Connecting Domains in Concept-Context Learning: A model to analyse education situations

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Abstract

The use of context-concept education alongside existing approaches is valuable. In this article we introduce a three-domain model for concept-context learning that supports both the design process as well as the idea of concept learning. The model shows how practical and abstract knowledge should be combined to improve context-concept learning. The model acknowledges the dual nature of products and the need to relate practical, concrete experiences to causal explanations. It distinguishes three domains: the social context, the concrete product and the abstract knowledge domain. Here, the model is used to analyze, explain and suggest improvements for training primary school teachers in the Netherlands. The research data from the in-service teacher training show how continuous movement between the three domains is needed to develop creative, socially relevant solutions. The training would be better aimed towards the needs of the learner if the connection between the theory, concrete experiences with products and the social context is made more visible and inviting.

Key words

concept-context learning, knowledge categories, in-service teachers, primary education, three-domain model, design process

Introduction

Presenting science and technology concepts through themes that make sense to pupils because they are closely related to everyday-life, provides an educational approach that is more comprehensible towards real problems and concrete objects than an approach that aims at teaching at an abstract level right away. The social context that comes with this approach offers a problem-solving situation to which learners can easier relate than to a theoretical formula, and it fosters positive attitudes towards science (Bennett et al., 2006). However, it is not clear how abstract and practical knowledge should be combined so that both concept learning and the development of creativity are supported.

Inspired by the research into context-concept based training of primary school teachers in the Netherlands in 2010 (Koski and De Vries, 2011),we introduce a model that helps to create a set of learning situations linking social context, concrete objects and abstract knowledge. Using these three domains, concept learning is enhanced without ignoring creativity and real-life problem-solving. The value of the model is demonstrated through examples from an in-service training of primary school teachers. Along with this, we show how the model should be applied, and in what situations, the aid that it provides, improves the learning and teaching experience.

Value of the concept-context learning

Science and technology as a topic in a school curriculum has many difficulties to overcome, but it has one advantage compared to the older subjects. Because of its unclear position, there are more possibilities of influencing the way it should be organized. But more importantly, because it does not have a fixed tradition, introducing a different approach is more likely to succeed than among established subjects like mathematics or history.

Context-based approaches have become widely used over the past two decades in many countries, e.g., Germany, the Netherlands and the USA (Pilot and Bulte, 2006; Bennett et al., 2006). The Dutch government wants to give more space to the context-concept learning and it has been implemented in the Dutch primary and secondary schools (Graft and Boersma, 2009; Eijkelhof and Krüger, 2009). Because of this policy, in-service teacher training also introduces the approach to primary and secondary teachers. Concept-context learning deserves more attention in research and maybe through this it will become a well noticed part of education.

When referring to concept learning, the intended meaning is the learning of scientific and technological concepts and principles. Often, these two are combined, e.g., a scientific law could be the law of Bernoulli and the relevant technological principle is the shape of the curving of the wing. Keeping the learning situation strictly focused on the facts and solid, well-tested topics is a common approach to concept learning. This has its benefits of explaining the concept precisely without experiencing difficulties of unexpected outcomes. Although some theories cannot be explained through practice (Felder et al., 2000), context-concept education has a number of advantages (Bennett et al., 2006; Pilot and Bulte, 2006). Ideally, a concept, or part of it, is learned in a certain context and further examined and understood in other contexts. As a result, learners do not only understand the concept at a higher level but they increase their abilities to apply it in real-life situations simultaneously.

Vygotsky introduced a method for learning through a social context (Vygotsky, 1978). He claims that humans learn through being and acting in a cultural context and in a sense they re-invent the learned matters in that culture (Crawford, 1996). According to Vygotsky, a learner builds cognitive structures through the needs and purposes, through actions and the meanings that they attach to an activity, and their relationship with other people (Crawford, 1996). This same underpinning of needs and purposes is presented by Knowles et al. (2011) in the theory of Andragogy when he states that adults need to know why they are learning what is taught to them. Knowles et al. (2011) does not talk about social context, but he states that adults relate the learning to their previous experiences and lived life.

The combination of theory and practice in concept-context learning provides an interesting field to be explored. Here, the intention is to introduce a model that enables us to apply the learned concepts more effectively in everyday-life, in real-life problems.

Literature study and the three-domain model for concept-context learning

How are concepts related to concrete real-life situations? What are the relevant knowledge levels that are ideally included in concept-context learning situations? In answering these questions, literature from various fields such as design and technology education, design methodology, technology philosophy, creativity education and inquiry-based education is combined.

It is clear that knowledge about specific physical objects is relevant in concept-context learning. The objects used in context-concept learning are often taken from daily life (e.g., balloons or a kitchen-scale) although one may use specific measuring instruments (e.g., a pH meter). It is assumed that learners are most likely to develop an in-depth understanding of any object, change or event if they experience it first-hand (Wenham 2005; Rocard et al., 2007). Wenham (2005) however, notices that the primary school teachers, who give practical work, are often not focused on understanding at a more abstract level. The focus of these teachers is on the facts (what happens), they do not explore ideas, abstract concepts or develop and encourage the explanations with their pupils (why it happens). Although pupils as well as primary school teachers are not able to grasp every abstract concept, Wenham (2005) states that the why-domain needs more attention in education.

In design and technology assignments, concrete and abstract knowledge levels are distinguished as well. Design methodologists such as Van Aken (2005), Muller and Thöring (2010) made a taxonomy of knowledge categories used by adult designers and included knowledge about the concrete product as a separate category. Van Aken (2005) describes object knowledge as knowledge about the characteristics and properties of artifacts and their materials. Muller and Thöring (2010) call this category ‘design artefacts’ and describe it as form, gestalt or embodied knowledge. Another term used in the literature is device knowledge (Gott, 1988; Compton, 2004). In concept-context learning, learners need to collect information about the concrete product. The tool “technology glasses” is commonly used in the Dutch classrooms. This tool contains a number of questions focusing on the concrete product, e.g., where is it made and what the different elements are.

Design methodologists, as well as authors in the field of philosophy of technology, emphasize the importance of abstract knowledge in design and engineering. Various types of conceptual knowledge categories are described in the literature:

- Fundamental design concepts (Vincenti, 1990). These design concepts are ‘normal configurations’ of a product, e.g., standard images of an end product or a number of existing designs (Broens and De Vries, 2003). They describe the generic idea behind a design.
- Structural rules (Ropohl, 1997) concerning the assembly and interplay of the components of a product or technical system form a similar category.
- Scientific or natural laws (Broens and De Vries, 2003).
- Mathematical models or technological rules (Vincenti, 1990; Broens and De Vries, 2003). Designers apply mathematical methods and theories, formulas for calculations, technological rules and/or rules of the thumb in design processes.

These abstract concepts are used to understand the operation of an existing product. Furthermore, designers use them as heuristics in design processes. Although scientific and technological concepts never dictate a solution, they often guide the search of the designer and point towards specific, promising directions (Kroes, 1995). As educational researchers Cropley and Urban (2000) argue, abstract concepts are a powerful tool in creative problem-solving processes. Naturally, design processes are not always based on explicit concepts. Designers also use trial and error strategies (Vincenti, 1990; Kroes, 1995), engineering experimentation (Vincenti, 1990) or intuitive, tacit knowledge (Polanyi, 1966).

Since design processes are creative problem-solving processes, we can conclude that learners have to apply both concrete and abstract knowledge in the product design activities. The concrete product domain (what) and the abstract concepts (why) are not only relevant in the inquiry-based learning, but also import in the design and technology education.

The third knowledge domain that should be included in concept-context learning originates from the dual nature of products. Products have a physical and their intentional (functional) nature (Kroes, 2002; Kroes and Meijers, 2006). Products are physical objects that are described by physical properties at the concrete product domain. However, products function in social contexts and derive their meaning from intentional or functional aspects.

Successful designers are well aware of the specific social context and the various actors that will be put in touch with the products. Philosopher Ropohl (1997) emphasizes the importance of social-technical knowledge. He indicates that designers use knowledge about the social context as well as insight in the interrelationship between the technical objects and their social meaning. And Vincenti (1990), who studied design practices in the aircraft industry, points towards (design) criteria and specifications. These criteria originate from the social context but are often formulated in physical terms. The social context is thus a third knowledge domain. A number of questions from the "technology glasses" tool acknowledges the dual nature of products, e.g., who will use it, and what is the function of this product.

Based on the literature described above, closer attention is required to the way abstract and practical knowledge should be combined to support concept learning in real-life situations. Most authors emphasise only two knowledge domains, but the literature study revealed that three domains need attention. Therefore, a three-domain model for concept-context learning that supports both the design process as well as concept learning is introduced. The model visualizes important factors in the design process and describes how to emphasise teaching and learning of concepts in specific contexts.

In the first part of the model, we have divided the learning process into three domains; social context, concrete object and abstract knowledge (see Figure 1). The first domain provides the social context for the learning. The next domain is about concrete objects, where information about a specific object or a product is gathered and examined. In the third domain, the information is deepened with abstract knowledge. This level contains concepts from technical and engineering sciences. Concepts from natural science are even more abstract.

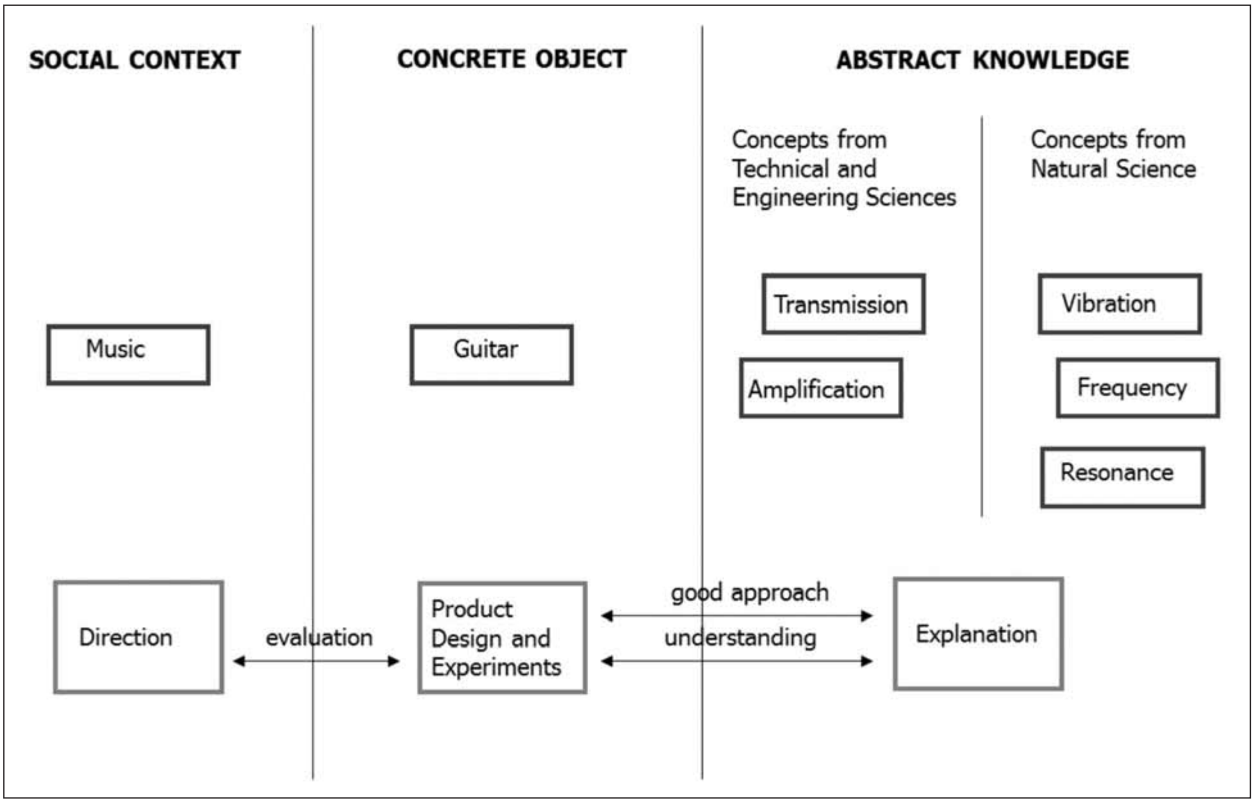

Figure 1. Three-domain model for concept-context learning with music as an example.

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In the first domain the learner is confronted with real-life problems, e.g., a music instrument that is broken. Therefore, the social domain provides the right context to intrigue and trigger the learner into studying the social context, concrete objects and concepts. This domain can be compared Vygotsky's social context. Including this domain in educational situations also responds to the need of (adult) learners , described by Andragogy (Knowles et al., 2011).

Evaluation is (partly) placed in the social domain and it is about the value of the experiments and the designed products for human beings. Since evaluation serves as a link between the social context and concrete objects and concepts, it directs the learning process in a sense of what needs to be done and why it needs to be done.

In the domain of concrete objects the learner is confronted with objects such as products, materials, tools and hands-on-experiments. Here, as in Levin's action research model, the here-and-now concrete experience is important (Kolb, 1984). The learner faces a concrete thing or collects factual information from experiments. Relevant elements, such as the strings or the specific shape of the sound box of a guitar, need to be identified.

In the next domain, the abstract knowledge domain, the explanations and the relevant abstract concepts are explored. The conceptual knowledge obtained can be technical or scientific. With this obtained knowledge, learners can choose a better approach for a further exploration of objects or develop an alternative, improved object, e.g., an enhanced string instrument.

Each domain enriches and inspires the learning in the other domains. This enrichment should happen until the task is finished. Learning should not take place in a pipeline from context to theory; learning in one domain is connected in various ways to learning in the other domains.

Examples from research on concepts related to air and water

In this section, the three-domain model is used to reflect on how in-service teachers learn concepts related to air and water. The examples are part of a larger study (Koski and De Vries, 2011) conducted in Spring 2010 during an in-service teacher training program. Here, the purpose is to show how having an insight into the three domains and their connections can be used to improve the teaching and learning processes. It should be noted that the focus is mainly on the learning of concepts.

Dealing with confusion

The first example is a comparison of two questions. In the first question teachers were asked to compare the weight of two glass bottles, one filled with air and the other, a vacuum one. This question tested if the teachers see air as something with weight. The second question asked if it is possible to pump air into a swimming ring that has five books on top of it. This questions tests if the teachers consider air as something with a quality of force. In the table below (Table 1), answers from four teachers to both questions are presented.

Teacher	Answer to Q1: glass bottles	Answers to Q2: swimming ring
A	Air is something, but it has no influence on the weight.	Yes, the air goes into the ring and everything is lifted.
B		Yes, the band becomes firm.
C		Yes, that is possible because the increase of air makes the ring thicker.
D	Air is nothing.	The books will rise if you put enough air in. The mass of the air is more than the books.

Table 1. Two questions about air.

In the answers to the first question, more than half of the teachers (answers A, B and C, Table 1) stated that adding or removing air from the bottle does not change the weight. Given the replies, it seems as if air is believed to be weightless. When comparing these answers to the ones about the lifting power of air, the confusion of the characteristics among the teachers can be observed. In the answers, such as given by Teacher D, air was stated to be nothing, however, it could lift the books. Similar results have been reported by Rollnick and Rutherford (1990), where pre-service teachers' answers about air and air pressure contradict the scientific concept.

The confusion indicates that the theories are learned as detached units. The universal use (Yin et al. 2008) of a theory is hampered due to the isolation of the theory from its applications and the situations in which to use it. The offered aid by the three-domain model is that a theory (abstract knowledge domain) supports the understanding of an experiment (concrete object domain) and, as a feedback, experiments support the more universal understanding of a theory. Since a more practical example triggered correct answers, experiments should be

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connected to the social context domain to have a direction in the learning. The cycles made between the domains, attach understanding to a theory and meaning to an experiment.

Making the knowledge more accessible

In pre- and post-training questionnaires, two teachers were asked why an ice cube floats in one of the glasses and sinks to the bottom in the other one. The ice cubes themselves are identical and they are placed in identical glasses.

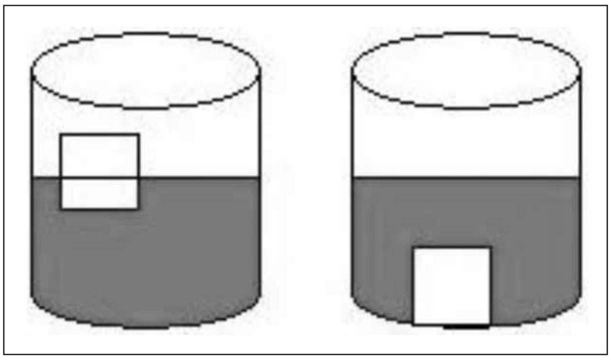

Figure 2. Identical ice cubes in different liquids.

In the pretest, the above picture was given (Figure 2). In the posttest, the same situation was explained by a written text and an addition was given that one glass is filled with water and the other one with alcohol.

Teacher	Answer in the pretest	Answer in the posttest
A	In the one block there is more air? That's why it floats.	The density of alcohol is bigger than water's.
B	The liquid is from another kind (e.g., salt or soup).	It is a matter of another density, in ice the molecules are closer to each other than in the water around them. In alcohol this is not the case.

Table 2. Comparison of pre- and posttest answers of two teachers

In both answers, it can be seen that the investigation process is somehow inadequate and the meaning of density is wrongly understood. In the case of the Teacher A (Table 2), a more practical idea of what makes an ice cube float has changed into scientific explanation. Teacher B has an idea of density before the training takes place, even though the term itself is not used. But after the training, like Teacher A, the concept has changed into a wrong one. This contradicts the study of Loverude et al. (2003), where the students explained floating correctly in terms of lower density.

Here a new, wrong interpretation of the theory can be seen. To avoid this, based on the three-domain model, the new information is related to what is already known about the topic (evaluation) and therefore, better questions can be asked, namely questions aiming towards a better explanation.

The answers also show how obtained knowledge becomes isolated and meaningless, especially if the experiments support trial-error type of learning and when they are rushed through. With the movement in the model, the relationship between the theory and practice becomes more evident and the explanation is better connected to the experiment. In the course of this, more reflection is put into learning and the learning becomes more critical. If a critical comparison and reflection to the previous knowledge happens, the learner is able to notice “the lack of logic”.

Obtaining usable knowledge

In the last example about the concepts, teachers were asked what makes the first balloon stay put and the other balloon rise (Figure 3).

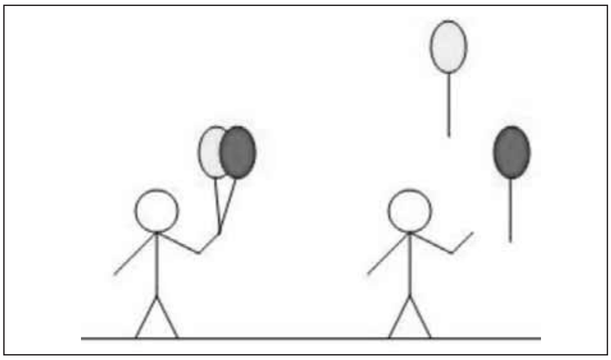

Figure 3. Two balloons with different behavior.

The concept examined here was ‘lighter than air’. In one third of the given answers the term was used correctly (Teacher A, Table 3). Another third of the teachers (Teacher B) cautiously replied something about lighter weight or heavier gas. For research purposes the last third of the answers form an interesting group. Answers such as those given by Teachers C and D (Table 3) on the special behavior of gas, show gases being completely different from air. Contradictory results have been reported in

Rollnick and Rutherford (1990). Here it is thought that air consists of many gases.

Teacher	Explanations of what is happening in the picture
A	In the yellow there is helium and in the red one there is blown air. Helium is lighter than air.
B	The yellow balloon is lighter in terms of weight.
C	Due to the gas the balloon rises.
D	There is probably gas in it.

Table 3. The question about the two balloons.

The answers that divide gases into air and other gases are based on a practical way to approach the concept of gas. The explanation could be that in the carnival, balloons are sold and they are filled with gas that comes out of the cylinders. This gas makes the balloons rise and this knowledge is enough in everyday-life. The problem arises when this everyday conceptualization is confronted with the scientific explanation of the same phenomena.

Starting with this practical knowledge and refining it towards scientific knowledge happens progressively, while moving between the domains in the model. An idea, even a wrong one, sets a certain goal to what to expect. Hence, the result of an experiment seeks explanation from the abstract knowledge and this is reflected to the original idea. Investigation includes repetition and by gradually building the knowledge, correcting wrong ideas, scientific theories become more natural. This does not only help the teachers to see the theories in a more applicable way, but also it introduces a method to teach them to the students and hopefully reassures the teachers in using the theories.

The model helps to structure the teaching and learning so that more attention can be paid to scientifically false ideas and into the process of moving away from them. Iterations between the three domains offer an approach, whereby knowledge is obtained based on learner's needs. To move away from the impression that the teacher in front of the classroom provides all the information, and that this is the right knowledge and the right way to present it can be accomplished by using the model.

Examples from research on creative design

In this section, the three-domain model is used to understand how the three domains are used in the development of creative design solutions. Four groups of primary school teachers following a context-concept based course of six afternoons have been video-taped. Each group was trained by a different trainer. A complete overview of the research will be published elsewhere. Here the purpose is to show how continuous movement between the three domains is needed to develop creative, socially relevant design solutions.

Include three domains in product evaluation

The selected social context in one of the training sessions was a flying contest. Participants were asked to design and test a paper airplane that is either very fast, stays very long in the air or flies in a funny way. A short description of how to build three different models was provided and the learners were asked 'to adapt these examples to make them better'. Trainers gave examples of elements that could be changed in the design, e.g., use of different material or make the model bigger. Earlier, concept cartoons and practical experiments with air were used to learn about related concepts e.g., air is something, air has force, the Bernoulli principle and wing shape. Two examples of the focus in the training on the concrete object domain and not on the abstract domain are given below.

Example 1. A lucky throw

Primary school Teacher D tosses a paper airplane. The first time it covers a short distance, the second time it reaches the other side of the classroom.
Trainer: "This is better".
D nods and tells: "A previous time, the plane reached the blackboard, the plane is able to cover a larger distance ….
Trainer: "ah".
D: "The plane is thus better than we just saw".

In the discussions, causal explanations and why questions are, however, almost nonexistent. The testing and evaluation of the planes is mainly used to check facts. They focus on finding out which plane flies the longest distance, but the trainers do not encourage the learners to explore and understand why one covers a longer distance than another plane. However, there were a few exceptions. In each course one of the participants started to connect the abstract and the concrete domain, e.g., Teacher C describes what is happening in factual terms and provides a causal explanation.

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Example 2. NASA airplane (see Figure)

Teacher B has made a very large NASA airplane from paper.
Teacher A calls: "Throw it to me!".
B throws the large NASA airplane.
A shouts with joy: "Yes!"
Teacher C, holding a smaller model of the same NASA plane in her hand, is watching.
C: "This is really strange, it is different when I do it, when you throw the plane one of the loops is at the other side."
B throws the large NASA model again.
B says: "Yes, this is because the loop is slack"
C: "When the model flies, that one loop is below the straw'.
The teachers throw the model again.
C: "Yes, the loop falls down, but the air pressure raises it again. You can see a sort of rotation."

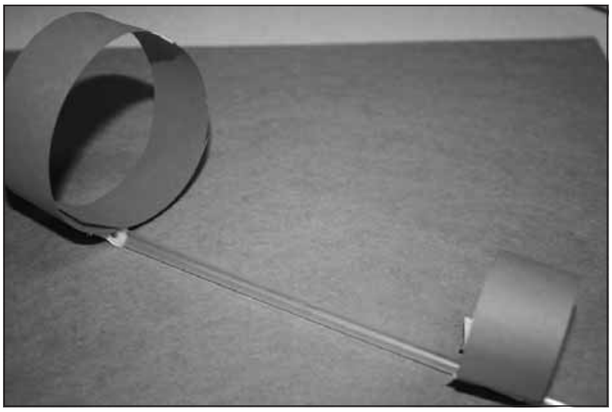

Figure 4. Unconventional NASA airplane.

Although some of the scientific explanations of the behavior of paper airplanes can be hard to grasp, a number of generalizations can be understood by primary school teachers. They may learn during the evaluation that the behavior of the plane is not determined by just one element or concept. The lucky throw example shows the influence of the throwing behavior and trainers could refer to a number of optimal throwing strategies described on the internet.

Concrete product information (form, materials, size) should be related to more abstract concepts during the product evaluation. Why-questions should be stimulated as well as references to the concepts that were central in prior activities in the training (concept cartoon discussions and practical experiments). During the design process, trainers may challenge participants to develop and list abstract concepts that they think will be helpful in explaining the behavior, such as the rotation point of the plane. Learners may be able to develop a few generalizations from the testing part of the design cycle.

In this way, design experiments are used to understand abstract concepts in a specific context. A why-focused evaluation may enhance creativity and innovation. Although causal explanations do not tell exactly what one needs to do differently, they help to find plausible directions to search for alternative designs.

Evaluation should be about the value of the designed products for human beings (see section 3). During the training, the need to cover a long distance was however in the limelight, whereas social needs such as staying long in the air and funny flying were neglected. As a result the learning process was not (re)directed through evaluation in the sense of what needs to be done and why it needs to be done. Focusing on all social needs will stimulate a more varied production of airplanes at the concrete domain and lead to a deeper conceptual understanding. Goals from the social domain will motivate learners to explore the concrete and abstract domain (Bennett et al., 2006).

The training session on flying included the three different domains but this is not enough. The domains need to be connected in the learning activities to arrive at effective concept learning and successful design outcomes. Linking of domains should be repeated in a continuous movement and the design process provides ample opportunities to connect all three domains.

Including the social domain in all learning activities

Quite often, learners do not explore the 'needs' in the social domain in a sufficient way. The next example is about a training session at the Oceanium, a large aquarium in the Rotterdam Zoo, that was fruitful in integrating the social domain in all learning activities.

Participants were asked to design a combined living quarters for sharks and corals using the expert method. This method entails that each participant becomes an 'expert' in a particular area and explores and approaches the problem from a specific perspective. Next, the experts with different backgrounds form a design team.
After casting the parts, exploring the problem situation started. This was done through lectures from designers of real-life aquaria and marine biologists and expert study groups. Each design team contained six experts that were responsible for respectively:

1. Entertaining and educating the public
2. The needs of sharks

3. The needs of corals
4. The needs of the keepers of the animals
5. Water management
6. Building technology

The role-play (expert method) stimulated most of the learners to integrate the needs-element in the learning activities. A selection of examples in which integration takes place is given below.

During the lecture by a marine biologist on the research conducted at the zoo on corals and sharks, many questions were asked from a specific interest. During the design assignment, each expert informed the team on the needs of a specific actor group and felt responsible for the inclusion of these needs. In the example below, a shark expert approaches the design criteria from the perspective of the sharks:
Real-life problems are messy and reframing problems is an important quality to learn. The next fragment is taken from the central presentation of the designs:

Teacher 1: "Let's share our information and start with the sharks."
Shark expert (SE): "Most sharks need to swim continuously, else they will sink."
Other teachers laugh.
Teacher 2: "These animals are not very intelligent!"
Teacher 3: "OK, what else do we need."
Shark expert: "Water."
3: "What kind of water? I assume salt water?"
SE: "This depends on the shark. I have also written down which other animals can be put in the aquarium. Animals who are able to live together with sharks like a turtle."
Teacher 4: "How about corals?"
Coral expert nods.
4: "Are sharks able to cope with light?"
SE: "It is very important that sharks do not swim near electricity and magnets, because their alarm system will go off the rails."
4: "They are stress puppies."

Teacher: "Our team started with the requirements related to the sharks but discovered that corals require different conditions. During the tour in the aquarium, we decided to have a deep and a shallow part in the aquarium. The corals will be put in a separate, shallow compartment due to their need for pure water. However, the visitors will experience the aquarium as a whole because the segmentation is not visible."
In the designs of the Oceanium, different viewpoints are integrated. Teachers in an expert role are motivated for the task, e.g., they are not satisfied with the first design sketches when their interest is not taken into account.

Coral expert: "I do not agree, corals are not able to live in this aquarium. Corals need sunlight and will die in the deep water that you just selected for the sharks. Corals live only on rocks. We have to design specific areas (in the aquarium) for the corals".

Connecting the social domain with the concrete and abstract domain provides ample possibilities to motivate learners. Role-playing and the expert method are a way to motivate learners to include the social domain in all activities. The evaluation forms of the training show that the design assignment at the zoo was among the highly valued activities. Teachers are socially oriented people according to career-researcher John Holland (1973) and approaching design from a social perspective matches their personality (Bras-Klapwijk, 2005).

Connecting concrete elements with the concepts

The marine animals, the huge water basin, the rusty pump, the very thick materials used for the aquarium windows and shark eggs are among the concrete elements that learners respond to. However, these objects need to be linked to abstract concepts when the learners design an Oceanium.

In the lecture, the marine biologist focused on a number of biological concepts that are helpful in understanding the needs of the corals and other marine animals in an artificial environment. For example in order to enable sexual reproduction moonlight is necessary. In the actual design, participants had to think of ways to enable reproduction and the growth of young corals, e.g., by imitating moonlight and designing healthy places to which corals can adhere to. Hence, the learners needed to apply biological concepts.

Throughout the training, the participants identify concepts that are essential for designing a safe and healthy living environment. The following fragments provide some examples:

Design team in their central presentation:
"We focused on the construction of the aquarium. What we need to build it. With respect to the water pressure, we have seen a piece of glass, and man, this was thick (makes a hand gesture to show the size)."

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In addition, the team tells about the various materials that can be used for the windows and that it is important to use calculations to determine the thickness needed.

> *Design team:*
> *Teacher: "We want to know how you know that a shark will give birth because we want to protect the young ones. And how can we transport the pregnant shark to the separation area?"*
> *Expert working in the zoo: "Sharks are not viviparous, but we do have this problem with other marine animals".*

However, after the central presentation, no further learning activities were conducted and important concepts were not further explored. The training session motivated participants to learn about concepts but did not include time and activities to actually gain this new knowledge. At this point one could repeat the movement from the social and concrete domain to the abstract domain, exploring concepts that have been identified earlier. For example, the team who described the materials and thickness of aquarium windows could increase their understanding of water pressure and constructions and end up calculating the exact thickness needed.
In the Oceanium case, the training included the three domains and various fruitful connections. A repetitive continuous movement between the three domains is needed for proper concept learning. Sufficient time for each domain is needed as well, e.g., to study identified concepts thoroughly.

Discussion

The literature study indicates the importance of paying attention to three domains, the social, the concrete and the abstract. The examples from the in-service teacher training show that it is not enough to include each of the three domains individually. Connecting these domains is just as essential and should be repeated. For clarification, a figure (5) below is included to show the continuous movement between the three domains.

The movement improves concept learning and these concepts provide additional heuristic strategies for the development of creative designs. In a rough sense, social context provides the beginning input for the learning process, but in this model the intention is for it to be present throughout the learning process, giving it direction. Educational activities that stimulate learners to empathize with actors from the social context, is a concrete way to achieve this presence. Movement between the first-hand experiences with concrete products and processes and the abstract concepts is part of the model. This involves, amongst other activities, the exploration of theories and concepts that explain the concrete experiences or that are fruitful heuristics in concrete design activities.

The position of the concrete object-element, the concrete experiences with products and processes, is not arbitrary. The concrete domain is situated between the social and abstract domains because products have a dual nature, namely their physical and intentional nature (Kroes, 2002; Broens and De Vries, 2003). The importance of connecting three domains of knowledge is also emphasized by the taxonomy of De Vries (2003), which is also based on the idea that designers have to take the dual nature of products into account.

What can be difficult in concept-context education, is to stop the process when students are creating, but moving away from the original assignment. Teachers may think that as long as the learners are designing and developing, everything is on a good track. In the end this might lead to creative, innovative products and designs but they do not

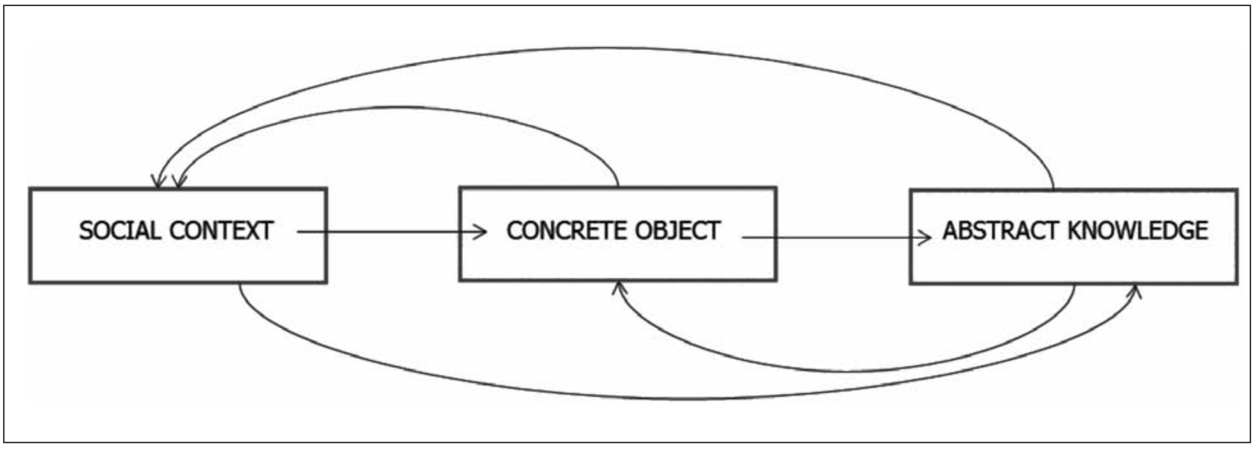

Figure 5. Continuous movement between the three knowledge domains

provide answers to the original question. This is not necessarily a bad outcome, but with the model this messiness of the topic can be safely included in a learning process due to the checks, when moving between the domains. The model allows the exploration of possible wrong paths and this way an opportunity of getting acquainted with the fuzziness of science and technology but at the same time the process is kept under control with constant reflection on the previous activity but equally on the following one.

In any design assignment more than one technological or scientific concept is needed to execute the design process. This requires knowledge from many different concepts, some of them relatively unknown or difficult to the learner. This asks for a flexible use of knowledge of concepts that many trainers regard as above their expertise. This might be a reason why trainers avoid any type of open design assignment or tend to neglect the fact that they have to focus on conceptual knowledge in design processes. However, science and technology education has a good opportunity to introduce learning that happens gradually. With the help of the model the learner builds the knowledge as the process goes on. Therefore, a teacher does not have to have all the answers at hand. The purpose of science and technology education should be to prepare the learner for functioning in a society, in which new technologies and applications keep on emerging with increasing speed. Science and technology education should be about getting away from learning just formulas and abstract theories. The focus should be on providing education in such a way that this ability is given time to develop and become part of the natural way of thinking. Focusing on one concept, as Crismond (2001) proposes, might be a solution, but then the natural characteristics of science and technology as being a messy topic, disappears.

According to our perception, a sort of disorder in learning the concept is in place. Science with its theories and technology with its applications are complicated and therefore, they should be allowed to be learnt as such. One concept is more important and influential in one phase and later, e.g., when finalizing the design or product, understanding of another concept becomes more critical. However, this approach should not be mixed with isolating one concept. Sometimes it is important to know which concept needs attention among many concepts to be mastered. Learning to apply new knowledge and expand existing ones, is applying science and technology into practice, into everyday-life.

Conclusion

Concept-context learning could benefit from more optimal use of practical work on artifacts in the learning of concepts. The three-domain model takes the dual nature of products into account as well as the need to relate practical, concrete experiences to abstract, causal explanations.

One may use the model to analyze existing situations and to develop new trainings that have:

1. A better balance between the three knowledge domains
2. Many iterative connections between the domains
3. Regular checks when moving from one domain to another.

The three knowledge domains were present in the training for primary school teachers and in some cases effectively connected. However, connection between the theory, concrete experiences and the social context need to be more visible and inviting.

By knowing that the teachers have a tendency to go back to the practical explanations and avoid scientific ones, trainers are advised to get frequent information about unclear parts and possible wrong abstract reasoning.

Furthermore, the analysis shows that existing misconceptions were often ignored in the training. As a result, these concepts tend to appear again in other contexts or are combined with the newly provided theoretical information into a new misconception. We suggest using the existing common ideas, misconceptions and practical explanations of the learners as a starting point for teaching and learning.

The analysis also shows how useful connections between the three domains can be realized. Product-evaluation focuses often only on the concrete domain, but is a good 'location' for connecting the three domains. Why-questions and approaching the evaluation from specific needs of an actor stimulates in-depth learning and creativity.

Iterative connections are needed to develop an in-depth understanding of the concepts. Usually different concepts are needed to develop a holistic, in-depth understanding of a specific product. Hence, trainers need to be aware of the complex nature of concept-context learning.

The three domain model is useful in understanding how concepts are related to real-life contexts and to improve the effectiveness of concept-context learning. It emphasizes the importance of moving between knowledge domains and paying attention to connections.

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