
**Abstract**

In times of knowledge exchange across geographical and temporal borders, the question arises as to how not only explicit or factual knowledge can be exchanged over distance, but also knowledge-in-use, with its high amount of tacit knowledge. This article introduces patterns as an established method for supporting the exchange of this knowledge-in-use. We first provide a theoretical basis for our assumption that patterns facilitate the exchange of knowledge-in-use, because they are *external* representations that are highly analog to people’s *internal* knowledge representation.

We then present two experiments testing this assumption: A field study with practitioners (*n* = 46) who had accumulated experiential knowledge-in-use over a period of several years, and a laboratory study (*n* = 61) where the students acquired knowledge-in-use during a standard learning period. Both experiments support the hypothesis that patterns facilitate the externalization of knowledge-in-use. With patterns, users described more solution-relevant features of a problem and focused more on abstract features of a solution than participants who explained their experiences without a pattern.

Keywords: *Knowledge exchange* *Knowledge-in-use* *Computer-mediated* *Patterns* *Schema theory*
1. **Introduction**

Over the last several years technological innovations, and especially the use of social software, have changed education a lot. It is becoming more and more obvious that people do not just learn in formal courses at schools or universities, where teachers directly instruct students. Education and knowledge acquisition also take place when people participate in communities and social networks (Hsu, Ju, Yen, & Chang, 2007; Dede, 2004, 2006; Junco, 2012; Yang & Chen, 2008; Scherer Bassani, 2011), exchange their experiences in forums (Blooma, Kurian, Chua, Goh, & Lien, 2013; Wachter, Gupta, & Quaddus, 2000; Watabe, Hamalainen, & Whinston, 1995), wikis (Moskaliuk, Kimmerle & Cress, 2012; Kump, Moskaliuk, Dennerlein & Ley, 2013) or databases (Cress, Barquero, Schwan & Hesse, 2007; Cress, Held & Kimmerle, 2013; Schwind, Buder, Cress & Hesse, 2012). In such informal settings students and practitioners increase their knowledge and skills and swap ideas with other participants.

Most studies about learning in these informal settings take into consideration the exchange of explicit knowledge. But what seems to be at least as important is the exchange of personal experiences, or the exchange of *how* to perform an activity. In the AP teacher community (a community of teachers for courses that offer college-level curriculum and examinations to high school students in the Unites States) (http://www.apcommunity.collegeboard.org) or in TeachQuest (http://www.teachquest.com) for instance, teachers discuss their teaching strategies and lesson plans online with their mentors, share their experiences and materials and can connect themselves with other practitioners (Lin et al. 2008; Matzat, 2013).

Such *knowledge-in-use* (De Jong & Ferguson-Hessler, 1996) is embedded in daily experience (cf. Greeno, 1998). It can be characterized as being a combination of declarative knowledge and procedural knowledge (see e.g. Bereiter (2013) who makes the same point about, as he names it, principled practical knowledge). That is, knowledge-in-use contains both knowledge about facts and terms that can easily be externalized and knowledge that is much more difficult to externalize, since it is mainly tacit (Polanyi, 1966) and is used unconsciously and automatically (Anderson, 1983; Smith, 2001).

That means that in order to ensure effective and permanent communication, exchanging personal experiences *over distance* needs special support for externalizing the tacit parts of knowledge-in-use. Our
main hypothesis is that patterns, as they first were described by Alexander et al. (1977) and then taken up by others, provide this kind of support. We assume that they provide external structures that are highly analogous to the internal representation of knowledge in human memory (Kohls & Scheiter, 2008; Wodzicki, Moskaliuk & Cress, 2011).

In the following we first describe what patterns are. We then present two experiments that investigate in detail how patterns support the externalization of knowledge-in-use. Experiment 1 was conducted as a field-study with participants who had to externalize knowledge-in-use they had acquired during their own work practice over a period of several years. Experiment 2 was conducted in a laboratory setting with participants who acquired knowledge-in-use just during the experiment. This enabled us to reexamine the results we had gained in the field. So the two experiments cover both a situation where people are heterogeneous with regard to their level of expertise and a situation in the laboratory, where everything is controlled and people differ only with regard to the use of patterns. Because of their experimental design (which compares groups with and without pattern) these studies are the first to provide causal evidence for the effect of patterns.

2. Patterns as external representation of knowledge-in-use

The use of patterns was first described by Alexander et al., (1977) for knowledge transfer in the area of architecture, and then taken up by many other researchers in several domains (Avgeriou, Papasalouros, Retalis & Skordalakis, 2003; Beck & Cunningham, 1987; Carroll & Farroq, 2007; Derntl & Motschnig-Pitrik, 2005; Frauenberger & Stockmann, 2009; Gamma, Helm, Johnson & Vlissides, 1995; Goodyear et al., 2004; Köhne, 2005; Manns & Rising, 2005; Matschke, Moskaliuk, Arnold & Cress, 2010; May & Taylor, 2003; Wodzicki, Moskaliuk & Cress, 2011, Wedekind, 2011). Generally speaking, a pattern provides a structure that supports users in externalizing their knowledge-in-use and in collecting the knowledge of practitioners, based on proven solutions for recurring problems. A pattern forces users to structure their own individual contributions into pre-defined categories, with the aim of stimulating abstraction. That is, “each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use
this solution a million time times over, without ever doing it the same way twice” (Alexander, Ishikawa & Silverstein, 1977, preface pp. x). Thus, patterns contain problem-solutions pairs that are abstracted from individual cases and that include the invariant aspects of a solution relevant for all problems of one class (Frauenberger & Stockmann, 2009; Kohls & Scheiter, 2008; Kohls & Uttecht, 2009; Wodzicki, Moskaliuk & Cress, 2011). In its basic form, a pattern describes the problem which occurred, the associated solution that proved successful, the situation in which the solution may be useful and forces which contain competing requirements that influence the solution of the problem (Alexander et al., 1977). Many patterns also provide concrete examples from real life to illustrate and clarify the invariant aspects of different cases. Coherent patterns that generate an interconnected set which is used to solve problems in a specific problem domain are called a pattern language (Kolfschoten, Lukosch, Verbraeck, & Valentin, 2010; Lukosch & Schümmer, 2006; Manns & Rising, 2005). Figure 1 shows a pattern delivering knowledge about a teaching method (e-lecture). The pattern structure serves as an input-format for a repository. Thus the pattern and the repository provide an example for a pattern-based knowledge exchange (see also Matschke, Moskaliuk & Cress, 2012).

--- Insert Figure 1 about here ---

Most empirical research about patterns is based on case studies and software evaluation. Many studies have shown that patterns can facilitate learning and communication and support the knowledge transfer of good practices (Derntl, 2005; Frauenberger & Stockman, 2009; Kolfschoten, Lukosch, Verbraeck, Valentin, & de Vreede, 2010; Köhne, 2005; Lukosch & Schümmer, 2006). But these studies did not systematically compare knowledge exchange with and without patterns. So they cannot provide evidence that patterns causally influence knowledge transfer. Furthermore, the research literature lacks a theoretical foundation that could explain the positive effect of patterns. We fill this gap and provide experimental studies that are based on schema theory. Using this theoretical framework we continue the work of Kohls and Scheiter (2008) and Wodzicki et al. (2011) who were the first to apply this theory to patterns.
3. **Fostering the exchange of knowledge-in-use: a perspective from cognitive psychology**

We assume that patterns serve as external representations of knowledge-in-use. With their main subcategories *situation, problem* and *solution* patterns support the externalization of knowledge-in-use because these subcategories have a high correspondence to the internal cognitive structure of knowledge-in-use.

3.1 Schemas as mental representations of knowledge-in-use

Knowledge-in-use can be described as a combination of (1) experiences from several situations, (2) problems that could occur in these situations and (3) established solutions to solve those problems. Research on expert knowledge has shown that experts facing a new problem retrieve solutions they have applied to similar problems in the past. They refer to their stored experience and re-use what they found to be an adequate strategy for solving the problem (Chase & Simon, 1976; Kohls & Scheiter, 2008). They thereby activate their mental representations of their experiences, so-called *schemas*. A schema is a structural unit in the long-term memory that contains a generalized concept (Marshall, 1995). So it offers an abstracted representation, capturing distinct experiences of situations that have similar features (Gick & Holyoak, 1983).

Knowledge-in-use is knowledge surrounding a problem type, a so-called problem schema. Problem schemas unify superficially disparate problems by making structural similarities salient (Blessing & Ross, 1996; Chase & Simon, 1973; Chi, Felteovich, & Glaser, 1981; De Jong & Ferguson-Hessler, 1986; Hinsley, Hayes & Simon, 1977; Schoenfeld & Herrmann, 1982; VanLehn, 1989). In other words, problem schemas contain structural features of problems. These features are abstract and solution-relevant and *categorize problems* to find appropriate solutions. They disregard surface features of problems that are not relevant for the solution of the problem. As opposed to structural features, surface features include setting information (e.g. time, people, objects) and *describe* a problem instead of categorizing it (Adelson, 1984; Bernardo, 1994; Blessing & Ross, 1996; Catrambone, 1998; Catrambone, 2002; Chen, 2002; Cummins,
Thus, problem schemas are established on the basis of structural problem features – that is, those features that are both relevant for the solution and abstract enough to be relevant for other situations with the same problem type as well.

Experienced people can make use of their problem schemas. If they encounter a new situation they can identify similarities between the new situation and the problem schemas they already have acquired (Chase & Simon, 1976; Gick & Holyoak, 1983; Marshall, 1995). In contrast, less experienced people do not have many schemas. So they can only use representations of separate experiences and find solutions to a new problem through analogical problem solving. For this process, they try to adapt the principles of a source domain (a problem already solved) to a target domain (a new problem within the same problem class) (Reeves & Weisberg, 1994; Ross & Kennedy, 1990). That is, less experienced people try to map concrete experiences from the past to new situations. They cannot abstract by identifying which features of a new situation are on a structural level as they only can focus on surface problem-features (Reeves & Weisberg, 1994; Ross & Kennedy, 1990). So, whereas experienced people activate automatically and unconsciously adequate problem schemas, less experienced ones need support in recognizing structural problem features (Cummins, 1992; Gick & Holyoak, 1983; Silver, 1981).

3.2 Structural similarity: Pattern-support for the retrieval of solution-relevant problem features

We assume that patterns, based on their inherent structure, facilitate this recognition process.

With regard to the concrete processes two different views exist: The so-called *eliminative induction* theory (Mackie, 1974) postulates that “only structural information is maintained and exemplar-specific details are discarded after schema induction” (Reeves & Weisberg, 1994, p. 383). Opposite the *conservative induction* (Medin & Ross, 1989;) theory holds the assumption that even after an abstraction, situational information is restored separately (Gentner & Gentner, 1983; Hintzman, 1986; Holyoak, 1985; Holyoak & Thagard, 1989; Spencer & Weisberg, 1986; Thagard, Holyoak, Nelson & Gochfeld, 1990). The latter view has been empirically confirmed (Catrambone & Holyoak, 1989; Spencer & Weisberg, 1986) and leads to the assumption that an internal problem schema consists of the sub schemas *problem* and
solution, but also of a situation subschema that still contains concrete information about the setting. As described above, an external pattern as an input format also contains the categories situation, problem and solution (Alexander et al., 1977). So if patterns are used for the computer-mediated exchange of knowledge-in-use, people have to consider all these categories, if they externalize their personal experiences. So the use of pattern forces people to structure their own knowledge according to these categories which should support the externalization of knowledge-in-use.

To sum up, we assume that the pattern-inherent structure supports the description of solution-relevant abstract information. Patterns cause people to focus more on structural problem features and abstract solutions and thus support them in making their knowledge-in-use explicit.

4. Experiment 1: Field Study

Experiment 1 tests the impact of patterns on externalization of knowledge-in-use in a field setting. The participants were experienced in church-based youth work, a complex task that requires people to build up tacit knowledge about effective teaching methods over the years to be able to teach others in church settings. In the experiment, the participants had to externalize this knowledge by writing case descriptions for a shared knowledge repository. The case descriptions had to contain important experiences with successful teaching strategies that could be useful for others. According to the analogy of knowledge-in-use and patterns, we expected that patterns would lead to better descriptions and thus derived the following hypotheses:

Hypothesis 1: Case descriptions with patterns as the input format contain more structural problem features than case descriptions without patterns.

Hypothesis 2: Case descriptions with patterns as the input format contain more abstract solutions than case descriptions without patterns.

4.1 Method

4.1.1 Participants
Forty-six adolescents who had taken an active part in church-based youth work in their community (34 of these were female), and who were between the ages of 13 to 21 years \((M = 16.22, SD = 2.76)\), participated in the study. All participants had first-hand, experiential knowledge about leading children’s church services, that is, they were experienced in preparing child-oriented liturgy for younger children. On average they had about 24 months’ experience \((M = 23.89, SD = 24.86)\) in this domain.

4.1.2 Design and procedure

The participants were randomly assigned to one of two conditions (23 participants in each condition). In the pattern condition they used a pattern which provided text fields for the categories situation, difficulties (corresponding to “problems” in the standard pattern-structure) and organization of the Sunday school (corresponding to “solution” in the standard pattern-structure). In the without-pattern condition they worked with a blank template, which was just a text field without any structure. In both conditions, the participants were asked to provide an example of leading a group of children, based on their own experience. For this, we provided them with a short description of a typical challenge. This contained two different types of problems of teaching dynamics: problems that focused on surface features (surface problem features) and problems that focused on structural features (structural problem features). The surface problem features were explicitly stated in the description, e.g. “for some kids it is difficult to concentrate for over 15 minutes”. This statement refers obviously to the problem of difficulties in concentration. The structural problem features were not directly stated in the instruction. In order to identify these problems the participants had to extrapolate the structural features from the superficial statements, e.g. “10 kids at the ages of 8 to 12 will attend this Sunday school”. The problem of age difference within the group had to be inferred by the ecclesiastical practitioners.

At the beginning of the study, all participants got written instructions. After reading the instructions, all participants passed through two phases: a team phase and an individual phase. In the team phase, we randomly grouped the participants in pairs by giving each participant his/her own number and the number of the person they should work with. They had to discuss with this team-mate how they would solve the described challenge. The participants were encouraged to refer to previous situations they already had
experienced in their work. The team phase lasted 15 minutes and ensured that the participants had reflected upon the situation, and referred to their own experiences before they had to externalize their knowledge. For the second phase one participant from each group was assigned, by being given a random number of a corresponding computer, to the experimental group, where the computer displayed a pattern, and one to the control group, where the computer displayed a blank template to be filled in.

In this second, *individual phase*, each participant had to write down an example (as a case description) for how to lead a typical Sunday school for children. Each participant was told that this text should be based on one’s own experience and should help others to benefit from this experience. The participants in the pattern condition used the pattern structure to write down their case description, whereas the participants in the unstructured condition used a blank text field. In total, the participants had 30 minutes for writing down their case descriptions.

### 4.1.3 Dependent Measures

We analyzed the content of the written texts with regard to the descriptions of problems and solutions. A detailed coding scheme along with coding examples is in the appendix of this paper.

*Content of problem descriptions:* We first counted how many *surface problems features* and *structural problem features* participants mentioned in the text. The next step was to measure problems that the participants had derived on their own, that is, that were not mentioned in the described challenge, for example, general motivational problems of children. We labeled these problems as *own derived problems*.

The following examples clarify our classification: One participant wrote: “In general, the difficulty with long stories is that children cannot sit still and listen for a long time. Furthermore, the difference in age of the children could be another difficulty if you do not split the group in two age groups for telling the story. It could also be possible that the children simply do not want to listen due to nice weather outside” (translated by the authors). We coded the first sentence as *surface problem feature*, as it clearly refers to a statement the participants got directly in their instruction (that is, *difficulties in concentration*). The second sentence mentioned an aspect extrapolated from the description of the typical challenge (that is, *age difference within the group*) and was coded as *structural problem feature*. The *motivational*
the participant mentioned in the third sentence was coded as own derived problem, as this problem was not mentioned in the description of the challenge but was derived independently by the participant on his or her own.”

This leads to three categories of the dependent variable measuring the content of the problem description: surface problem features, structural problem features and own derived problems.

Content of solution descriptions: We classified the reported solutions into the categories concrete and abstract. We counted solutions as concrete if they referred to a concrete title of songs and prayers or action like “Play the game ‘acid river drops’ at the beginning so that the kids get to know each other”. We counted solutions as abstract if they did not include a reference to a concrete title or action, as in this example: “Simple games that are known to be a good way to ensure the understanding and to integrate the new kids as well”.

This led to two categories of the dependent variable measuring the content of the solution descriptions: concrete solutions and abstract solutions.

4.2 Results

We compared the two conditions by t-tests for each dependent variable to test whether case descriptions with patterns contained more structural problem features (Hypothesis 1) and more abstract solutions (Hypothesis 2) than case descriptions without patterns. The results are reported one-tailed, since we have directed hypotheses, and effect sizes using Cohen’s d. For all dependent variables we report the absolute as well as the relative values to ensure that effects are not based just on the fact that participants mentioned more problems and solutions overall. All means and standard deviations are reported in Table 1 for the problem descriptions and in Table 2 for the solution descriptions.

4.2.1 Intercoder reliability

Twenty percent of the material was coded by a second independent rater to calculate the intercoder reliability. The intercoder reliability for the rating of the problem features was $r = .86$, $p < .01$ and for the rating of solutions $r = .90$, $p < .001$. 

4.2.2 Number of words

Participants who used patterns for their descriptions wrote overall more words ($M = 246.65, SD = 101.27$) than participants without patterns ($M = 196.39, SD = 85.17$) ($t(44) = 1.82, p < .05, d = 0.53$, one-tailed).

4.2.3 Content of problem descriptions

As Table 1 shows, overall the pattern descriptions contained more problems than descriptions without pattern ($t(44) = 2.15, p < .05, d = 0.64$, one-tailed). Furthermore, pattern descriptions contained more structural problem features than descriptions without patterns ($t(44) = 3.50, p < .01, d = 1.02$, one-tailed), with regard to surface problem features there was no difference between the conditions ($t(44) = 0.35, p = .37$, n.s., one-tailed). For own derived problems we found that pattern descriptions included more own derived problems than descriptions without pattern ($t(44) = 1.88, p < .05, d = 0.56$, one-tailed).

--Insert Table 1 about here--

With regard to the relative number of problems, the results revealed that pattern descriptions mentioned a higher number of structural problem features ($t(39) = 2.01, p < .05, d = 0.63$, one-tailed) and that pattern descriptions contained fewer surface problem features than descriptions without patterns ($t(39) = -3.11, p < .001, d = 0.99$, one-tailed). In addition, pattern descriptions contained more own derived problems than descriptions without pattern ($t(29.5) = 2.06, p < .05, d = 0.62$, one-tailed). These results support Hypothesis 1.

In sum: Participants with patterns provided more problems than those without patterns. With regard to the relative number participants with patterns mentioned more structural problem features and derived more own problems than participants without patterns.
4.2.4 Content of solution descriptions

Table 2 shows that overall, pattern descriptions included fewer solutions than descriptions without patterns ($t(44) = -4.19$, $p < .001$, $d = 1.23$, one-tailed). In detail, pattern descriptions contained fewer concrete solutions than descriptions without pattern ($t(44) = -3.97$, $p < .001$, $d = 1.16$, one-tailed) but there was no difference concerning abstract solutions ($t(44) = -0.31$, $p = .38$, n.s, one-tailed).

With regard to the relative number, pattern descriptions included more abstract and fewer concrete solutions than descriptions without patterns ($t(44) = 2.97$, $p < .001$, $d = 0.88$, one-tailed). These results support Hypothesis 2.

In sum: Participants with patterns provided fewer solutions than those without patterns. But with regard to the relative number they focused more on abstract solutions and mentioned concrete solutions to a lesser extent.

--Insert Table 2 about here--

4.2.5 Qualitative findings

The findings of our field study revealed some qualitative differences. There were characteristic differences in the writing style of participants who used a pattern and participants who used none for their case descriptions. Whereas the style of with-pattern participants was determined by focusing clearly on the problem (“Be aware of X before doing A”), the style of without-pattern participants stood out due to the frequent use of course of action descriptions. They often mentioned single action steps one by one (“Please do A, then B and finally C”), without elaborating much on possible problems that can occur in the situations. For example, subject 03 (without-pattern condition) drew up a description as follows: “The upcoming children’s service is about the Book Ruth 1.1-16. At the beginning, we sing the song Halleluja out of the Songbook for the Youth with the number 389. Next we will read the story of Ruth together – we will read it very slowly! The kids get clothes to do masquerades and to re-enact the story spontaneously. After the story, we will pray that we all keep well and fit and that we will never be in a situation like Ruth’s.” This is a prototypical description for without-pattern participants: They mentioned a lot of
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concrete solution steps but did not explain why – that is, they did not elaborate on the problems that were causal.

By contrast, subject 38 (with-pattern condition): “If kids feel unchallenged, unrest may arise which messes up the whole group. Therefore, it must be ensured in a role play that it is age-appropriate and inspiring. We will choose a song that can be sung in different languages. In this way, the Spanish kids can sing as well. At the end of the children’s service we are going to serve cookies and snacks for an informal exchange. So the relationships among the kids and between the kids and the tutors can be promoted.”

With-pattern participants described their Sunday school generally more abstractly and mentioned solutions in relation to the respective problem.

4.3 Discussion

Experiment 1 was a field study with young ecclesiastical practitioners who had accumulated knowledge-in-use about church-based youth work during regular practice and training. The results of Experiment 1 confirmed our assumption that patterns support practitioners in the externalization of their knowledge-in-use.

First, people with patterns focus more on structural problem features by pointing out relevant aspects under the surface. In the pattern condition, the participants considered more relevant problems in their texts that were not directly stated in the described challenge than participants without patterns. This enhanced awareness for problems which occur frequently was also supported by the result that problem descriptions in the pattern condition included more own derived problems that were not mentioned in the instruction than the problem descriptions in the condition without patterns.

Second, people with patterns abstracted their solutions more by relinquishing solution-irrelevant information. With regard to the abstractness of solution descriptions, we found that pattern descriptions contained more abstract solutions, and descriptions without patterns contained more concrete solutions. Both the explication of structural problem features, the derivation of problems based on specific context factors and the abstraction of possible solutions are crucial requirements for successful adaption of knowledge to new situations.
One aspect is important for the interpretation of these results: This study was done with practitioners who gained their knowledge from experience. Thus, they naturally had different levels of knowledge. This might have induced some variance between the participants. So in a further study we investigated the impact of patterns on the externalization of knowledge-in-use in a setting where the knowledge-in-use was more homogeneous. For it we conducted a laboratory study where we could induce knowledge-in-use in a very compact way. So the second experiment standardizes the expertise of the participants and tries to replicate the findings of Experiment 1 under these more controlled conditions.

5. **Experiment 2: Laboratory study**

Experiment 2 was designed to test the impact of patterns on the externalization of knowledge-in-use that was acquired just for the purposes of the experiment and that had to be abstracted across two different situations. Referring to the results of Experiment 1, we derived the same two hypotheses.

*Hypothesis 1:* Case descriptions with patterns as the input format contain more structural problem features than case descriptions without patterns.

*Hypothesis 2:* Case descriptions with patterns as the input format contain more abstract solutions than case descriptions without patterns.

5.1 **Method**

5.1.1 **Participants**

Sixty-one subjects between the ages of 19 to 50 ($M = 25.58, SD = 6.00$) participated in the study (39 were female). The participants had no substantial prior knowledge of first aid.

5.1.2 **Design and Procedure**

The participants were randomly assigned to one of two conditions (29 participants in the pattern condition, 32 in the unstructured condition). In the *pattern condition*, they had patterns as the input format to externalize their knowledge. The pattern provided text fields for the categories *situation*, *problem* and *solution*. In addition to these three categories also the category *forces* was used. A frequently used
additional pattern feature is one that contains competing requirements in the first-aid situation. This pattern category is used in domains where the choice of a wrong solution could have unintended effects like in object-oriented software development (Beck & Cunningham, 1987; Gamma, Helm, Johnson & Vlissides, 1995; Lukosch & Schümmer, 2006) or introducing new ideas in organizations (Manns & Rising, 2005). In the condition without patterns the participants just had a text field without any structure.

We used the domain of first aid. This is a suitable domain because it allows participants to acquire new knowledge-in-use in a relatively short time and in an implicit way, just by practicing and without our having to deliver explicit facts. We did not instruct the participants how to handle the scenarios but asked them to explore by “trial and error” the appropriate actions, that is, how to behave correctly at the scene of an accident. We did this in order to control their prior knowledge about first aid. To ensure that all participants gained the same knowledge, the scenarios consisted of definite sequences of action. An observer made sure that the participants could only get to the next sequence if they had behaved correctly in the previous one. In this way all participants acquired similar knowledge-in-use during the experiment and not just declarative knowledge, for example, by being told some facts about first aid.

All participants passed through two phases: a learning phase and an externalization phase. In the learning phase, the participants had to learn to handle two simulated accident scenarios with a first aid doll. In one scenario, for example, the participants had to imagine that they were witnesses of a motorcycle accident on a freeway. We provided essential props for both scenarios. In the same example of the motorcycle accident, for instance, the first aid doll was equipped with a motorcycle helmet and long clothes, and the participants could find a reflective vest and a warning triangle to secure the accident scene.

After a short introduction, the participants had to behave like first aiders and take care of the victim (first aid doll). Both scenarios differed in the concrete measures that had to be taken after arriving at the place of an accident. Although these measures differed in the two scenarios, the rule for how to behave was actually the same: self-protection was the most important. So the participants needed to realize that they had to protect themselves – despite the different context-factors which characterized the two scenarios. Thus, it was an isomorphic task, in that the participants had to recognize the same important
structure within both accident scenarios beyond superficial dissimilarities (Reed, 1999). We chose two accident scenarios, since comparing multiple examples within a problem category fosters the identification of structural features and stimulates abstraction (Gick & Holyoak, 1983; Reeves & Weisberg, 1994).

During the following externalization phase, we asked the participants to externalize the knowledge they had acquired in one description – either in a pattern or in a blank template. The participants were told that they should write a case description in a way that it would enable possible readers to behave correctly if they entered a situation with similar problems.

5.1.3 Dependent Measures

We analyzed the content of the written texts with regard to the description of problems and solutions. A detailed coding scheme along with coding examples is in the appendix of this paper.

Content of problem descriptions: Like in Study 1, we counted how many surface problem features and structural problem features participants mentioned in the text. If a participant, for example, wrote in relation to an accident scenario on a freeway “As a first aider you need to pay attention not to be run over by other cars”, we classified the problem under surface problem features, as it referred specifically to a concrete feature of one of the two scenarios the participants had received training for earlier in the experiment. In contrast, we coded participants’ problem descriptions as structural problem features if the problems were abstracted across the two scenarios and did not show any concrete references, for example, if a participant wrote “As a first aider you need to protect yourself”.

This led to two categories of the dependent variable measuring the content of the problem descriptions: surface problem features and structural problem features.

Content of solution descriptions: We counted the number of solutions mentioned in the texts and classified them either as concrete solutions or as abstract solutions. Concrete solutions had a concrete reference to the simulated scenarios, as in this example: “You should wear a reflective vest to be visible for the other road users while trying to help the unsuccessful motorcyclist”. Abstract solutions were more general and did not make any concrete references, as in the example, “You should take appropriate measures to protect yourself as a first aider”.
5.2 Results

For all hypotheses we compared the two conditions by t-tests for each dependent variable to test the hypotheses that pattern descriptions contained more structural problem features (Hypothesis 1) and more abstract solutions (Hypothesis 2) than descriptions without patterns. The results for the t-tests are reported one-tailed, as we have directed hypotheses and effect sizes using Cohen’s d. Like in Experiment 1, we report the absolute as well as the relative values for all dependent variables, to ensure that effects are not based just on the fact that participants mentioned more problems and solutions overall. All means and standard deviations are provided in Table 3 for the problem descriptions and Table 4 for the solution descriptions.

5.2.1 Intercoder reliability

Twenty percent of the material was coded by a second independent rater to calculate the intercoder reliability. The intercoder reliability for the rating of the problem features was $r = .76$, $p < .01$ and for the rating of solutions $r = .93$, $p < .001$.

5.2.2 Number of words

Participants who used patterns for their descriptions wrote overall more words ($M = 365.90$, $SD = 142.10$) than participants without patterns ($M = 282.38$, $SD = 162.15$) ($t(59) = 2.13$, $p < .05$, $d = 0.55$ one-tailed).

5.2.3 Content of problem descriptions

As Table 3 shows, overall pattern descriptions included more problems than descriptions without patterns ($t(59) = 3.99$, $p < .001$, $d = 1.01$, one-tailed). In detail, pattern descriptions contained more structural problem features than descriptions without patterns ($t(59) = 5.12$, $p < .001$, $d = 1.33$, one-tailed). Both conditions differed with regard to surface problem features ($t(59) = -1.77$, $p < .05$ $d = -0.45$, one-tailed).
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The relative results revealed that the pattern descriptions included more structural problem features and fewer surface problem features than descriptions without patterns ($t(57) = 2.25, p < .05, d = 0.59$, one-tailed). These results support Hypothesis 1.

In sum, pattern descriptions contained overall more problem features. With regard to the relative number, participants mentioned more structural problem features and fewer surface problem features in pattern descriptions than in descriptions without patterns.

5.2.4 Content of solution descriptions

As Table 4 shows, pattern descriptions included fewer solutions than descriptions without patterns ($t(59) = -2.01, p < .05, d = 0.51$, one-tailed). The absolute results related to concrete solutions also revealed that pattern descriptions contained fewer concrete solutions than descriptions without patterns ($t(43.5) = 3.85, p < .001, d = 0.98$, one-tailed). Regarding abstract solutions, pattern descriptions and descriptions without patterns did not differ from each other ($t(59) = 0.44, p = .33$, n.s, one-tailed).

The results of the relative number of abstract solutions revealed that the pattern descriptions included more abstract and fewer concrete solutions than descriptions without patterns ($t(59) = 2.48, p < .05, d = 0.64$, one-tailed). These results support Hypothesis 2.

In sum, pattern descriptions contained overall fewer solutions than descriptions without patterns. With regard to the relative number, pattern descriptions included more abstract and fewer concrete solutions than descriptions without patterns.

5.2.5 Qualitative findings
Similar to the findings of the first field experiments, we found also in this study that participants who had a pattern for their descriptions highlighted focusing on the specific problem, for instance, “Be aware of X before doing A”, whereas participants who did not have a pattern for the descriptions mostly mentioned a sequence of action steps for behaving correctly at the scene of an accident, for instance, “Please do A, then B and finally C”. For example, subject 3 (with-pattern condition) wrote: “The victim must be moved out of the danger zone, without jeopardizing the victim’s and one’s own life.” Contrary to this statement of the overall problem, subject 6 (without-pattern condition), for example, gave the following suggestion: “After arriving at the place of accident the first aider must firstly set up a warning triangle and put on a protective vest.” It is recognizable that with-pattern participants interrelate the problem with the respective solution description. Similar to study 1, they often did this within the problem category (that is, the problem and the respective solutions description). Without-pattern participants, however, list all concrete single steps a first aider has to take to stay safe.

5.3 Discussion

In contrast to Experiment 1, where individuals with experiential knowledge participated, the participants of Experiment 2 acquired new knowledge-in-use in a very standardized way under laboratory conditions. This experiment replicated the results of Experiment 1: Patterns led to case descriptions that contained more structural problem features and more abstract solutions. So we have strong evidence that patterns facilitate the externalization of knowledge-in-use (if it is knowledge that was acquired over some time, or if it had just been learned) by supporting the participants in focusing on structural features and abstract solutions. Study 2 showed that participants who used a pattern as input format for their case descriptions realized that the scenarios they had just experienced were only superficially different. In their description they mainly focused on the structural features of the two accident scenarios. At the beginning of the study, the participants were instructed to write the description in such a way that other inexperienced first aiders would be able to act adequately after reading the descriptions. Patterns supported participants in writing more abstract case descriptions with the main message “self-protection is most important”. This is exactly what patterns are supposed to do. They support participants in their
externalization of their tacit knowledge-in-use by enabling people to abstract their experiences across different situations and identify the structural problem features which were relevant for a successful solution.

6. **Summary and concluding discussion**

In this article we investigated whether patterns could be a tool for supporting the computer-mediated exchange of knowledge-in-use. We used a cognitive psychology perspective that sees the potential of patterns in the structural analogy between patterns and knowledge-in-use: Patterns as external representations and knowledge-in-use as internal cognitive structure both consist of the same subcategories *situation*, *problem* and *solution*. Knowledge-in-use is always knowledge about solving problems within the same problem category, that is, problems that occur in different situations but that have the same solution-relevant problem features in common. The main assumption was that patterns facilitate the recognition of these solution-relevant structural problem features.

We investigated the impact of patterns on the externalization of both experiential knowledge-in-use (Experiment 1 in the field) and knowledge that was acquired just for the experiment (Experiment 2 under laboratory conditions). Both experiments provided similar results: the use of patterns supports people in externalizing their knowledge-in-use at a more abstract level. Patterns facilitated the derivation of very implicit or even new problems *from a specific situation* based on prior experiences and they helped people in recognizing solution-relevant features shared by two *different situations*.

Taken together, the results give first evidence that patterns could be an appropriate technological tool for supporting knowledge externalization, regardless of whether that knowledge is experiential or acquired just before it has to be externalized. They provide an important precondition for successful knowledge exchange: the externalization of personal knowledge-in-use. The externalization of this knowledge is difficult, as it is mainly tacit (Polanyi, 1966) and used unconsciously and automatically (Anderson, 1983; Smith, 2001). Our results show that patterns can support people in handling the challenges of externalizing not only explicit but also tacit knowledge. This is important as only by capturing explicit and implicit knowledge are institutions like schools and universities able to link individual learning and exchange of experiences.
The similar results of the field study and the laboratory study found under controlled experimental conditions give strong evidence for the assumption that these results could be applicable to real settings of computer-mediated knowledge exchange. Therefore, the importance of supporting knowledge exchange for learning should be considered for the design and the implementation of learning settings, especially when learners are distributed and the communication occurs computer-mediated. Learners have to be able to communicate their own knowledge and to understand knowledge of others to benefit from others experiences and to construct knowledge acquisition by themselves. By using patterns as tools in computer-mediated learning settings, researchers and practitioners can give essential support for overcoming this crucial cognitive barrier for knowledge exchange and enable sustainable documentation and application.

Patterns already proved themselves in practice as they are applied to existing learning settings, like in case of the internet platform www.geistreich.de (German for spirited) from the Evangelical Church in Germany. The aim of this platform is to support the exchange of good practices and the development of a common knowledge base via web 2.0 technologies between practitioners active in clerical contexts. Another practice platform that uses patterns for transferring knowledge between practitioners in higher education areas is www.e-teaching.org, an information portal for the usage of e-learning in universities. Patterns can thus act as catalysts for improved quality in education and knowledge transfer.

However, one limitation of both experiments is that our participants did not have a very high level of expertise. Although we had participants with an average of 24 months’ experience in leading children’s church services in Experiment 1, none of the participants was a professional. Thus, the next research steps to be taken should be to implement a pattern-based knowledge exchange system for professionals with really high expertise.

Further research is needed to see whether more abstract descriptions are in fact more efficient for people receiving case descriptions. In fact, this is one main idea of the pattern approach: Make successful solutions of experts useable for less experienced people by abstraction (Alexander et al., 2007; Carroll & Farooq, 2007; Winters & Mor, 2009). So the question is, can people, reading such abstract reports, in fact use this knowledge provided by another user in order to behave more efficiently in situations they might experience in future? In our experiments we could show that patterns support learners in externalizing
their own knowledge-in-use. The next step is to show if they also support learners in internalizing the knowledge-in-use of others. Based on three case studies, Kolfschoten, Lukosch, Verbraeck and Valentin (2010) concluded that receiving patterns can reduce the cognitive effort to understand and perform a design task; that is, patterns can reduce the cognitive load (Sweller, van Merrienboer, & Paas, 1998) and make problem solvers more efficient in their actions by facilitating the application of different solutions to new situations. Considering this preliminary evidence and based on our theoretical approach, we would expect a positive effect of patterns on knowledge internalization and transfer as well.

Externalization and internalization are crucial preconditions for knowledge exchange and collaborative knowledge construction. Learners have to be able to contribute their own experiences and have to understand the experiences provided by others. Based on the co-evolution model (Cress & Kimmerle, 2008; Held, Cress, & Kimmerle, 2012; Kimmerle, Cress, & Held, 2010; Kimmerle, Moskaliuk, Cress, & Thiel, 2011) that focuses on knowledge transfer and knowledge creation in large groups and that describes the mutual development of a single user and a digital artifact that bundles the activities of all users of a community, a next step would be to investigate how people adapt others’ experiences and integrate them into their own practices. In this context, the question also arises as to how learners can work together on patterns as a common digital artifact.

One other aspect we have to investigate in detail in follow-up studies is the expertise reversal effect which states that, depending on the level of knowledge, one and the same instructional method can have different effects on the learner (Kalyuga, 2007). Learners with little knowledge often benefit from well-guided instructions, whereas the performance of learners with much knowledge is better off with reduced guidance (Kalyuga, Ayres, Chandler, & Sweller, 2003; Kalyuga, 2007). In cases where learners are already very knowledgeable, they have to compare and integrate redundant information (their own evolved schema and the externally provided guidance), which in turn can lead to increased cognitive load (Kalyuga, 2007). Here, the question arises as to whether patterns are differently supportive for learners with different expertise levels in terms of the internalization, transfer and collaborative construction of knowledge-in-use.
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