Understanding is identifying a structure

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Abstract Understanding means identifying and using a structure. The core of understanding consists in identifying relevant relations between objects, between parts and their relation to the whole that is to be understood. Identifying relations contributes to enhanced understanding since finding more relations makes it possible to understand from different points of view. Understanding is thus closely related to problem solving. To understand involves solving a difficulty, finding out how something works, merging two different viewpoints etc. All of these tasks involve solving some kind of problems. I argue that emotions function as a beacon and play an important role when understanding occurs. First, emotion is used as a cue to identify where there is a difficulty, e.g. if something seems to be ambiguous. Secondly, using emotion as a tool for evaluation, the ongoing process of understanding can be monitored. My arguments are primarily discussed and interpreted in relation to understanding occurring in an educational perspective.

1 INTRODUCTION

Understanding seems to be of fundamental interest to humans. Gärdenfors (2006) claims that humans have an extraordinary ability to seek meaning and want to make things meaningful, even when there is no meaning to find. When things are not meaningful to us and when we do not understand, we feel anxiety and display different forms of stress, both mentally and physically. An example is the result of a study by Bruner and Postman (1949). People were asked to sort playing cards into clubs, spades, hearts and diamonds. In the deck there were also a few unusual cards such as red spades. The cards were displayed for short time intervals starting at 10 milliseconds and were sorted into existing categories. As the exposure time increased, people started to hesitate on how to sort the strange cards. They even expressed feelings of unease, until they realized the existence of strange cards (Bruner and Postman, 1949).

In everyday life we try to make things meaningful, to understand how they are related to each other or how they fit in with what we already know. Understanding is an emotional experience and emotions may function as a signal indicating a difficulty. Understanding is a complex phenomenon described on different levels, from neuronal chemical explanations (Jung Beeman et al, 2004; Bowden and Jung Beeman, 2003; 1998, Mai et al., 2004) to complex cognitive behavior (Mayer, 1992; Marton and Booth, 2000; Köhler, 1969; Wertheimer, 1959). My aim is to find evidence supporting the idea of understanding as identifying and using a structure. Evidence and arguments from a variety of research fields including philosophy, Gestalt psychology, neurophysiology, emotion research and education are presented.

1.1 A philosophical division of understanding: interpretation versus explanation

Von Wright (1971) identifies two sides of understanding. On the one hand understanding concerns the interpretation of something; e.g. to understand, interpret, why John behaved with good manners even though he hated Ben. On the other hand understanding is an explanation of something; e.g. to understand, explain, why the moon is not floating away from earth out into space. The distinction between interpretation and explanation originates from a methodological controversy between the positivist tradition and the anti-positivist tradition. The positivist side claimed that all sciences should be examined using the same method, whereas the anti-positivist side claimed that there must be a separation between sciences trying to generalize knowledge and sciences trying to describe individual and unique features of objects and events (von Wright, 1971). Natural sciences explain things whilst cultural sciences interpret things. Identifying this distinction, understanding as interpretation versus understanding as explanation, provides a first answer to why the concept of understanding is sometimes hard to grasp. For some people understanding is explaining why certain events happened, and for some people to interpret an event is to understand (von Wright, 1971).

1.2 Thesis

The outline of this article is as follows. First I will argue that understanding is the ability to structure knowledge in a domain or a concept into a comprehensible and useful structure. I suggest that when we understand, we are applying a structure that enables us to identify important features of what we want to understand. I will refer to this as our ability to identify relevant relations. These relations should be seen as underlying structures that enable us to organize our knowledge into useful and applicable structures. Understanding, as the ability to organize a knowledge domain into a structure by identifying relevant relations, has a strong connection to problem solving. Facing a problem requires that we know what we are supposed to do, and this means that we have to understand what the problem consists of in order to solve it. I argue that the ability to identify relevant relations and the ability to identify the difficulty in a problem are intertwined. Identifying a relevant relation means that we acquire knowledge of how a certain feature contributes to the whole that we want to understand. However, if we fail to identify a relevant relation, we will at some point encounter a difficulty. The difficulty in a problem will draw our attention to the influence of a certain feature and how this feature contributes to what we want to understand. Realizing the feature of the difficulty will lead to identification of a relevant relation.

Secondly, I will also argue that our ability to understand is affected both positively and negatively depending on our pre-knowledge (that is, all our knowledge which we consciously and unconsciously use when we try to understand a knowledge domain by solving a difficulty in a given problem).

Finally, I propose that emotion functions as a beacon, indicating the presence of a difficulty. Understanding is always accompanied by an emotional factor. The emotion of interest has one interesting feature which claims that what attracts attention is something complex or unfamiliar. This is exactly what we are paying attention to when we try to understand a knowledge domain or to solve the difficulty in a problem. Using emotion as a form of meta-cognitive strategy can provide students with a cue of what to pay attention to when understanding learning material.

I suggest that to understand is to organize a knowledge domain into a structure by identifying relevant relations. This is similar to identifying a difficulty when solving a problem. Understanding is influenced by pre-knowledge, which is all the knowledge we have before we try to understand. Finally, I propose that emotion functions as a beacon by identifying the difficulty to be understood.

2 UNDERSTANDING IS PERCEIVING A STRUCTURE

2.1 The structure

First I turn to understanding, the ability to organize a concept or a knowledge domain into a structure. Gestalt psychology claims that understanding is achieved when relations between objects and events are identified (Wertheimer, 1959; Köhler, 1969). The given in a problem has to be rearranged for understanding to occur (Wertheimer, 1959). If we wish to solve the problem in figure 1, we have to transform the parts into something that we can solve.

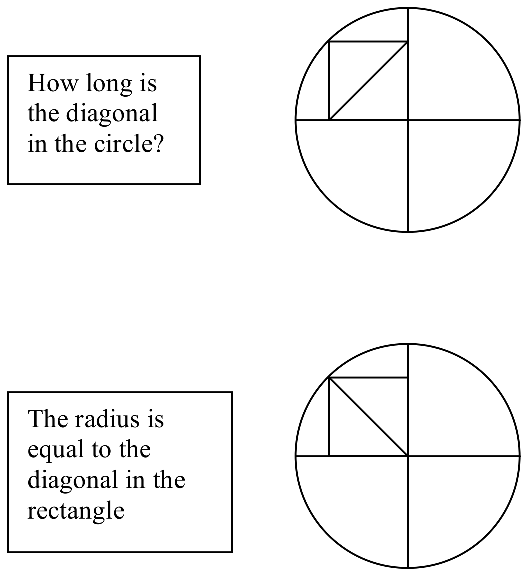

Figure 1. The given in a problem needs to be restructured in order to solve the problem. How long is the diagonal in the circle? The radius is equal to the diagonal in the rectangle.

According to the Gestalt tradition understanding means reconstructing the given into a comprehensible form, thereby identifying relevant links between the different elements. Solving the problem in figure 1 means identifying that the diagonal in the rectangle is the same length as the radius in the circle.

The important features, that enable understanding are related to what Gärdenfors (2006) calls hidden variables. My interpretation is that these variables can be seen as analogues to the relations described by the Gestalt psychologists (Köhler 1969; Wertheimer, 1959). Understanding requires identification of specific relations or hidden variables and realizing their significance, e.g. realizing that the diagonal in the rectangle is the same as the radius in the circle in figure 1. To gain insight is to move from a state of relative confusion to one of comprehension (Dominiowski & Dallob, 1995). One difference between understanding and insight is the time frame.

An aha-experience can occur while solving an insight-problem. The insight-solution has three characteristics (Bowden and Jung Beeman 1998; 2003; Jung Beeman et al., 2004; Knoblich et al., 2001; Jones, 2003; Mai et al., 2004). First, the problem solver reaches an impasse. Secondly, the problem solver does not know what to do to overcome the impasse. Thirdly, an obvious insight solution is suddenly revealed (ibid.). Selz proposed that insight occurred when a problem solver filled in a gap in the structural complex (Mayer, 1992; 1995, Murray, 1995). The core concept of understanding is to put bits and pieces together to create a comprehensible structure. Bruner claims that understanding is realizing how an idea or a fact is related to a general knowledge structure. When we understand we create a general knowledge structure (Bruner, 2002)

Greeno (1977) describes a close relation between problem solving and understanding. He suggests three criteria for achieved understanding: coherence, correspondence and connectedness. Coherence refers to useful representations of the problem at hand. Correspondence means that the representation and the object of the problem should bear a resemblance to each other. Connectedness refers to how well the understood object is related to other knowledge acquired by the individual. Understanding has internal and external features, and Dominowski and Dallob (1995) provide a couple of examples. An external aspect is to use an analogue to facilitate understanding. An internal aspect concerns the relation between the components of an entity and how the parts constitute the whole, e.g. to understand a sentence requires knowledge of the meaning of the word, the syntax etc. (ibid.). Further examples of how thinking can influence understanding and the ability to solve problems are presented by Mayer (1992) who refers to different ways of conceptualizing what thinking is, e.g. thinking as an effort to find meaning, thinking like an expert etc. (ibid.).

2. 2 Relations

I suggest that understanding is organizing by using a structure. Organizing involves seeing, identifying and realizing the importance of different kinds of relations; between parts in relation to the whole and between parts making the whole. For example, to understand an ecological system one has to understand how animals and forests contribute to the balance, but also how different animals and species affect each other and how the relations affect the ecological balance. Furberg (1981) states that one fundamental thought in Dilthey's philosophy is that what is to be understood are *"hidden connections."* This idea has similarities to what Gärdenfors (2006) calls hidden variables, which are the building blocks in patterns used to understand. Gestalt psychology also claims that seeing and identifying relations between objects in the world is essential for understanding (Katz, 1942; Wertheimer, 1959; Köhler, 1969). These examples provide evidence that understanding requires structure in order to occur and that the essential feature of understanding is the ability to identify relations.

Pestalozzi was one of the first to point out the beneficial educational relation between theory and practice (Svedberg and Zaar, 1993). The father of *"learning by doing,"* John Dewey, acknowledged that children have to understand what they are doing. Dewey saw the problem of industrialization at the beginning of the twentieth century and the subjects taught in school. Before, children had learned and explicitly/implicitly understood the relation between production and consumption in the society. During industrialization this relation became invisible to the user of the product (Dewey, 1980). Dewey described this as the invisible society. He believed that school had to be organized in such a way as to make these connections visible again. To accomplish this, Dewey started schools where children had to learn by doing things. He claimed that this was the only way children could understand society and production. Children learned to contribute to the production of stock; they became skilful in a practice and by trading their goods at the market they learned news from around the place. The thoughts of Dewey and Pestalozzi are illustrative examples of the necessity of making learning material meaningful and the importance of identifying relevant relations. The idea of identifying relevant relations in order to understand is present at all levels of understanding, e.g. identifying relations between theory and practice as well as identifying relations between parts in a theory.

Köhler (1969) says that when we are trying to solve a problem we have some facts, the given material with which we are supposed to solve the problem and the given situation containing the problem. He poses a question which describes what it means to be able to understand. *"How must we change the situation so that the difficulties disappear and our problem is solved?"* (Köhler, 1969). Köhler clarifies that what is *"given"* is not simply available in the same way to all persons. He says that the material is constituted in such a way that only those who are acquainted with it can fully benefit from the material. Köhler claims that productive thinking involves a subjective awareness of relations (Wertheimer, 1959). When people look around in the world and think about things, they are aware of certain kinds of relations, e.g. distance relations, semantic relations etc. In a given problem, when we at first are not capable of seeing these relations between the "given," we cannot solve the problem. In order to solve the problem one has to find the relation providing the key to the solution path. Relations are sometimes difficult to find since they are abstract and consist of sets of relations, e.g. relations within relations (Köhler, 1969).

This section has provided initial evidence that understanding requires different forms of structures. In the following section I will describe how structures for understanding are related to problem solving.

2. 3 How is problem solving achieved?

Understanding can be analyzed on different levels as described earlier. Understanding is the ability to apply and generalize knowledge in an appropriate and creative way. An example is to understand how to bake a blueberry cake; for one person it refers to the ability to follow a recipe, for another person understanding is the ability to know how different ingredients chemically interact with one another, thereby giving the possibility to improve his or her blueberry cake.

I am primarily concerned with understanding in the context of education. In educational settings there are often problems to solve, e.g. finding a mathematical formula or finding arguments for a solution in an ethical discussion. Understanding is problem solving. Dominowski and Dallob (1995) consider that what constitutes a problem is *"a difficult or perplexing situation."* When trying to understand a concept or a knowledge domain there is often some aspect that is difficult or problematic to grasp, and this has to be resolved in order for understanding to occur. As I will demonstrate below, emotions may play an important role in identifying these difficulties. Dominowski and Dallob (1995) further describe problem solving as reaching a goal, but the means to reach the goal are not clear. To understand a concept like democracy, to realize how the market for crops affects society in the third world, to comprehend the relevance of an historical event or to have a sudden insight when solving a mathematical problem are all related to an organizational activity by our brains. The origin of understanding is the result of identifying a difficulty and solving it. The difficulty arises from the fact that we do not yet have the key to decipher and interpret the underlying structure for the concept or the knowledge domain. Understanding involves making the difficulty meaningful in order to feel satisfied and not stressed and anxious.

2.3.1 Following a plan

According to Hayes (1989), problem solving involves transforming a given situation into a desired situation or goal. Solving a problem includes having a representation with a description of the given situation, operators or actions to change the situation and finally a test to determine whether the goal is reached. The problem space is searched in order to find situations that satisfy the test. The problem space is usually very large and thus we need to have a good strategy in order to solve the problem within an acceptable period of time.

2.3.2 Polya's four steps

Polya (2003) suggests four steps to solve a problem. He claims that first one has to understand the problem, which means that one has to find out what has to be done. This is exactly what one will do when trying to understand a domain, finding out the problem by identifying the difficulty. Secondly, one has to make a plan. This refers to analyzing bits and pieces in order to find out how they are related to each other. Thirdly, one has to carry out the plan, which means testing the implications of the relations identified in the previous steps. This also involves verifying the plausibility of the relation and thus also whether the domain is understood. Fourthly and finally, Polya suggests looking back at the solution to be certain that it is a correct solution and to think about how to use it later. A corresponding activity is to relate what one has understood to other domains. I interpret Polya's steps as a hermeneutic approach to gaining understanding. Understanding as problem solving fits very well with subject domains specified in education, e.g. understanding how to solve the area of a rectangle is a special problem that needs to be described in its context; students have to identify the constituents and strategies to apply the formula of a rectangle and to evaluate the result.

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2.3.3 Heuristics

Heuristics in problem solving are general plans of actions or strategies exemplified by rules of thumb or short cuts (Mayer, 1992). A specific heuristic is called means-end analysis. The purpose is to evaluate the difference between the initial state and the goal state, and to diminish the difference. When differences are eliminated the problem is solved. A classic example is the tower of Hanoi, figure 2.

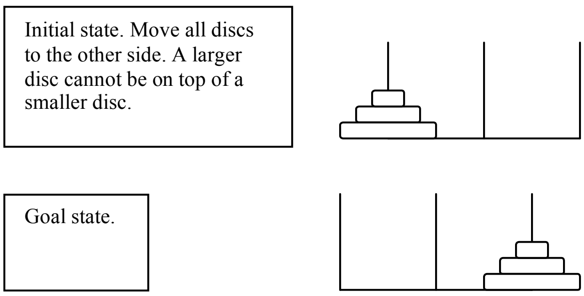

Figure 2. The tower of Hanoi.

The task is to move one disc at a time from one side to the other with the restriction of not putting a larger disc on top of a smaller disc. This strategy is used to describe overcoming impasses in insight solutions (MacGregor et al., 2001). An insight solution to a problem is characterized by a sudden understanding of how to solve the problem and is accompanied by an aha-feeling (Bowden and Beeman, 1998). Means-end analysis is a plausible explanation for how understanding is achieved. Understanding occurs when differences separating the initial state from the goal state are removed one by one. When insight occurs, all differences are removed at the same time, thereby evoking the sudden insight solution.

2.3.4 Heuristics in judgment

When people try to understand a difficulty in a problem they constantly try different strategies. Strategies for judging are chosen by how well one believes they will fulfill a goal. Tversky and Kahneman (1992) investigated what contributes to our beliefs. They found that people use a limited amount of heuristic principles, which often are very useful but sometimes lead to error. They describe a couple of features that govern how people make judgments. Probability estimates are one feature used for uncertain judgments. A probability estimate is an approximation of how likely something is. A common feature is to use representativeness, for example to evaluate how well a penguin or an ostrich are representatives of birds. Availability is another feature people use for making judgments under uncertainty. It is a feature characterized by how well a cue or a feature can estimate the frequency or the probability of an event. Both representativeness and availability can be used to draw inferences about relations.

2.3.5 Hermeneutic circle

Understanding is a process continuously changing over time. There is no final state resulting in divine insight to all knowledge. Recall the example of baking a blueberry cake. Early in the learning process of baking a cake, understanding involves the ability to follow a recipe. At a later point, understanding consists in profound knowledge of how adding a certain ingredient will enhance the taste of the blueberry cake. Understanding requires the ability to identify a relevant relation in a domain, which provides the possibility to understand more complex aspects of the domain. Gaining new knowledge requires going back and forth between hypotheses and the material until a fit is achieved (Føllesdal, 2001). The fit between the hypothesis and the investigated material must be suitable both for the whole and for the parts of the investigated material. The interpretation of the material is always affected every time a new viewpoint is considered. This is called the process of the hermeneutic circle. The fluctuation between the whole and the part is one part in the hermeneutic circle. According to Føllesdal (2001) there is a question-answer circle and a subject-object circle as well. He describes these circles in relation to the interpretation of texts. However, I claim that these circles can be applied and used for describing what happens when understanding occurs. The question-answer circle can be applied to understanding a knowledge domain, like the French revolution, and changes occurring as we gain more understanding of the material. In the same way as an interpretation changes when a text is studied, the same occurs with understanding.

I will now turn to how the hermeneutic approach can be used in an educational setting with the help of technology, and especially so-called pedagogical agents. For example, a pedagogical agent is an animated figure that is part of a learning environment helping students in various ways by pointing, providing feedback, offering information etc. Studies with teachable agents have concluded that students gain more understanding when teaching their agent by using questions to test their knowledge and revising the agent's knowledge (Leelawong et al. 2002). The same idea is present in Socrates' dialogue method. By asking and defining what is meant, the person gains more and more understanding of his thoughts, and the consequences of his arguments. My interpretation is that there is an underlying structure present organizing and enabling refined understanding. If an underlying structure did not exist, we would have difficulties organizing all our knowledge in a meaningful way. We would most certainly be frustrated and confused. If an underlying structure exists, confusion would not be the case but understanding would be refined, since the structure of understanding facilitates combining information into meaningful chunks.

2. 4 Creative thinking

Creative thinking is often used to solve insight problems, e.g. to see novel relations between existing knowledge or to examine information in an unusual way (Wertheimer 1959). Bowden and Jung Beeman (1998) describe two components involved in insight problem solutions. First, there has to be an activation of relevant information in order to solve the problem. This would correspond to searching for the adequate pattern to understand the problem. Secondly, the problem solver must be able to recognize the solution (ibid.), which would correspond to identifying relevant variables and important relations among the objects to understand.

Bowden and Jung Beeman (1998) argue that when people solve insight problems they use creative thinking since the solution of the problem usually requires an unusual application of something known, e.g. in the box-candle problem, subjects are asked to attach a candle to the wall without it dripping wax on the table (Dominiowski and Dalob, 1995), figure 3.

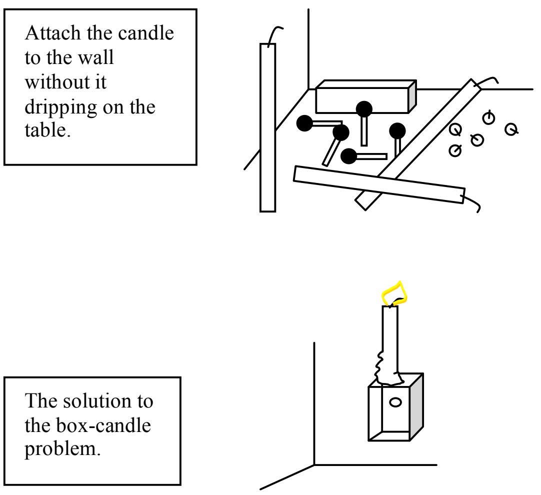

Figure 3. The box-candle problem.

Materials to use are three candles, matches, pins and a matchbox. The solution is to use the box as a platform. Creative thinking has been located in the right hemisphere. Since insight solution is based on retrieval of unusual interpretation of information. Bowden and Jung Beeman (1998) assumed more activity in the right hemisphere. The right hemisphere is involved in coarse semantic coding while the left hemisphere is involved in fine semantic coding.

An example to confirm this dissociation comes from people with right or left hemisphere damage. When people with right hemisphere damage are presented with words they focus on the meaning, that is, the denotation of the word (Brownell et al. 1984). People with left hemisphere damage focus on the metaphoric interpretation, the connotation of the word (ibid.). Bowden and Beeman (1998) argue that if diffuse semantic activation occurs in the right hemisphere this might help to solve verbal insight problems. Activation in the left hemisphere is more sensitive to misleading information. If the search field is focused on an incorrect interpretation of the problem at first, it is difficult to find a new interpretation. This means that it is more likely to come to an impasse if the initial representation is incorrect. My interpretation is that there might be an underlying structure guiding attention to common interpretations of words. When insight occurs a more unusual relation is identified.

Bowden and Jung Beeman (1998) claim that an unconscious process might be necessary in order to solve insight problems, since an impasse is overcome by activation of the right hemisphere. This would correspond to the fact that not all necessary variables or hidden connections have been identified. A study by Bowden and Jung Beeman (2003) found that, when subjects solved insight problems, activation was stronger in the right hemisphere than in the left hemisphere. When subjects did not solve the problem there was activity in the right hemisphere, but not in the left hemisphere. Bowden and Jung Beeman concluded that an unconscious process contributes to the insight solution. Right hemisphere activation helps insight solution since it corresponds to a wider search for different interpretations of the target word. The task in the experiment is to find the unusual interpretation of a mutual word and the right hemisphere that corresponds to coarse semantic coding does this.

The task in the Mai et al. (2004) study was to solve Chinese riddles. Difficult riddles were supposed to evoke insight solution whereas the easy ones were used as control. Subjects were presented with a riddle and a word was displayed afterward. Subjects had to respond whether it was the correct word or if the word was unrelated to the riddle. Riddles evoking aha-solutions took 2.2 seconds and riddles evoking no-aha solutions took 0.9 seconds. Mai et

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al. claim that this indicates that it takes longer time to understand a new interpretation of the word. This seems to be a plausible explanation since a relation which is not obvious needs more time to be analyzed, especially if other more characteristic or available relations are examined primarily.

In this section I have argued that understanding is solving a problem by identifying a difficulty. When understanding occurs the difficulty is solved. I have provided examples of how the difficulty can be solved and how different steps are related to the idea of understanding as organizing in a structure. Understanding expressed by creative or productive thinking provided some neurophysiological evidence that activation in specific areas contributes to understanding. The next section gives examples of successful organization by experts and how this differentiates from the way novices organize their knowledge.

2. 5 Differences between expert and novice understanding

An expert has acquired certain skills that a novice has not. Experts have vast knowledge and they know how to use it and when to use it, and they do this rather effortlessly compared to a novice who does not yet possess these skills. Several key points are suggested as to what differentiates an expert from a novice (Bransford et al., 2000). Experts are much better than novices detecting important features and locating meaningful patterns. This corresponds to identifying relations. A classic example is DeGroot's (1965) study of how chess players comprehend chess configurations. DeGroot found that chess masters identified meaningful patterns of chess configurations and that they could evaluate the implications of the configurations, thus making a more suitable and a better thought-out move. Chase and Simon (1973) conducted a similar chess study where actual board positions and random board positions were presented to novices and experts. They found that experts could remember more pieces from the actual board positions than novices could. In the random board condition both novices and experts recalled equally poorly. This corroborates that understanding involves organization in a structure. These examples clearly demonstrate that understanding requires identification of specific features, which is the ability to identify certain relations. The examples also show the importance of making a concept, e.g. board positions, meaningful for understanding to occur.

Miller (1956) found that humans could only hold a limited amount of information in short-term memory. An expert chunks information in meaningful structures. Novices do not yet posses this skill since they lack the overall hierarchical structure (Bransford et al., 2000). This means that novices have not yet acquired a stable structure of the knowledge domain. A crucial feature of being an expert is the ability to organize knowledge into meaningful entities and to identify relevant representations of problems (ibid.). The expert's knowledge is built around core concepts in a way that a novice's knowledge is not. Bransford (2000) describe a study by Chi et al. (1981), where they examined how experts and beginners in physics verbally described how they would solve a problem in physics. Chi et al. found that experts usually described the problems in relation to core concepts or physical laws. Experts can also provide an explanation of why they would use the principle in question (Chi et al. 1981). Larkin (1981) found that novices seldom referred to physical laws or general principles; instead they described which equation to use and how they would solve the equation practically. Findings from research on experts support this view that understanding is related to organizing knowledge into meaningful patterns. I also claim that understanding means that one can apply knowledge in thoughtful way and that the ability to generalize has developed. This is also what has been shown with experts. They have the ability to conceptualize a problem into meaningful, comprehensible and informative chunks. Novices use fragmented knowledge, for example, they try to find a relation between the problem representation and an applicable equation they are familiar with, instead of analyzing the problem in terms of general principles.

Experts have a lot of knowledge. To solve a problem they only use a relevant part of their vast knowledge. Experts have learned what kind of knowledge is relevant in certain kinds of problems. The term for this kind of knowledge is "conditionalized," which means that knowledge includes a specification of the context in which it is useful. This extra "tag" is very useful for experts since they can use only the relevant part of their vast knowledge. A drawback is that conditionalized knowledge has to be conditioned by the right cue; for example if relevant knowledge is associated with chapter 4 in the Math Book instead of a general principle of geometry, this is obviously a wrong cue.

Bransford (1979) (in Bransford et al. 2000) describes how students who worked with well-structured working sheets and did well on those assignments were negatively surprised when they did tests that were not based on a well-structured form. Students thought that they had learned very

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well but in fact they had not. Due to educational misfortune they did not manage to conditionalize their knowledge. A useful method to conditionalize the applicable knowledge is to use meta-cognitive strategies. The ability to conditionalize seems to be an important factor in explaining why transfer does not occur. For example, if knowledge is "marked wrong" then we will not be able to use it accurately. Fluent retrieval is another essential characteristic of expert abilities since it reduces the pressure on conscious attention. Humans have a limited capacity to process information (Miller, 1956) and if pressure is reduced there are more resources that can focus on the object to understand.

This section provided examples of differences existing between an expert and a novice. The main difference is the ability to organize the knowledge domain by meaningful structures and to know which part of the vast knowledge is relevant. The next section will describe the role of pre-knowledge for understanding.

3 PRE-KNOWLEDGE

3.1 Pre-knowledge—a starting point

Köhler said that *"...some previous learning is often needed not only for the solution of a problem but also for its understanding as a problem"* (Köhler, 1969). To organize an unclear or ambiguous difficulty into something comprehensible, which means understanding, requires some form of previous knowledge. Pre-knowledge is important for it is the origin of understanding. Pre-knowledge can facilitate identification of the underlying structure necessary for understanding a domain. Socrates pinpointed the importance of pre-understanding, which is what one knows before trying to understand something. As stated previously, understanding involves a process of modifying and identifying what is unclear into a clear whole.

Husserl said that all our experience, including interpreting a text, *"is imbued with meaning: there is always a web of anticipations involved.... They form a horizon, a background..."* (Føllesdal, 2001). I interpret anticipation as a form of pre-knowledge, a platform from where the process of understanding originates. Gadamer further emphasized this idea and he called these anticipations fore-structures or fore-meanings (ibid.). Another example of how this idea of the influence of pre-knowledge is represented in research literature comes from insight studies. An explanation why impasse in insight occurs is that the person holds an initial representation that is misleading (Knoblich et al., 2001). For example, a person interprets a bucket as something you use for carrying a substance, and then suddenly realizes that it also could be used as a pendulum when tied to a rope (figure 4).

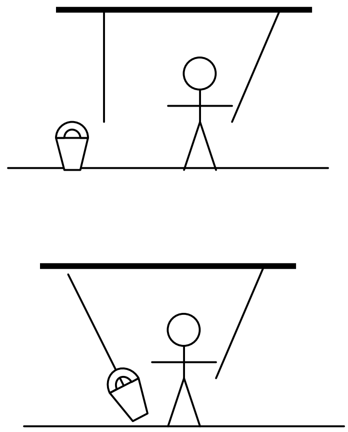

Figure 4 The use of a bucket as a pendulum instead of something to carry a substance or a fluid in.

This idea of anticipation and what kind of knowledge an individual already possesses or has knowledge of, is essential to consider when trying to describe what understanding is. The criterion of understanding (according to Føllesdal, 2001) is the *"fusion of the horizons."* I interpret the fusion of horizons as a process establishing the structure underlying understanding. Fusing the horizon involves incorporating parts summing up the whole. This means identifying relevant relations and applying the structure of understanding in a domain. Gadamer argued that we could only interpret our world and ourselves within our own horizon from the past. The horizon determines what kinds of questions and concepts we have available. Understanding an unfamiliar text involves a melting of the horizons and as a result our horizon is changed. The horizon is thus the border of pre-knowledge. The notion of horizon seems to be related to Vygotsky's zone of proximal development (Lindqvist, 1999; Vygotsky, 2001) in that it is transformable and is influenced by pre-knowledge.

According to Furberg (1981) two conditions have to be fulfilled for understanding. The first condition is called the subjective empathetic condition, which means that in order to understand *x*, e.g. how a car works, one has to have some form of experience, knowledge or opinion about, e.g. pre-knowledge about what a car is or how cars are useful. The second condition is called the objective empathetic condition, which means that in order to understand how a car works, it has to be conceptualized in a way familiar to the person, e.g. by describing a car as a machine etc. When these conditions are combined into one statement, it can describe why people seem to understand when they in fact do not. If *x* is something one cannot recognize, one has not understood. If *x* is not described in a manner familiar to the person, one has not understood *x* (Furberg, 1981).

Mayer et al. (2002) investigated how pre-training affected understanding and transfer. They wanted to test a two-stage mental model construction based on previous work by Bobrow (1985, in Mayer et al., 2002) The first stage is that the learner builds a component model of the system; in the study they used a braking system for a car. Secondly the learner builds a causal model of how the parts are related to one another. Both kinds of knowledge are present in a paper presentation as well as in a computer animation. However the researchers argued that it is likely that the learner will be overloaded with information and thus cannot grasp the component knowledge or the causal knowledge about the system. By letting some of the participants receive pre-training on the component model of the braking system, the learner had the opportunity to pay attention only to the causal explanation that was presented conjunctly. Mayer et al. (2002) found that participants receiving pre-training scored significantly higher on retention tests and on transfer tests. The effect size in both conditions, paper-based version and computer animation, were large, 0.91 and 1.54. This study provides an example of the positive effect of pre-training. The pre-training is used as a form of pre-knowledge for understanding and also facilitates transfer. Providing a student with decomposed learning material seems to increase the possibility for understanding to occur.

The previous examples provided support for learning different parts first and then merging them to an understandable whole. Mayer and Jackson (2005) conducted a study where they investigated how quantitative details, such as formulas, affected qualitative understanding, that is, the ability to form a mental model of a domain. They found that by adding quantitative details such as formulas to an explanation of ocean waves, learning was influenced negatively. They wanted to test the *coherence principle,* which is based on the cognitive load theory. The coherence principle is that people learn better when extraneous material is excluded than when it is included in a multimedia lesson (Mayer, 2001). Mayer and Jackson (2005) point out that when an inexperienced learner apprehends material and builds a model, it seems to be more fruitful to provide qualitative information rather than quantitative details such as formulas. This study is an example of advocating that learning is increased when the overall structure is present first and then details such as local features or formulas are added. One should bear in mind that this is only one study and there is some truth in both stories. There might be individual features that favor the-part-to-the-whole approach of learning whereas other individuals favor the-whole-to-the-part approach. But as Mayer and Jackson (2005) suggest, it would be interesting to find out which way is more fruitful, adding quantitative details first or after a qualitative mental model has been built, or if both features should be present at the same time.

3.2 Misunderstanding

According to Husserl, anticipations are unconscious, which is a great challenge to hermeneutics, because they can shade our understanding without us knowing it, e.g. if I understand that the earth is spherical and at the same time I have an understanding of a theory claiming that earth is flat, I will at some point in the future be faced with an inconsistency. Gardner (2000) claims that misunderstanding occurs because students have naïve notions and even though they have years of education they still retain their naïve notions of a domain or a concept.

There are positive and negative effects of pre-structures. If a person believes that the earth is flat, this will lead to confusion when apprehending domains that do not have the same assumptions about the world. Awareness gives yet another dimension to understanding. We are not a tabula rasa when we understand a new knowledge domain. My argument is that there is always some kind of pre-knowledge present. Even though we are unfamiliar with a knowledge domain, there is nearly always an opinion about the domain; e.g. it is difficult to comprehend quantum physics; a feeling, e.g. the subject of particles seems very interesting; a judgment e.g. “Why should we understand the demands of the market? It is useless to know anything about ancient European history”, etc.

3.2.1 Inappropriate or misleading representations

Knoblich et al. (2001) presented the representational change theory of insight. They claim that insight problems cause impasses because they mislead problem solvers into constructing inappropriate initial representations of the problem. An impasse occurs when a problem solver reaches a point where he or she does not know how to solve the problem and thus does not understand how to proceed. Insight occurs when the initial representation is changed, thereby causing the aha-effect. According to Knoblich et al. there are two problems to solve concerning impasses. First, why

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do impasses occur when individuals have sufficient knowledge to solve the problem? Secondly, how are impasses resolved? They claim that their theory can answer both questions. Earlier theories have just explained one or the other problem. Some explanations for the first question are functional fixedness, mental rut and Einstellung. Functional fixedness refers to the fact that we are used to interpreting the functional meaning of a familiar object and therefore are not able to see different uses of the object. Mental rut refers to they way we tend to go over the same path again and again, thereby adding more and more activation to this solution strategy. Einstellung means that if we find one strategy we do not look for another one. Answers to the second question, how we overcome an impasse, include the Gestalt theory of reorganization. Another interpretation is that the impasse is not caused by misleading representations, but due to incompleteness of the initial representation (Kaplan and Simon, 1990).

Bowden and Jung Beeman (2001) conducted an eye-tracking study of people who solved matchstick arithmetic (figure 5).

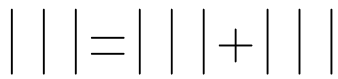

Figure 5. Matchstick problem.

They predicted that when subjects encountered an impasse fewer eye movements would be registered because the subject would not know what to do and thus stare at the problem. They also predicted larger time allocation of eye movements in the initial representation on the values than on the operators. The duration of the fixation would indicate different types of processing. The results supported the theory. Using eye tracking to investigate what people look at when solving a problem can lead to interesting findings about the development of understanding.

Mai et al. (2004) describe insight as the process from not knowing to knowing. They claim that the difficulty in solving insight problems is that the task makes us focus on inappropriate parts of the problem. If the mental fixation can be broken, the result is insight. They further claim that insight is a complex process involving a cognitive conflict between the right thought and the wrong thought and a conscious meta-cognitive process acknowledging when we realize the error. Support of conscious awareness when we realize something comes from Eriksson et al. (2004). In their study they showed that different brain areas are involved in conscious identification of an object and in sustaining the perception of the object in mind (Eriksson et al., 2004).

3.2.2 Illusion of knowing

Illusion of knowing (Glenberg et al., 1992) may be another explanation of misunderstanding. An illusion of knowing is defined as a belief that comprehension has been attained when, in fact, comprehension has failed. Glenberg et al. describe the illusion of knowing as a failure to identify a contradiction concerning facts in a presented text. Subjects read a text including a key passage which contained a contradiction. This contradiction appeared early, intermediate or late in the text. Subjects had to rate how well they comprehended the text. Subjects rated their comprehension after reading a passage containing a contradiction. The illusion of knowing was defined as rating the material with the contradictory as comprehended (ibid.). The results indicate that the illusion of knowing was more frequent when the contradictory sentence was presented late in the text. The illusion of knowing occurred even though the subjects were instructed explicitly to look for contradictions in the text.

When subjects read the text with the contradictory passage they claimed high comprehension, but they did this without noticing the contradiction. An interpretation is that subjects have not yet identified relevant relations. When reading a text each passage is understood as an isolated chunk of information. In order to detect a contradiction subjects need to identify what is relevant. If subjects fail to identify and comprehend the whole, the content of the text, they might easily miss the contradiction since they just interpreted the sentence in isolation without a relation to how it constitutes the whole, the entire text. Glenberg et al. argue that the syntactic structure might fool some subjects because the contradictory information is presented in a form that indicates new information. It is also possible that the subjects tried to make a coherent comprehension of the text, but they used a low level, analyzing sentence by sentence, when a high-level approach, analyzing the whole text, might have been more successful.

It also seems as if subjects have a “default assumption of comprehension,” which means that understanding is assumed to occur unless there is a signal of error (Glenberg et al. 1992). An example of a signal of error is when one is reading a text and there is an unknown technical term presented without an adequate explanation. I suggest that it is useful to use meta-cognitive strategies, e.g. using an active hermeneutical circle by asking questions,

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discussing the issue and explaining in order to enhance learning and understanding. Glenberg et al. pinpoint that it might be most difficult to identify a contradiction, a difficulty, when reading some completely new material, which means that the illusion of knowing is an obstacle to effective learning and instruction (ibid.).

This section has described the influence of pre-knowledge on understanding. Pre-knowledge was also described in relation to misunderstanding. Different ideas of what constitutes misunderstanding, such as inappropriate, misleading representations or illusions of knowing, have been presented. The ability to monitor the detection of a difficulty is important and suggests that meta-cognitive strategies are important. In the next section meta-cognition is described and the role of meta-cognition for understanding is discussed.

4 META-COGNITION

4.1 Different aspects of meta-cognition

Flavell (1979) investigates meta-cognition from a developmental perspective and divides it into four constituent parts; meta-cognitive knowledge, meta-cognitive experience, goals and strategies. Meta-cognitive knowledge refers to the person, for example the cognitive abilities of the person, the task at hand, how familiar the person is with the task and the strategies to be used (Flavell, 1979). Meta-cognitive experience can be an experience at some point in the process of solving a problem, for example a feeling of being able to solve a problem. Paris (2002) describes two forms of stimuli for meta-cognition: thought initiated by oneself and by others (ibid.). Self-initiated meta-cognition originates from either a pause in thinking, due to identification of a difficulty, or when we think how others see us, e.g. if something is problematic or if a friend makes a negative remark about our ability to solve a problem. As stated previously, understanding involves solving a problem and an important feature is the ability to identify what is problematic. Paris (2002) says that: *"uncertainty and confusion lead us to monitoring the meaning of our understanding."* The other self-initiated meta-cognition is related to our self-representation to others. For example "Does she think I am smart, clumsy or bright?" The cognitive perspective on meta-cognition has studied the consequences of monitoring one's own knowledge. Meta-cognition is divided into monitoring and control. Monitoring involves evaluating one's own knowledge. Control refers to regulation of behavior (Flavell, 1979).

At certain points in cognitive processing, meta-cognitive abilities are helpful, but there are also situations where meta-cognition can be debilitating for cognitive processing. Paris (2002) suggests three situations where the use of meta-cognition improves thinking, leading to better ideas, decisions and actions. First, Paris claims that meta-cognition is important when people learn new skills. If a child is learning a new task, he or she has to learn the goal of the task, which are the useful strategies to apply, how the task can be decomposed into comprehensible pieces and so on. Understanding a new concept or a new knowledge domain should thus benefit from using meta-cognitive strategies. A second situation when meta-cognition is helpful is during instruction, since the teacher needs to know how to present a vast amount of material in comprehensible chunks, which in the end can be interpreted as constituting a whole. Paris's third situation is that meta-cognition is useful when people are troubleshooting. This is a suggestion I will get back to when discussing the role of emotions for identifying difficulties.

Meta-cognition can have a negative influence on self-evaluation. People may think they lack the ability necessary for solving a certain kind of problem. A common example is a student who wants to succeed in school and values this highly, but fails repeatedly (Paris, 2002). This leads to a negative self-evaluation. Other examples of when meta-cognition has a negative influence are obsessive thinking and delusional thinking, e.g. if a student is to complete a task which involves critical thinking and the student does not know how to begin or structure the task, the frustration can be an obstacle to doing anything at all (ibid.).

4.2 Meta-cognition and conscious awareness

One group of researchers claims that all meta-cognition requires conscious awareness. The other group claims that only some meta-cognitive abilities require conscious awareness. When people select which strategy to use they are influenced by two meta-cognitive processes, monitoring and control. Siegler (1987) shows that children use and change strategies that give the best result concerning speed and accuracy in the task. Children choose fast strategies to solve a problem if the strategy yields the correct result, and they choose a slow strategy to solve a problem when a fast strategy yields an incorrect answer and the slow strategy yields the correct answer. Cary and Reder (2002) investigated whether children chose strategies consciously or unconsciously. Previously research indicates that people tend to choose different strategies in a given problem and in

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similar problems occurring later. People use different strategies and they adapt to the situation.

An example of adaptation comes from Reder and Schunn (1999), who investigated how air traffic controllers adapted to changing factors in the environment. Air traffic controllers directed planes to either a long or a short runway. If the plane was a 747 it had to use the long runway. When there were few planes the air traffic controllers used both runways. To test the air traffic controller's ability to adapt, researchers manipulated the amount of 747's in the incoming rate. The result supports that subjects adapt their behavior to the share of 747's. This would thus be a proof of when meta-cognition is used but the subjects are not aware of the underlying factor governing their behavior.

This section described different aspects of meta-cognition and when it is useful or debilitating. Meta-cognition and consciousness were described briefly.

5 EMOTION AS A BEACON

5.1 Signaling what needs to be attended to

Understanding involves problem solving and I shall argue that emotion functions as a beacon. First, emotion directs attention to the difficulty. Second, by identifying a difficulty there is a possibility either to change direction or to improve the situation. In *The MIT Encyclopedia of the Cognitive Sciences* emotion is defined as *"a psychological state or process that functions in the management of goals."* Emotions are positive when the goal is achieved and negative when a goal is hindered. According to Frijda (1986), *"The core of an emotion is readiness to act in a certain way."* Silvia (2005) described how interest is an emotion related to appraisal of novelty and appraisal of coping potential. Appraisal of novelty refers to things that are unfamiliar or complex and appraisal of coping potential means the ability to understand the new, complex thing (ibid.). Trying to understand something, we usually pay attention to the difficulty or to what seems problematic, and often when trying to understand we are interested, no matter what our motives are for understanding. I propose that when we encounter a problem there is an emotional signal telling us that we need to pay attention to the problem. The problem is often something unfamiliar or complex (Silva, 2005) attracting interest and attention to it. The feeling of not being able to identify the problem and solving it may cause an emotional response that can be either positive or negative. Bless et al. (1996) describe how people in happy mood are more likely to use heuristics, use scripts, and follow schemas (Gasper and Clore, 2002). If there is a positive emotional response when finding a problem, these strategies are used for finding the solution to the problem. If there is a negative emotional response research has revealed that people focus more on local elements and rely on more effortful problem-solving strategies such as examining data more thoroughly (Clore et al., 1994). Different moods may also explain why the illusion of knowing occurs. Since it seems as if people do not interrupt the processing of information as long as there is no signal of error, when you read a text and you think that you understand it, this may be equivalent to processing information in a happy mood. That is, people rely on an overall schema of consolidating information about at domain. Since there is no indication of error or problem, there is no need to allocate processing resources to examine something that is thought to be correct, comprehending the text correctly, for something to be mistaken, that is, the fact that the text is not understood.

Harp and Mayer (1997) investigated whether adding emotional interest or cognitive interest to scientific learning material increased learning and understanding. They present the term emotional and cognitive interest that Kintsch coined in 1980. Emotional interest is based on the belief that adding interesting but irrelevant material to a textbook lesson energizes learners so they will pay more attention and learn more overall because they will be more curious and the arousal will influence cognitive abilities (ibid.). Cognitive interest is based on the belief that a scientific passage will be more interesting when it is understood. Adding summaries and highlighting key-points are features of cognitive interest. Harp and Mayer found that both retention and transfer were affected negatively when features of emotional interest were added to the text. The results show that features of emotional interest, such as adding interesting but irrelevant text and pictures, did not improve the understanding of scientific explanations (ibid.). Researchers argue that emotionally interesting features take away the attention necessary for building causal models of the scientific explanation and that features of cognitive interest are more helpful for learners since they enjoy the material more when they understand it. This corroborates that understanding requires organization since features of cognitive interest were more helpful than adding features of emotional interest to a learning material. This is a limited example and experiment but it suggests important aspects of the design of learning material. As Dewey (1980) argued, a learning experience must be organized in order to be educative; not just any experience will do and an experience can be

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miseducative if it distorts further growth of experience. This could occur if features of emotional interest are incorporated in learning material without careful consideration.

I interpret the notion of reappraisal, coined by Lazarus (Parkinson, 1995), to be related to the notion of the hermeneutical circle. When people learn new concepts and new knowledge they make judgments as to how to relate the new information to the old, but also in relation to how relevant a concept seems to be in the existing structure. Since appraisal theory describes emotions as a cognitive process contributing to how we are to classify a situation (Parkinson, 1995), the theory agrees with the notion that understanding means organizing in structures. Appraisals direct our behavior and attention to what is important in a situation. It is therefore plausible to assume that the emotional experience, when learning and understanding occur, is relevant as a marker to what to pay attention to.

Silvia (2005) found that people who appraised their own coping ability highly were also more interested in the abstract pictures shown in his study. This finding is relevant concerning how teaching and learning proceed in school. If students find a curriculum task difficult, e.g. they do not understand what to do, or they do not see the benefit, this might deteriorate their ability to understand. If students are not interested they are less prone to see what is perplexing or intriguing in a task. Their coping potential may then be reduced, since they do not see the point. This will lead to a negative learning spiral.

Fredrickson (1998; 2001) presented the "broaden-and-build" theory of positive emotions. The theory claims positive emotions to have a broadening effect on personal cognition, to facilitate a broader scope of cognition, attention and action, and to build resources to enhance the individual's physical, intellectual and social resources. The "broaden-and-build" theory is interesting in relation to Silvia's (2005) study about interest. Silvia says that people who perceived their own coping ability as high are more interested, and my prediction is that they would also be more able to find the difficulty in a problem. The feeling of being able to understand a domain makes it more interesting, and thus a student would also be capable of understanding more since the feeling of being able to understand evokes positive emotions. The "broaden-and-build" theory suggests that our cognitive abilities are enhanced when influenced by positive emotions.

5.2 The role of emotion for understanding in education, a social perspective

Educators have assumed that understanding will occur if the right learning strategy is used. Learning can occur without understanding fundamental structures or principles governing a concept, e.g. routine learning of a mathematical theorem without understanding what it is a representation of (Gardner, 2000; Wertheimer, 1959). One should keep in mind the need for different degrees of understanding (recall the example of baking a blueberry cake) and that understanding involves the ability to apply and to use what one has learned. Understanding in an educational setting often requires an additional effort to the learning process. When understanding is required in order to make adequate decisions or to solve a problem, the ability to understand the internal features of a concept or a knowledge domain is essential and cannot be substituted by automatic actions or routine learning.

Findings from Fredrickson's "*broaden and build*" theory provide useful tools interpreting possibilities and difficulties related to how students understand in an educational setting. Baumeister et al. (2001) claim that they have found evidence that bad is stronger than good as a general principle. They say that bad things, which occur over life, have more impact than good things happening to us. Baumeister et al. claim that we process bad things more than good things. This is additional evidence supporting the importance of providing a positive atmosphere when students try to understand.

Emotions persistent over a longer period of time are called moods (Parkinson, 1995). Studies concerning the effect of mood on judgment and behavior have yielded interesting results (Isen and Simmond, 1978). There seems to be a limit when a happy person will help another person. If helping another person means that the happy mood decreases, the likeliness to help diminishes. The explanation is that people in a good mood want to stay in a good mood and thus engage in so-called mood-maintenance and mood-protection strategies (Isen, 1984). This finding is important in relation to educational setting. Children's prowess to help their friends may be negatively affected if a helping child feels less happy after helping a friend. This could lead to situations where children avoid helping each other, contributing to a less tolerable atmosphere in the classroom, which may affect emotions negatively. It is also plausible that children seeking help from more skilful friends stop asking for help because they are afraid of being rejected. A positive effect could be that children feel that this is a good way of learning and that helping a friend gives satisfaction. As has been shown in studies by

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Biswas et al. (2001), teaching someone else increases the learning outcome.

Langston (1994) found that if people share good news or celebrate a good event, they experience greater positive affect, beyond increases associated with the valence of the event itself. Langston called this capitalization, which refers to the process of informing another person about the occurrence of a personally positive event and thereby deriving additional benefit from it (ibid.). Gable et al. (2004) conducted studies where they examined what happened intrapersonally and interpersonally when people told others about a good thing. Two of the studies revealed that if a person is communicating and sharing a personal positive experience with others, this increases the daily positive effect and well-being. If the person who was told responded actively and constructively (and not passively or destructively) to capitalization attempts, the benefits were further enhanced (Gable et al., 2004). Even though these studies used couples as participants, I would claim that these results might be generalized to other relationships, such as student–teacher in a school setting. At least is this a plausible implication since student and teacher spend a lot of time together in primary school. The study by Gable et al. (2004) has interesting implications for how positive emotions can affect an individual. In relation to Fredrickson's "broaden-and-build" theory these findings are important to consider as facilitating and stimulating a beneficial learning process resulting in understanding in the educational setting. Setting students in a positive social atmosphere gives advantages for understanding the knowledge domain.

5.3 Emotion in relation to insight

Bowden and Jung Beeman (2003) wanted to link the subjective feeling of insight with an objective measure, priming for the solution. When solving problems people have used feeling-of-warmth judgment (Metcalfe, 1986b) to rate how close they are to the solution, e.g. if one is close to a solution the warmer it gets. When solving non-insight problems subjects are better at judging whether the solution is near, but when solving insight problems subjects are worse at judging whether the solution is in reach (Metcalfe, 1986a). Results from Bowden and Jung Beeman (2003) indicate that when subjects are presented with priming words in their left visual field right hemisphere, lvf-right hemisphere, they have a priming effect advantage in their rating of the solution as insight solution. Subjects made solution decisions more quickly when the target was presented to the lvf-right hemisphere. The researchers claim that the fact that subjects manifest priming indicates that they had solution-related activation; the fact that they did not solve the problem indicates that such activation was below the threshold of awareness. The result further indicates that sub-threshold activation occurs more often in the right hemisphere than in the left hemisphere and that the activation of right hemisphere is more strongly connected with the aha-experience (Bowden and Jung Beeman, 2003). They conclude that right hemisphere has an important and special role in solving insight problems and in feelings of insights.

5.4 Emotion and meta-cognition

Identifying a problem obstructing understanding involves an emotional response that identifies a difficulty. By using meta-cognitive cues the problem-solving process might be facilitated. Efklides (2002) investigated the relation between meta-cognitive experience and emotions; feeling-of-knowing, feeling-of-difficulty, feeling-of-confidence and feeling-of-satisfaction during different phases of cognitive processing. She assumes that meta-cognitive feeling is a product of inferential processes. Feeling-of-familiarity, refers to fluency in processing and the origin of the fluency, e.g. a stimulus which is known from the past (ibid.). Emotion has an important influence on understanding since its influence contributes useful information and guides understanding. The feeling-of-familiarity would be an emotional response present at the beginning of a learning process when pre-knowledge is assessed. Feelings-of-difficulty refers to the identification of an obstacle or an interruption in the cognitive process (Fridja, 1986). This corresponds to the identification of a difficulty by using emotion as a beacon. Emotion may thus function as proof of whether one has understood or not. The notion of using emotion as an indicator referring to a difficulty is supported from a meta-cognitive perspective.

Efklides conducted a study investigating the relationship between the meta-cognitive experience and feeling-of-knowing, feeling-of-difficulty, feeling-of-confidence and feeling-of-satisfaction. The result points to the importance of meta-cognitively monitoring fluency and detection of interruptions in the processing to form feelings-of-familiarity and feelings-of-difficulty. This evidence corroborates that meta-cognitive feelings are inferential and use different cues, e.g. feeling-of-knowing, feeling-of-difficulty (Efklides, 2002). The importance of detecting a difficulty is essential for understanding. If a difficulty or an ambiguity is not detected, understanding is undermined. Recall the example of the study where people were asked to read a text containing a contradictory statement. Important relations are likely to be missed, and if

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the ambiguity passes unmarked this will be a probable cause of misunderstanding occurring at a later point in time. Meta-cognitive strategies enhance understanding since they provide important information to us by detecting emotions signaling that there is an obstacle in the fluency of processing. Providing a student with meta-cognitive strategies would lead to enhanced learning since the student can monitor where he or she is heading.

6 TRANSFER AS A TEST OF UNDERSTANDING

Transfer is a desirable feature of the learning outcome. One of the aims in education is for students to transfer knowledge from one domain to another. Students are encouraged to use knowledge from one domain in order to solve problems in a given domain by analyzing the problem using different strategies. In the past, transfer was defined in a narrow way as the independent and immediate application of knowledge skills in one situation to another (DeCorte, 2003). This has also been called the direct-application theory of transfer. An alternative and broader definition of transfer has developed. Transfer is defined as preparation for future learning (Bransford and Schwartz, 1999). By using this definition of transfer the focus is on the individual's ability to learn in a new context, using different forms of external support, such as different tools, other people's knowledge etc. (ibid.).

Bransford et al. (2000) suggest four key characteristics important for transfer. First, one has to be sure that initial learning has occurred. If not, there is obviously no knowledge to transfer. If the knowledge is only partially learned it is difficult to transfer to a new situation since relevant knowledge is missing for analyzing the new situation. Secondly, if knowledge is learned in an over-contextualized environment this might reduce transfer. The reason is that the structure to apprehend is too transparent and the learner will not be able to discriminate the general knowledge structure from the contextualized learning situation to another situation. Bransford et al. (2000) suggest that abstract representation can promote transfer. Useful strategies are to use analogies, models and contrasting cases in order to clarify the underlying structure for the knowledge. Thirdly, they suggest that transfer should be seen as an active and dynamic process rather than a passive process. Using the definition of transfer as a preparation for future learning provides the learner with a broader sense of what it means to learn and understand a knowledge domain. Finally, the authors suggest that all forms of new learning rely on previous transfer. That is, when we learn something new this is based and incorporated with regard to our pre-knowledge.

Mayer et al. (2001) have shown that when students learn by using a multimedia animation it is important how much information is present on the screen. They found an effect called the *redundancy effect*. This effect refers to the fact that, when on-screen text is added to a narrated animation, the text can overload the visual information-processing channel (ibid.). This means that the learner has to split attention between two sources of information, words through both the visual (on-screen text) and auditory (narrated voice) channel. Mayer et al. (2001) also found that adding interesting but conceptually irrelevant material to the multimedia-learning environment resulted in poorer performance on retention and transfer tests. Participants produced fewer creative solutions on transfer test when there was interesting but irrelevant material present. The results are in accordance with the cognitive theory of multimedia learning and the associated split-attention hypothesis which predicted that adding on-screen text to the multimedia animation would disturb the learner and thus transfer would be poorer. This is explained by the fact that multimedia learning is enhanced by the possibility to use both visual and auditory channels, but if one channel is overloaded due to extra information this will decrease the learner's performance as suggested by the split-attention hypothesis.

This section briefly summarized a couple of key features enabling transfer such as the importance of initial learning, not over-contextualizing learning, transfer is an active process and all learning is based on transfer from previous learning situations.

7 DISCUSSION

What I am suggesting in this article is not entirely new. My proposal is to provide an idea that has the possibility to consider important issues related to what constitutes understanding, and how understanding can be described is coherent with existing suggestions as to how learning and understanding occur. The benefit of the idea presented here is that it can be used to examine more carefully what is the core of understanding. The idea of understanding as a structure, a pattern, provides a framework to be tested on various levels and in different knowledge domains. Especially interesting is to investigate further the difference between expert understanding and novice understanding. Since the goal of education is to transfer knowledge to real life and much of what we do in real life is what we are good at, it seems

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fruitful to identify the differences between experts and novices in order to pinpoint the essentials of what it means to understand a knowledge domain.

In this article I have sketched a picture of factors constituting understanding. I have presented my arguments primarily from an educational perspective, where understanding is a central feature. I have chosen to relate understanding and problem solving since the core is to find relevant relations contributing to a structure for interpreting knowledge. Understanding involves solving difficulties.

I propose that to understand is to organize knowledge into a structure. Both theoretical and empirical research supports this view. Gärdenfors (2006) describes understanding as the ability to use patterns, while Gestalt psychologists claim that understanding involves recognizing relevant relations between parts by restructuring the given (Wertheimer, 1959; Köhler, 1969). The structure underlying understanding enables us to organize our problem into a comprehensible structure. Research investigating what differentiates experts from novices provides clear evidence that understanding a domain involves creating meaningful representations of a domain and the relevant problems.

Trying to understand a problem involves recognizing a difficulty or that something is unfamiliar. When understanding occurs, a structure is used to organize our problem, and thus our knowledge. Understanding involves identifying relations among parts in order to create a complete and clear picture of the objective to understand. The ability to understand depends on pre-knowledge, e.g. what we already know. Initially our structure might be fragile and unstable. We can have naïve notions about how something works or lack sufficient pre-knowledge. Sometimes our structure lacks an essential part, and when we find the missing part we at once understand the difficulty.

It is important to realize how pre-structures may influence students' understanding since the pre-structures can both facilitate and hinder understanding. An essential part in understanding is to identify relations. At certain times when understanding occurs it involves so-called productive or creative thinking. This entails finding unusual interpretations of how something should be interpreted. Evidence from neurophysiological (Bowden and Jung Beeman, 1998) research supports this as well as studies done in educational settings (Wertheimer, 1959).

I propose that meta-cognitive abilities are useful in the process of understanding. In the cognitive tradition much research has been done on monitoring and controlling cognitive processes. Identifying a difficulty and finding a solution to the difficulty requires identifying different forms of relations. Some processes are conscious and others are unconscious. Meta-cognitive abilities seem especially useful for identifying a difficulty due to interruption in processing fluency.

Emotion is an important factor contributing to understanding, and I suggest that emotion functions as a beacon identifying the difficulty to be understood. Emotions guide students to pay attention to where the problem is and enables them to take action on how they should come to understand. It has been suggested that positive emotions have a broadening effect on intellectual abilities (Fredrickson, 1998, 2001). Other studies show that if good events are shared and appreciated by others, there is also a positive effect on well-being. These findings are very important to consider when educating students to understand what they are learning. Emotions direct our attention to the difficulty by guiding our attention to what is problematic. The core in understanding is to identify relations. The relations are used to organize what we would like to understand into a structure. Emotion guides attention to the difficulty, enabling us to solve the problem, and thus resulting in understanding.

Further investigations should examine more closely what constitutes understanding. First, we need to identify what differentiates a person who understands from a person who does not. Secondly, behavioral and physiological features of understanding should be identified. I suggest the use of eye tracking to investigate possible patterns accompanying understanding when looking at visual stimuli. Thirdly, I would like to investigate the role of acknowledging emotional monitoring while understanding learning material. A prediction is that if participants pay more attention to their emotional reactions while trying to understand they will identify more relations essential for applying the underlying structure in future tasks.

Identifying a problem is the first step to understanding the task at hand. If a person fails to detect a problem or an ambiguity there will be problems later on in the learning process and the understanding of the topic may suffer from inaccurate knowledge. I suggest that the model of understanding as a pattern is a plausible cognitive model. It can explain both a novice's approach to understanding and an expert's understanding. To confirm the model of understanding as a pattern, experiments that can predict learning outcomes must be set up. More specifically, tasks involving a practical application of what has been understood need to be tested in a transfer task where understanding can be measured directly.

The model is testable on different levels of understanding, e.g. from more basic understanding of a domain to more complex domain expertise. The model also accounts for the progress of understanding over time, as the learner understands more and more. The challenge is to design an experimental task where all properties can be clearly identified and measured, which can provide supporting empirical evidence that understanding means having and applying a pattern.

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