, much effort is however invested in creating sound and pedagogically anchored design patterns and languages, and it is questioned what the impact actually is on everyday teaching practices due to the level of abstraction expressed in such patterns and pattern languages (Goodyear, Retalis, 2010; Mor & Winters, 2008). The abstracted description needs to be understood and translated into a concrete practice by the teacher, which poses a problem. Mor and Winters

acknowledge and approach this problem by developing a workshop format for how to create patterns together with teachers (Mor & Winters, 2008; Winters & Mor, 2009; Winters & Mor, 2008). The authors in their research thus not only focus the resulting patterns but also the process of creating these and how the process could count as a support for the teachers to continue to use in planning and carrying out of their teaching (Mor, Warburton & Winters, 2012).

In our work, we similarly assume a participatory design approach focusing the process of creating design patterns and pattern languages and the adaptations that need to be made to fit within the context of the school. This is done in an attempt to ascertain sustainability and continued development of designs for learning in practice. In approaching the risk of the patterns and the pattern languages becoming too abstract, we choose to stay on the level of contextual descriptions that the teachers have formulated using their own language.

Developing the Pattern Language

The pattern language developed over a period of 2 years during which a series of participatory design workshops (cf. Brandt, Binder, & Sanders, 2013) were carried out together with a group of eight teachers. The teachers participated during office hours, and all teachers signed a written consent of participation in this research project. The teachers work at a primary school in the multicultural suburbs of northern Stockholm. The motivation of the school and engaged teachers to participate in the workshop series was to continue their pedagogical and technological development as well as to initiate collaboration and exchange with researchers at the university.

In the description of how the pattern language developed we in this article focus the following questions:

1. How did the teachers make use of the concept of design patterns to capture, document and structure their solutions to recurring problems in the school context?
2. What kind of pattern language did the teachers create, and what design patterns were to be found in the pattern language?

We also investigate how the teachers successively constructed the pattern language, and what recurring themes that by the teachers were experienced to be central to their practice. And more specifically, experienced to be central in terms of providing additional structure and communicative value to that of individual design patterns or the early collection of patterns.

The workshops conducted were documented by use of video and audio recordings, photographs, direct observations complemented with taking notes. Other important data consisted in the designs patterns written by the teachers, as well sketches, storyboards, scenarios and digital representations of the design patterns and the pattern language. A short questionnaire was also used in order to understand what the teachers felt about the workshops, the work conducted and the results from them, about halfway into the workshop series.

Our roles as researchers in this work have primarily been that of acting as participatory designers during the workshops carried out. We of course prepared a general structure to the workshops; we introduced tools and techniques and conducted analyses between workshops to prepare for the next workshop in the series of six workshops. Part of the analyses conducted was reading about and investigating other similar approaches and examples to function as inspiration and possible input to the process of pattern language development.

Participatory design with teachers

Our design work together with the teachers started with a *future workshop* (Kensing & Madsen, 1992), reported in (Cerratto Pargman et al, 2014). The outcome of this workshop was very problem-oriented, including the following action points formulated by the teachers:

- There is a need for education/training and knowledge sharing both for teachers and pupils.
- There is a need to dedicate personnel, time and resources for IT in teaching.
- There is a need to develop rules and technical constraints for the use of technology in order to get a less stressful and more peaceful working atmosphere.
- There is a need to take care of many practical and technical issues related to the use of technology for teaching and learning.

These formulations made by the teachers counted as our starting point, and these were more than anything else a call for more resources. The format of the future workshop was certainly too limited to propose and find solutions for this urgent call. In entering into the series of workshops and conducting the future workshop our intuition of what the teachers might need proved to be wrong. We thought the teachers would suggest and ask for new and innovative technology when in fact what the teachers asked for was something else. To shortly conclude, we understood that the teachers experienced many problems with technology, but we also understood that they had ideas of how to solve these problems although they were not satisfied with many of the suggested solutions. When analysing the teachers' problems and solutions articulated during the future workshop, we further concluded that there was a need to provide the teachers with tools of how to approach and handle the digitalisation process in their school. Thus, there was a need for us to find and suggest a way of systematically capturing and documenting the teachers' experiences that included the use and design of learning activities. Since design patterns focus problems that are recurring and presents solutions to these (mature solutions as well as less mature solutions) while also providing with structure and relations between patterns, our intuition was that design patterns would fit this purpose well. This taken together

with that similar approaches to capturing the use of technology in schools have used design patterns (Goodyear & Retalis, 2010; Mor & Winters, 2008; Mor et al, 2012) convinced us to introduce the concept of design patterns into the participatory design workshops.

The process of a pattern language development can be characterized as containing six main steps Schuler (2002):

1. Pattern collecting
2. Pattern discussion and deliberating
3. Pattern language development
4. Pattern presentation
5. Pattern language use
6. Pattern language evaluation.

In the workshop series following the future workshop, six workshops in all focused on design patterns and pattern language development. The five first workshops were participatory design workshops, where the focus was on composition (Löwgren & Stolterman, 2004) – combining the teachers' existing design solutions with new designs in order deal with the action points from the future workshop as presented above. The sixth workshop was led by teachers participating in the workshop series. During the workshop the pattern approach was presented to the other teachers at the school. In terms of the characterization of design pattern and pattern language development described above, see **Table 1** below.

The workshops were all carried out during the teachers' office hours and in one of the teachers' classrooms. The duration of each workshop was two hours. The researchers led the first five workshops, and three teachers participating in the workshop series led the sixth workshop.

In the following presentation of the process of pattern development, the workshops, the analysis of the workshops and the outcome of these, we aim to answer the first research question of this article: "How did the teachers make use of the concept of design patterns to capture, document and structure their solutions to recurring problems in the school context?"

Collecting patterns

Following the pattern language development process, the first two workshops focused on the collection of design patterns.

The first pattern workshop: introducing the pattern approach

The workshop started out with us presenting the results from the future workshop and our interpretation that there was a need for finding a structured way to document problems and ideas, and of how to solve these. We presented the concept of design patterns with examples from different domains including architecture and interaction design. By presenting examples from different domains we wanted to illustrate to the teachers that this "way of thinking" was applicable to different domains and therefore plausibly also to them and their practice.

There are different implementations and levels of detail of patterns and what aspects these are meant to capture, i.e. aspects concerning pattern notation. For instance, within human computer interaction and interaction design, a number of different formats have been used to present design patterns (Dearden & Finley, 2006). A simplified version of those design pattern formats was used as a template:

- Title: pattern name
- Problem: a description of the problem that the pattern is meant to solve
- Context: a description of the context in which the problem occurs
- Solution: a suggested solution to the problem
- Maturity: the level to which the suggested solution has been tried out.
- Other info: other information relevant to understanding of the pattern.

Three levels of pattern maturity were introduced:

1. A very mature solution,
2. A solution exists but can be improved,
3. The solution is a proposal to makes things concrete.

Table 1: Overview of the workshop series, including themes and participants.

Workshop #	Theme/purpose	No. of participants	Date
1	Introducing the pattern approach and collecting design patterns.	4	June 2014
2	Introducing a developed pattern template and use of design techniques. Collecting design patterns through scenarios and storyboards.	8	October 2014
3	Pattern language development (sketching its structure)	6	June 2015
4	Pattern language development and pattern revision (finding the gaps in its structure)	5	September 2015
5	Pattern discussion and refinement using a wiki.	4	October 2015
6	Presenting the pattern approach to the whole school.	41 (incl. 4 teachers from the previous workshops)	January 2016

The template was given to the teachers on paper. The teachers wrote all the design patterns that were collected. The teachers have based on their practice in the school and experience from that decided what counts as problems and as suggested solutions. Our contribution in this process was presenting them with the concept of design patterns and pattern languages, scaffolding the process and answering to questions as these occurred.

The pattern format used at this time, did not contain references between patterns or references to larger and smaller patterns, which was originally included in the pattern notation used by Alexander et al. (1977). However, the concept of pattern languages was introduced at this time, but only expressed as a long-term goal with the workshop series.

In the reading of nine design patterns from the first pattern workshop two things in particular stood out:

- Many of the patterns revolved around what could be interpreted as basic technological and infrastructural problems, both in- and outside the classroom (see e.g. **Figure 1**), and proposed solutions to these, i.e. very much in line with what has been reported elsewhere (Jahnke et al; 2014).
- It became obvious that they focused on problems, and this being a central part of the pattern template might have led the teachers to focus on practical problems instead of taking the opportunity to document and communicate to other teachers about their use of technology in their teaching – design patterns that might count as good examples of design solutions to technology use in teaching and learning.

The second pattern workshop: introducing a new pattern template and use of design techniques

In the second workshop focusing on collecting patterns, the collection of patterns from the previous workshop was presented. A slightly different pattern template was introduced including "achieve goals" and "pedagogical possibilities" to the category "problem". In addition, "proposed solution" was now used instead of "solution". The reason for this development of the pattern template was that we perceived the teachers to be too problem-oriented, i.e. they documented problems they were experiencing but put less emphasis on proposing and detailing solutions to these. Also, the strong focus on problems seemed to get in the way of thinking of possibilities.

The design techniques scenarios and storyboards were also introduced to aid in the pattern design process. In this workshop there were two tasks for the teachers to conduct, they were first meant to create a scenario or a storyboard (Van der Lelie, 2006) to describe a teaching situation including successful use of technology, and to analyse the scenario/storyboard and identify and create the patterns used in this situation. The second task was to describe a future teaching situation where technology would improve on the teaching situation, and then to analyse and identify patterns that this scenario/storyboard could be based on.

The analysis of data (observation notes, eleven patterns, storyboards, and scenarios) from workshop 2 was carried out through a simplified analytical procedure resembling affinity diagramming (Lucero, 2015): A whiteboard and the teachers' constructions (patterns, storyboards and scenarios) supported by the observation notes were used to organize and analyse the workshop outcome. The results indicated that the teachers picked up on and used storyboards to both illustrate and reflect on a situation and use of technology from the perspective of being a teacher as well as that of being a pupil, thus reflecting on the situation and use from both perspectives. Having the storyboards also seemed to facilitate the writing of design patterns that were identified in the scenarios depicted. Similarly, in sketching and describing a future teaching situation where technology would hopefully improve it, the teachers discussed these both from the perspective of being a teacher and of being pupils. Also this transition

Pattern name	The projector
Problem	The teacher's use of the projector in the classroom when lecturing. Sometimes the sound does not work, sometimes no image.
Context	Every lesson
Solution	Wireless connection of iPad and computer using AppleTV. A responsible person makes a monthly review of projectors and other IT equipment in every classroom at the school.
Maturity	We have not tested it, but we know other schools that have this solution.
Other info	We have one teacher at the school that has tested it, and the idea is to implement the solution for all in next school year.

Figure 1: The design pattern "The projector" from the first workshop. The pattern describes a solution to the recurrent problem of using a projector in the classroom. The problem is present every lesson. The solution is to use a streaming device for presentations (translated from Swedish).

from scenarios to writing of design patterns seemed to be facilitated from having sketched scenarios of teaching situations. Introducing these design techniques thus seem to have facilitated the writing of design patterns. A plausible interpretation is that thinking in terms of teaching situations and technology use in these and sketching these, made it easier for the teachers to recollect and identify specific teaching situations. The representations in form of storyboards made it possible to collaboratively inspect and reflect on something visible and tangible, the latter having proved to be important for instance to collaborative sketching within interaction design (Sanders, 2000; Tholander, Karlgren, Ramberg & Sökjaer, 2008; Karlgren, Ramberg & Artman, 2015; Ramberg, Artman & Karlgren, 2013; Karlgren & Ramberg, 2012).

Pattern language development

The first two pattern workshops generated 20 design patterns and the problems defined and the solutions suggested varied between aspects relating to difficulties with existing technological solutions to didactic and pedagogical ideas of technology use in teaching. Following the process of pattern language development and there being patterns with different but complementing foci, the concept of pattern languages was reintroduced.

The pattern workshops 3 and 4 both focused on the pattern language development, but in different ways. Workshop 3 focused on the teachers and their sketching of a pattern language based on the patterns they had written. A short questionnaire was constructed and handed out at the end of workshop 3 with the purpose of taking in what the teachers felt about the workshops, the work conducted and the results from it thus far in the process. Workshop 4 focused on identifying gaps between patterns, i.e. the teachers' task was to identify relations and dependencies between design patterns. A suggested solution of how to digitally represent the patterns and to give the teachers a chance to collaboratively work with the patterns between the workshops, was also presented.

The third pattern workshop: Sketching a pattern language

Workshop 3 started with a brief on what a pattern language could look like, and how their patterns could fit into the structure of a pattern language. The teachers were presented with printed copies of all patterns they had written, and started to reflect on how they were connected. In total, 20 patterns were presented to the teachers (example of pattern 18 in **Figure 2** below).

Figure 2: Design pattern 18 on making ideas and knowledge of pupils visible and inspectable during class (translated from Swedish).

The teachers worked in two groups (Group 1 and Group 2) in sketching on pattern languages and their way of representing these differed significantly. Group 1 represented the language in a tree structure (see **Figure 3** below) whereas Group 2 thought of and represented their language in the structure of a building, with doors in-between rooms depicting different themes that the language was built around (see **Figure 4** below). Notable however is that regardless of the particular graphical representation chosen, is that the prominent nodes presented were the same in both, namely the themes of "teacher", "pupil" and "technology". Group 1 includes learning and management in their structure, while Group 2 includes pedagogy, methodology and didactics into their structure. There were also differences in how the patterns were connected, Group 1 made 12 explicit connections to specific patterns using numbers (e.g. #8), and a few were represented with pattern names. Group 2 made 19 connections to specific patterns, and with no references to pattern names.

The language resembling a building (**Figure 4**) was also spoken of as a building by the teachers with the theme "technology" forming its basement ("Teknik" in **Figure 4** above). Thus, this way of depicting the language to a larger extent puts technology in the forefront creating a common ground for teachers and pupils. A quote included in the sketch that signifies this is "Tekniken måste fungera för att vi ska våga utvecklas" (Eng. the technology must function to enable our development). The individual patterns the languages were built upon are all included in both languages and represented by individual pattern numbers. The relations and dependencies between the individual patterns thus become visible and inspectable, something that also fed into the next workshop focusing on identifying gaps between patterns.

The questionnaire that was filled in at the end of this workshop revealed that the teachers seemed hesitant as to the value of writing patterns and pattern languages of their teaching practice. The teachers also reported feeling uncertain of where the process was leading since we were not designing something specific, such as a new digital artefact or an innovative and new use of technology to support teaching. Also this was something that fed into the planning of workshop 4.

The fourth Pattern workshop: Revising and identifying gaps between patterns

Informed by the results from the questionnaire from workshop 3, we presented Schuler's method for pattern language development to show the teachers that we were following a suggested path to the development of design patterns and pattern languages (Schuler, 2002). The presentation gave an overview of the whole process, our current position in it and the long-term goals with

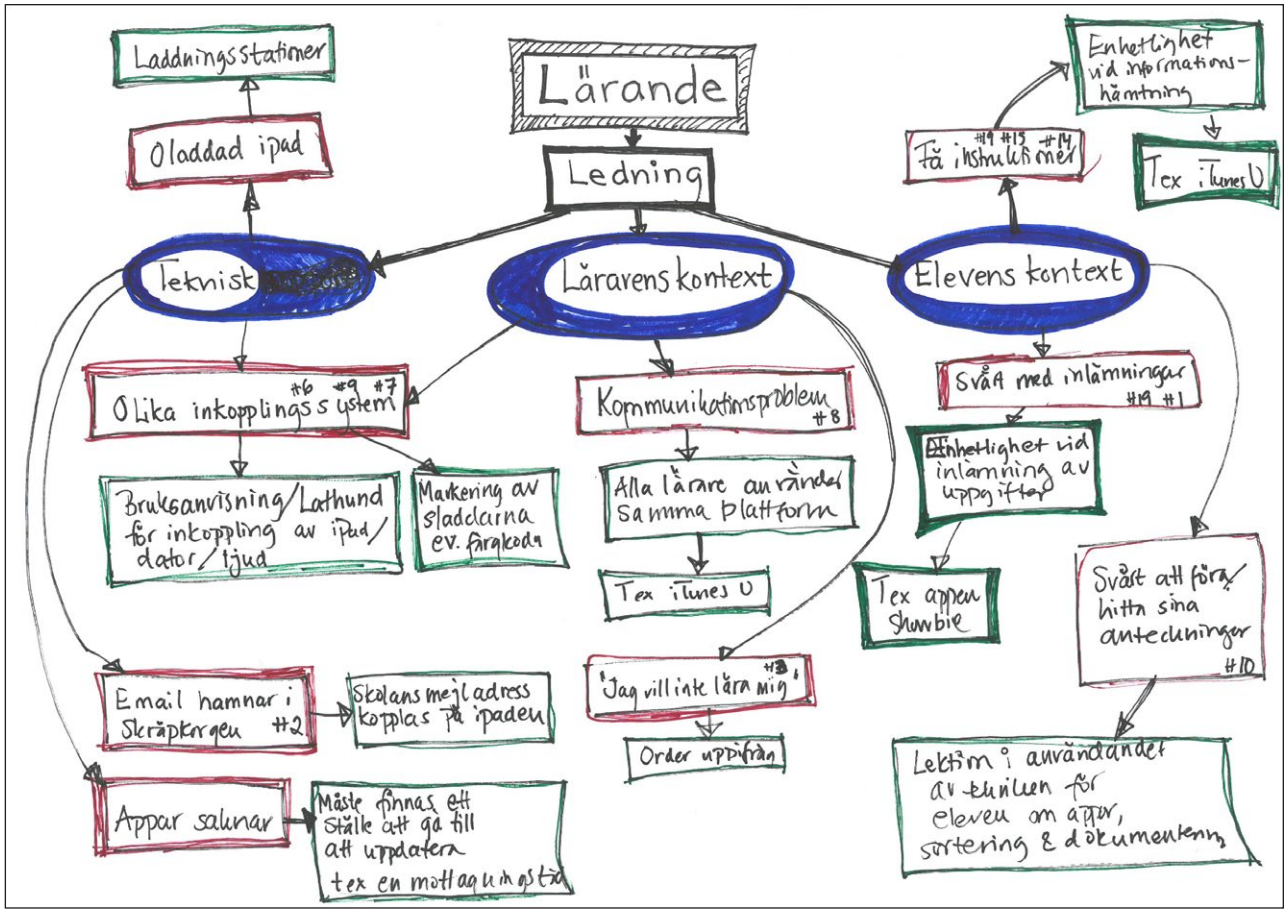

Figure 3: A sketch of a pattern language presented by the teachers (in Swedish). Patterns are represented as numbers (e.g. #6) as well as with pattern names, e.g. "Oladdad ipad" (Eng. Uncharged ipad).

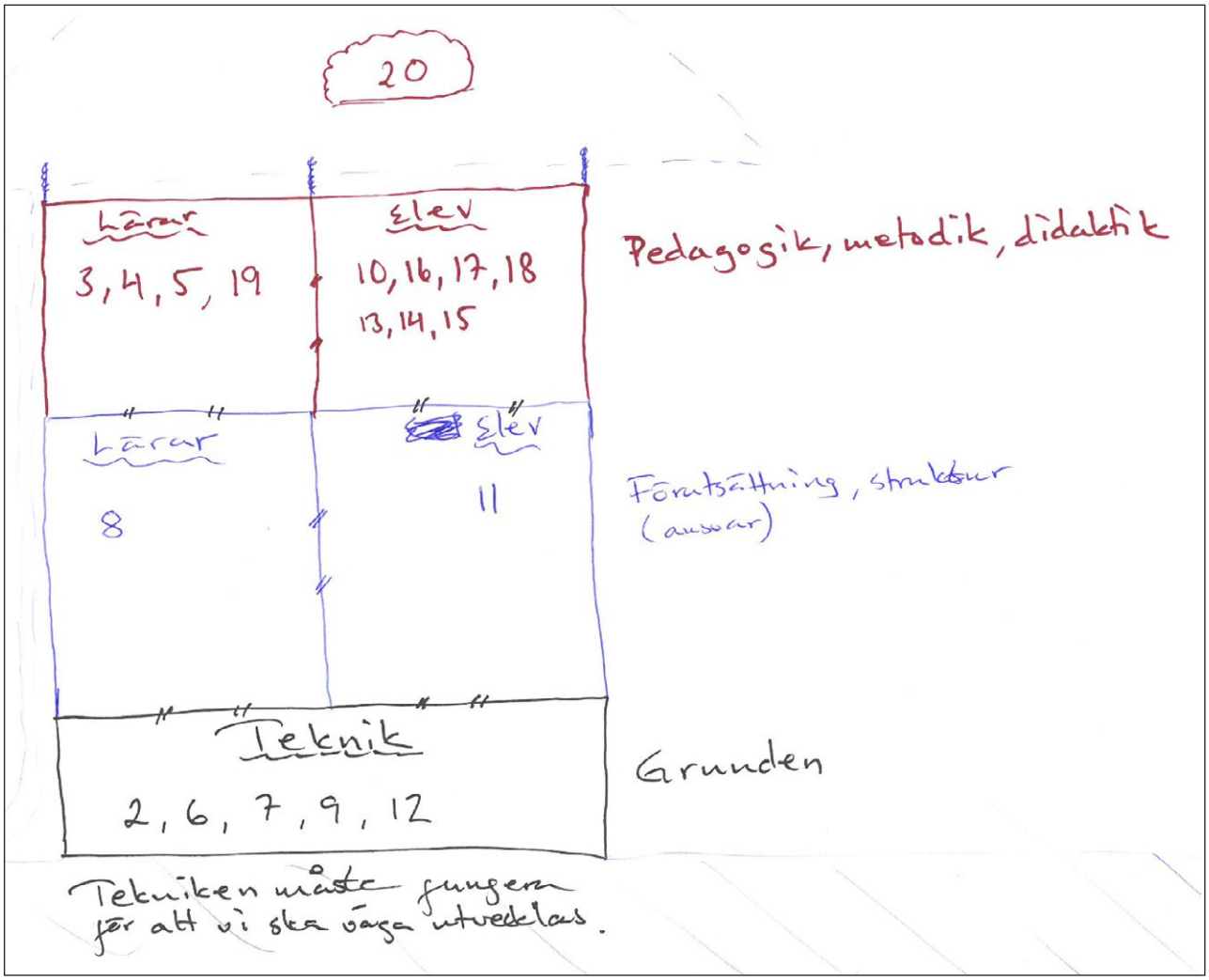

Figure 4: A sketch of a pattern language presented by the teachers (in Swedish). Patterns are represented as numbers (e.g. #6). 19 of 20 patterns are represented in this sketch of the pattern language.

the process. In our case these consisted both in collecting and writing design patterns and languages based on experienced problems and suggested solutions, as well as to collaboratively adapt design methods and techniques to fit within the context of the school. The reason for this being to try to ascertain sustainability and continued use in their practice. Platforms to enable a digital representation of the patterns, and tools for continued development of the patterns was discussed – a wiki tool was chosen on our proposal as a collaborative platform for furthering the development of the pattern language.

The main task the teachers had in this workshop was however to go through all the patterns and to make revisions to these and write new patterns when gaps between patterns were identified, i.e. identifying that in order to solve a more complex problem it is not enough to use one or two already existing patterns but new patterns are required to solve the problem. This could be seen as one of the main ideas of a pattern language – patterns that are connected make a whole – all patterns connected as a network makes a language for design. To solve a large problem several solutions are needed, and this is represented by the individual patterns of the language being connected to the larger pattern. The older patterns in the collection needed to be revised and updated because of progress made at the school concerning "design of ICT for teaching and learning". This was mainly because of a recent choice of learning platforms made by the management of the school. At the start of the workshop series the school had just begun to use certain platforms and many teachers were hesitant to this and felt uncertain of how to use these in their teaching. This was also reflected in the patterns that were written at that time.

In this workshop (see **Figure 5**), the teachers got printed copies of the whole collection of design patterns (20 patterns) which gave the teachers an overview of the patterns that had been written and thus enabled them to see relations and gaps between patterns (cf. Dearden & Finlay, 2006). Identifying gaps between patterns thus informed that a new pattern had to be written. The teachers also at several occasions expressed they were pleased to see that problems they had previously captured in a pattern now had been solved. However, the teachers also realized that solving one problem in turn gave rise to new problems calling for new solutions. At this point, the teachers seemed to realize that the use of design patterns not merely consisted in documenting problems and proposed solutions to these, but that the use of patterns is

Figure 5: Teachers revising design patterns and writing new patterns to fill in gaps between patterns, during workshop 4.

also a way of thinking and doing design that needs to be integrated into an on-going process of change.

Pattern presentation

Having collected patterns and created pattern languages we decided to move on to the next phase of pattern presentation. In our implementation of the pattern language development process (Schuler, 2002), we divided this phase into two different but complementing workshops.

The fifth pattern workshop: Pattern discussion, refinement and connecting patterns using the wiki

The purpose of the fifth pattern workshop was to familiarize the teachers to work with the design patterns and the pattern language in the wiki in order to facilitate continued and collaborative work with the patterns outside of the workshop context. Another purpose was to facilitate and enable a presentation of the results of the workshop series to a larger group of teachers at the school (see **Figure 6**, below). We also wanted the teachers to take ownership of the process, the patterns, their continued refinement and the tools to use in that process. The teachers' tasks were thus to get familiar with using the wiki, and to start commenting on patterns. They were instructed to use their sketches from workshop 3 in order to make connections between patterns (larger – smaller patterns) as well as to continue to make dependencies and relations between patterns clear and how these build upon one another. In practice this meant that many of the individual design patterns in the wiki started to contain references to other patterns (see **Figure 6**). Including references between patterns is important for the development of the pattern language, where the connections between larger and smaller patterns, as well as the dependencies between them create the structure of the language. The syntax of the pattern language is based on that every design pattern is connected to at least one other pattern, but many are connected to two other patterns: one larger (more abstract) and one smaller (more specific). The language thus has a hierarchical structure, and the patterns connect to each other in the form of a network.

Also this workshop proved to be beneficial for identifying gaps in the pattern language. In all, workshops four and five gave rise to eight new patterns. One example of improvement of the pattern language was that previously immature patterns now had become mature: e.g. pattern no 4 which describes a problem of "We don't know which paths the pupils use" with the proposed solution "place pebbles for learning on the pupils' paths", could now be complemented with a new and more detailed pattern solution by the use of social media (Instagram) to put small updates from the teacher about school work meant

Pattern-ID	#4	Comments
Pattern name	Pebbles on the path	Write comments here!
Problem	We don't know which paths the pupils use	Write comments here!
Context	The pupil's own motivation, what creates the pupil's desire and interest to learn	Write comments here!
Solution	Find the pupils' paths och place pebbles for learning on the pupils' paths. 150922: Ex: Instagram	Write comments here!
Maturity	No maturity.	Write comments here!
Misc		Write comments here!
Pattern creator and date of creation	X & Y, 2014-06-09	Write comments here!
Status of pattern		Write comments here!
Reference to larger pattern	PatternNumber3	Write comments here!
Reference to smaller pattern		Write comments here!
Pattern type	Teacher	Write comments here!

Figure 6: Example of design pattern 4 "Pebbles on the path" in the Wiki with connection to the larger pattern 3 "Share good examples to other teachers" (translated to English from Swedish by the authors).

to be "read" by the pupils ("Pebbles on the path", Pattern no 4 → "Social media for communication", Pattern no 26). Pattern 26 became a smaller and more detailed pattern than the more abstract pattern "Pebbles on the path". It is through the structure that the language provides with, that this becomes apparent. Working with the wiki facilitated making these connections, reflections and detailing of patterns. At the end of the workshop we discussed how to take the next step of presenting the patterns. Inspired by the introduction of the Wiki and the possibility to show the results of the workshops, it was suggested to have a workshop with all the teachers at the school.

The sixth pattern workshop: Teachers presenting the pattern approach to the school

The sixth workshop was the last workshop conducted and in the planning of it, it was decided three teachers should run it. The purpose with this workshop was to show the results of the process creating the pattern language thus far, to introduce the concept of design patterns to other teachers as well as different ways to work with design patterns. The workshop participants were 41 teachers at the school including 4 of the teachers that had participated in the previous workshops. In the teachers' presentation to the other teachers, they characterized the possibilities with "the pattern thinking" as:

- A way to discover and structure problems, with accompanying proposed solutions.
- An easy and fast way to document problems and solutions to these.
- Making it easier to discover solutions.

In presenting to the other teachers one of the presenters explained how he had looked upon the concept of design patterns and the approach assumed early on in the workshop series:

> *". . . I understood nothing! Tell us what to do and how to do it! We were not really ready then to understand where it would all end up and how this could come into use".*

The other teachers having participated in the workshops also corroborated this statement. An expectation we had was that the teachers presenting would focus on the design patterns and pattern languages that had been developed during the workshops. This could count as one way that the use of design patterns in teaching and learning have been adapted to the context of the school. The pattern language thus came into the background and the whole methodology of capturing solutions of recurring problems came into the foreground.

After the presentation the teachers divided themselves into groups of four teachers in each group, and they were handed templates of design patterns to be filled in. The instruction was that each group was to come up with two patterns each describing a problem,

a context and a suggested solution to the problem. Comparing how the larger group of teachers received this instruction and task as compared to when we initially introduced the concept of design patterns to the team of teachers participating in the workshop series, it all seemed to run more smoothly this time. The teachers' presentation of the concept already contained an adaptation of it and how to work with it that plausibly made it easier to the larger group of teachers to understand.

In all, 16 patterns were created during this workshop. Some were in line with patterns that had already been written and thus already being part of an identified language (technology, teacher, pupil). However, several of the new patterns concerned emerging problems in the school context and how to solve these. These problems concerned how to handle conflicts and disturbances in teaching, and thus pointing to problems and needs other than those that had already been captured.

The Pattern Language

In the following, we aim to answer the research question "What kind of pattern language did the teachers create, and what design patterns were to be found in the pattern language?" by presenting an analysis of design patterns as well as visualizing the structure of the pattern language. We base our presentation and analysis on the final pattern language as it was represented in the wiki the teachers used (consisting of 28 patterns).

What are the design patterns about?

We introduce the individual patterns through an analysis resembling affirmative diagramming resulting in Pattern Types (PTs). The analysis is based on the patterns themselves as they are represented in the wiki, but also on the scenarios and storyboards the teachers have created during workshops. Observational notes, audio and video from the workshops were used when necessary to understand the teachers "constructions". Pattern types are abstract categories based on the analysis of the 28 design patterns in the wiki. These are based on how the teachers use technology when designing their solutions to different types of problems. The PTs are described focusing the design solutions as formulated by the teachers and the design patterns are here presented through one-sentence descriptions.

PT1: DIGITALISATION OF TEACHING MATERIAL – for documentation and re-use, including video recording of lectures.

- Pattern#10: Increase the value of lessons by note taking.
- Pattern#12: Increase lecture sustainability by video recordings.

PT2: DIGITAL LEARNING ENVIRONMENT – to be used by all teachers and pupils. The main purpose is to push learning material and instructions to the pupils, and to collect the pupils' assignments in one place.

- Pattern#1: Easy submission of students' works.
- Pattern#2: One single e-mail address to be used.
- Pattern#8: Use the same general digital learning environment.
- Pattern#16: Teach pupils how to use the general digital learning environment.
- Pattern#21: Full use of the chosen general digital learning environment.
- Pattern#27: Automatic app download, tablets should be the same for all.
- Pattern#28: Limit the number of channels for communication.

PT3: OPEN CLASSROOM – communicative applications to open up the classroom physically and socially.

- Pattern#17: Display of pupil's work in the classroom.
- Pattern#18: Make invisible pupils visible by communicative apps.
- Pattern#19: Share ideas and thoughts using virtual whiteboards.
- Pattern#20: Allow pupils to work outside the classroom using communicative apps.

PT4: ROBUST CLASSROOM TECHNOLOGY – solutions for the physical classroom.

- Pattern#6: Design and equip classrooms the same way.
- Pattern#7: One display solution in all classrooms.
- Pattern#9: Wireless connection of tablets for display.
- Pattern#11: Charging stations for the tablets.
- Pattern#22: Classroom manuals for the tablets.
- Pattern#23: Lending services for the pupils.
- Pattern#25: Lending of tablets.

PT5: INSTRUCTION AND DOCUMENTATION TECHNOLOGY – teacher guided presentation, instruction and documentation of students' science labs.

- Pattern#13: Use the projector and apps for instruction and documentation.
- Pattern#14: Use templates when documenting science labs.
- Pattern#15: Use push messages to improve instructions.
- Pattern#24: Develop genre specific texts.

PT6: STUDENTS' DIGITAL ARENAS – learning and teaching in students' digital arenas.

- Pattern#3: Share good examples to other teachers.
- Pattern#4: Place pebbles for learning on the pupils' paths.
- Pattern#5: Games as teaching tools.
- Pattern#26: Communicate with pupils through social media.

By thematically structuring and connecting individual design patterns, interrelations between problems and solutions become visible and can therefore aid

the teacher in doing and communicating designs for learning.

The structure of the pattern language

The structure of the pattern language as presented in **Figure 7** is based on the patterns from the wiki and the connections that teachers made between larger (more abstract) and smaller (more specific) patterns (see **Table 2**). 9 patterns include links to other patterns. In all, 17 design patterns were connected through links to larger patterns or smaller patterns. This means that the teachers did not connect 11 patterns.

Figure 7 below, illustrates the references that the teachers have made between patterns. Dotted arrows show links to smaller patterns, and solid arrows show links to larger patterns. From the figure and the relations that are depicted, it can be concluded that certain patterns in the pattern language stand out as being more central as compared to other patterns.

Pattern 3 (P3) and Pattern 8 (P8) have a central position in the pattern language, meaning that these are central either in terms of being prerequisites for fulfilling a proposed solution or constituting a vision to be fulfilled. Pattern 3 "Share good examples to other teachers" (P3) only points to the smaller pattern 4 "Place pebbles for learning on the pupils' paths" (P4). This illustrates P3 being more central, and closer to a higher goal of the pattern language – a vision of sharing good examples with other teachers. In order words, a vision of mitigating an acknowledged problem – learning to use digital tools in teaching is a demanding task to many teachers. This hierarchy between patterns is further established through the links made from other patterns to Pattern 3. Pattern 5 "Games as teaching tools" points both to Pattern 3 and 4, which makes sense because of the inspirational nature of those two patterns, and that games might be a good place to "Place pebbles for learning on the pupils' paths".

Table 2: The table shows the links made from one pattern to smaller or larger patterns. Nine patterns include links to other patterns.

Pattern name (number)	Links to smaller pattern	Links to larger patterns
One single e-mail address to be used (P2)	No	Share ideas and thoughts using virtual whiteboards (P19)
Share good examples to other teachers (P3)	Place pebbles for learning on the pupils' paths (P4)	No
Place pebbles for learning on the pupils' paths (P4)	No	Share good examples to other teachers (P3)
Games as teaching tools (P5)	No	Share good examples to other teachers (P3), Place pebbles for learning on the pupils' paths (P4)
Design and equip classrooms the same way (P6)	No	One display solution in all classrooms (P7), Wireless connection of tablets for display (P9)
One display solution in all classrooms (P7)	No	Design and equip classrooms the same way (P6), Wireless connection of tablets for display (P9)
Use the same general digital learning environment (P8)	Increase lecture sustainability by video recordings (P12), Use the projector and apps for instruction and documentation (P13), Use templates when documenting science labs (P14), Use push messages to improve instructions (P15), Display of pupil's work in the classroom (P17) Allow pupils to work outside the classroom using communicative apps (P20)	No
Increase the value of lessons by note taking (P10)	No	Share good examples to other teachers (P3), Place pebbles for learning on the pupils' paths (P4), Increase lecture sustainability by video recordings (P12), Display of pupil's work in the classroom (P17)
Communicate with pupils through social media (P26)	No	One single e-mail address to be used (P2), Place pebbles for learning on the pupils' paths (P4)

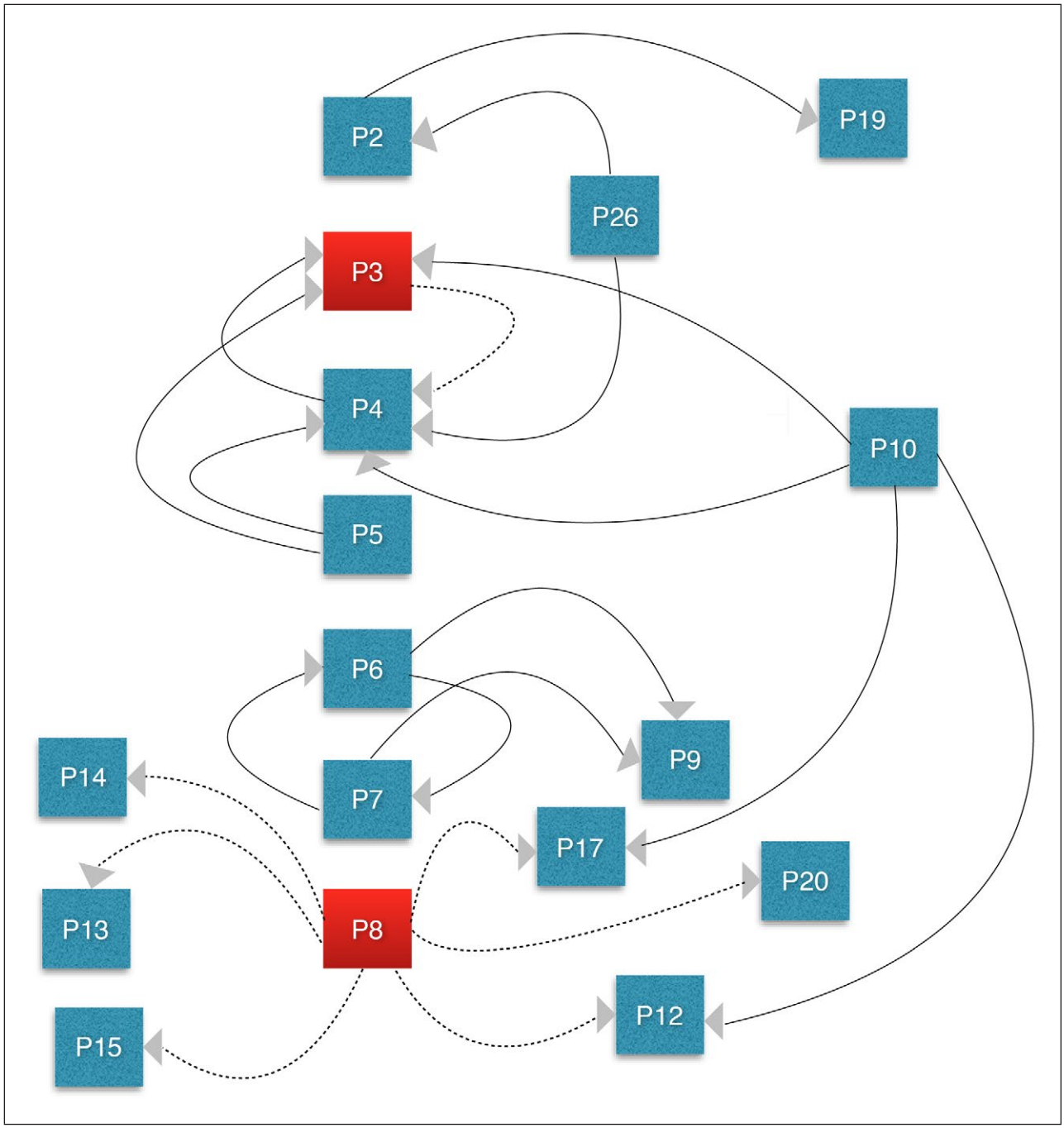

Figure 7: A visual representation of how patterns are connected in the pattern language. The visualization is made by the authors and is based on the 17 patterns that have connections to other patterns in the wiki (see **Table 2**). Pattern 3 (P3) and Pattern 8 (P8) are highlighted with red in order to show their central position in the pattern language.

Pattern 8 is connected to six smaller patterns that are all related to the solution of the general digital learning environment. It can also be read from the pattern structure that Pattern 8 "Use the same general digital learning environment" is connected to Pattern 3 and 4 through Pattern 10, 12 and 17, which are about new ways to teach by using new technology, and as such becomes inspirational both for teachers and pupils.

From the structure, and the way that patterns have been linked we can deduce that the teachers seek solutions to improved communication between teachers and pupils. This is witnessed by Pattern 2 "One single e-mail address to be used" being connected to the larger Pattern 19, which is about communication and more specifically "Share ideas and thoughts using virtual whiteboards" (P19). In addition, Pattern 26 "Communicate with pupils through social media" points to the larger patterns 2 and 4 that both concern communicating with pupils.

In the pattern language, there is a cluster of patterns concerning practical matters with the use of technology in the classroom. Pattern 6 "Design and equip classrooms the same way" and Pattern 7 "One display solution in all classrooms" are connected by the teachers to each other as they share the problem of the projector and its

role in the classroom, although presenting two different solutions. These patterns both point to the mature and implemented solution in Pattern 9 "Wireless connection of tablets for display".

To conclude, the pattern language is not complete, building a pattern language is a demanding process, which needs more time than just a couple of workshops. However, the pattern language presents a structure that informs on the teachers' design solutions and how the teachers value the importance of the patterns in the design process for teaching and learning in their school.

Discussion

Developing a pattern language, or languages, for an evolving technological and pedagogical landscape, is a very demanding process. While acknowledging the evolving and dynamic context of the teacher, this also points at an emerging need for tools and procedures to handle it. Thus, returning to the more general question we approached in this article of how teachers´ design solutions can be systematically captured, organized, and communicated, the simple answer would be "by the use of design patterns and pattern languages". We of course realize that a pattern language for such a context will never be finished but that is perhaps not what should be strived for when engaging in writing patterns and pattern languages, particularly when striving for sustainability and continued use and development in practice. This process is about design, identifying problems and solutions, and not only about working systematically with what has already been designed and implemented (mature patterns), but also solutions that are only sketched on (immature patterns).

On writing of patterns and pattern languages

Our team of teachers easily picked up on design methods and techniques and what concerns the use of concepts and pattern template (problem vs. idea), this seems to have strongly governed their thinking in writing of the design patterns. Sketching and narrating ideas further seems to have helped contextualizing problems and ideas and to reflect on these both from the perspective of being a teacher and of being a pupil. A plausible interpretation is that the process of collaborative sketching and reflection made it easier for the teachers to inspect and question their ideas, their understanding of problems, and their language use, thus very much in line with what has previously been reported regarding the benefits of collaborative sketching (Sanders, 2000; Tholander, Karlgren, Ramberg & Sökjaer, 2008; Karlgren, Ramberg & Artman, 2015; Ramberg, Artman & Karlgren, 2013; Karlgren & Ramberg, 2012). Sketching and narrating also seems to have facilitated writing of patterns and the creation of a pattern structure connecting different patterns.

The teachers used their own language; they did their own adaptations and abstractions when creating the pattern language and focused on design solutions to problems that work. In working with the design patterns and pattern language the teachers themselves reported they could see relations and dependencies between problems and solutions that would otherwise be difficult to see. Other benefits observed from using a structured approach to documenting problems and solutions supported by a digital platform, the wiki, is that it enables keeping track of when and how a problem has been solved and what new problems and possibilities this in turn gives rise to.

The pattern language tells a story of a school's design process

The design workshops and the use of design patterns have helped us (teachers and researchers) to put into words, structure problems and propose ways of how to overcome these. Interesting and slightly surprising was the strong focus on the many problems teachers had with the existing technology, and that the solutions to these were fairly straightforward. And when thinking of technology from a pedagogical perspective the patterns that were suggested for technology use were mainly focused on basic and stable characteristics of ICT and infrastructure – there seems to be no room for or reason to think innovatively about use of ICT in teaching if the core functionality and infrastructure is not there. This situation does however not seem to be unique to the school we have worked with (Jahnke & Kumar, 2014).

However, the structure of the pattern language might indicate something different than just dealing with the basic technologies (see **Figure 7**). Pattern 3 and 4 are high up in the hierarchy of the language, indicating that the pattern "Sharing good examples to other teachers" (P3), and the pattern "Placing pebbles for learning on pupils' paths" (P4) are very important issues for the teachers to strive for. The structure also shows that getting the general digital learning environment in place (Pattern 8: Use the same general digital learning environment) is an important node for making more innovative use of technology such as the smaller pattern 20 "Allow pupils to work outside the classroom using communicative apps" and pattern 15 "Use push messages to improve instructions".

When comparing the teachers' two sketches of the pattern language with the final language in the wiki as visualized in **Figure 7**, it becomes clear that the final pattern language does not have the more central nodes "teacher", "pupil" and "technology", that both sketches share. Such nodes might be necessary to formulate as design patterns in future languages because of their communicative value – they group smaller patterns together through structure, and make a pattern language easier to read and use.

Organizational and technological issues

Reflecting on and documenting problems and solutions takes time and serious effort. The school we have worked with is a progressive school and strives to be innovative in terms of technology use in teaching and learning. The management supports initiatives and the teachers participating in the workshops were allotted with time to devote to the workshops. There are however as witnessed by several of the early patterns that were written, problems with the technological infrastructure that puts requirements on the management to make appropriate decisions. In

fact, several of the earlier patterns asked for solutions in that direction. Three such suggested solutions to a problem built on a teacher experimenting with the use of a streaming device allowing to mirror content on tablets and computers (patterns 6, 7 and 9), and later on in the workshop series the management had picked up on the idea and implemented the necessary technology in the classrooms.

Thus, the use of design patterns as a way to document problems and proposed design solutions could therefore function as a collaborative and structured "bottom-up" communication with the management regarding problems and solutions that could alleviate these. Design patterns could function as a documentation, inspiration and agent for change. Further, the design process and the patterns could help and develop teachers thinking and their way of organizing and dealing with problems (cf. Gregory, 2003).

Another example pointing at the difficulties of implementing suggested solutions originating from the results of the questionnaire, is when we understood we needed to give the teachers easy access to work with a digitized material, mostly the patterns, and their first shot at the pattern languages. From this started a mail discussion with the management and one of teachers (in charge of the teacher group), on what kind of digital platform to use. The choice of a wiki as a platform for collaboration was the result of a process that was constrained by license questions, and what kind of tools the teachers used at that time. The wiki as such was perhaps not the ideal solution due to limited functionality (for instance in visualization capabilities). However, the wiki served its purpose as a first prototype, and fulfilled the purpose of having a common platform, and something to show to the school management and other teachers. It was a pity that visualizations such as the one in **Figure 7** could not be made in the wiki, but such visualizations could play an important role in future research on pattern languages as well as design pattern creation. If such instant visualizations were possible when writing the design patterns, the efforts of the individual teacher writing a specific pattern, would immediately have been illustrated as a contribution to the whole pattern language.

Admittedly, there is much at play here, there are economical, legal and political aspects involved in making decisions but one way to facilitate these processes could be to scaffold teachers' communication through the use of design patterns. The teachers' working solutions to teaching "problems" and the activity of constructing design patterns could thus be seen as an activity of avoiding re-inventing the wheel within an organization. The pattern language could be used to see both how teaching and learning could take place within an organization putting focus on functioning design solutions.

Conclusions

Design patterns do not only work for capturing design knowledge, and as documentation on what has been designed, but could also work as a tool for designing future solutions. The strive for a pattern language seems to be an important force in this, as well as using design techniques and a pattern template inviting sketching of design solutions. Those sketches could later find a solution, if the participants (teachers) are given the opportunity to work and revise patterns in a series of workshops.

The content of the design patterns show what problems that are dealt with by the teachers. The structure of the pattern language shows how problems and solutions are connected to larger goals for the teachers, such as good examples of improved communication with students, as well as the importance of sharing good examples between colleagues.

Future work

In terms of the pattern development process (Schuler, 2002) we have in our workshop series not specifically focused the phases "language use" and "language evaluation". The reason for this is because such processes were partly handled in other phases of our implementation, but perhaps more importantly the process was primarily driven by the teachers and their interest to present the results and come to use of these in their practice. An obvious thread for future work is to follow up on how the concept of design patterns and pattern languages have been picked up by the larger group of teachers at the school and how these are further adapted in their practice. Will the need of structure emerge or are the individual patterns still the most relevant contribution of the pattern language? A similar line of future work is to follow up on how design techniques that were introduced to support the writing of design patterns and pattern languages are further adapted in practice. Yet another thread of research is to analyse what pedagogies that come to expression in the teachers' design patterns and pattern languages (cf. Conole et. al., 2004), i.e. what perspectives on technology use in teaching and learning are expressed by the teachers in their descriptions of their technology use, as well as in their descriptions of possible and future use of technology (Rolf, Knutsson & Ramberg, 2017)?

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Competing Interests

The authors have no competing interests to declare.

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