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INFLUENCE OF STUDENTS' LEARNING STYLES ON THE EFFECTIVENESS OF INSTRUCTIONAL INTERVENTIONS

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ABSTRACT

This research contributes to answer the question whether learning/cognitive styles of students serve as a justified starting point for creating target-group appropriate instruction. The study was realized in a self-regulated problem-based learning environment. Data of 56 participants on their individual learning styles, their acquired problem solution and their increase in declarative knowledge were collected. Results indicate that a consideration of learning styles to design a matching instruction or learning environment does not transfer into higher quality problem solutions or an enhanced increase in declarative knowledge.

KEYWORDS

Learning style, cognitive style, preflection, prompting, mental models, self-regulated learning

1. INTRODUCTION

To be an effective self-regulated learner, students actively have to influence and adjust all learning processes of the cognitive, metacognitive, and motivational dimension. Such a multilayered regulation of learning enables improvements in procedures of the cognitive, metacognitive, and motivational component of learning (Schiefele and Pekrun, 1996, Bransford et al., 2000). Zimmerman's (2008, 2000, 1998) and Pintrich's (2000) models of self-regulation share those key-components and orchestrate their sub-processes in a cyclic-reflective understanding to specific phases of self-regulated learning.

Learning styles are regarded as one of the crucial factors to be taken into account when designing instruction and learning environments: "Instruction designed to address a broad spectrum of learning styles has consistently proved to be more effective than traditional instruction, which focuses on a narrow range of styles" (Felder and Brent, 2005, p. 59). However, the scientific understanding of the concept of learning style is rather inconsistent. Learning-style models range from holistic approaches (e.g., the Dunn and Dunn learning-style model; Dunn et al., 2009) to specific models that focus on certain dimensions of learning, i.e., information gathering, processing, and retrieval (e.g., the Felder-Silverman learning-style model; Felder and Silverman, 1988).

2. THEORETICAL BACKGROUND

2.1 Learning Styles in Theory and Educational Practice

The field of educational psychology comprises numerous learning style models, all aiming at an improvement of learning. Learning style assessments could contribute to the learner's intrapersonal knowledge as a part of his/her declarative meta-knowledge. Accordingly, intrapersonal knowledge is defined as knowledge about the own thinking, memory, and corresponding tendencies (Brown, 1984). Therefore, by knowing about specific preferences a learner unifies, he/she at least fulfills a basic prerequisite to self-regulate his/her learning process and/or environment in a way that suits his/her individual learning preferences.

However, assessing learning styles could not only contribute to the learners' meta-knowledge and subsequently create the basis for improvement of his/her control mechanisms in a self-regulated learning environment. Even before learners participate in a (self-regulated) learning environment, learning styles could be an important factor. As aforementioned, several ID-models advise to assess the actual learning styles of the target-group as a central aspect of the learners' characteristics (e.g., Morrison et al., 2011, Rothwell and Kazanas, 2008). Analogous to self-regulation mechanisms of learners that can occur in the phases of self-regulated learning, instructional designers could consider the predominant learning styles of their target-group when designing instruction. Theoretically this has to result in an optimization of the designed instruction by improving its suitability for the target group/learner.

The relevance of learning styles for instructional designers as well as the field of self-regulated learning and according research, thus, seems to be unquestionable. However, a vast number of different understandings of learning style definitions, theoretical positions, models, and measures can be identified. This leads to an increasing lack of clarity what a learning style is and how it facilitates instruction and (self-regulated) learning processes. Cassidy (2004) states: "As a consequence of the quantity of research, the disciplines and domains in which the research is conducted, and the varied aims of the research, the topic has become fragmented and disparate" (p. 419). To deal with learning styles, first, a basic understanding for the concept is obligatory and to be presented in order of not to contribute to further dilution of the concept.

Hawk and Shah (2007) consider learning styles not as a state. The authors mention that learning styles and learning style models all share the basic assumptions that "students learn in different ways", the concept of "learning style is a component of the wider concept of personality", and "learning style falls into the categories of dispositional traits and characteristic adaptations where there are differences across individual humans but there are groupings of humans who have common or similar learning style characteristics" (Hawk and Shah, 2007, p. 2).

Referring to Hawk and Shah's (2007) characterizations as a basic premise, an interchangeable use of the terms "learning style" and "cognitive style" seems to be possible. Some models comprise solely cognitive aspects of gathering, processing and retrieving information (e.g., the Felder-Silverman model), whereas other models include constructs dependent on the age-appropriate assessments administered, e.g., environmental stimuli (sound, light, temperature, seating, etc.) that feature no direct relation to cognitive processes (Dunn et al., 2009). Riding and Cheema (1991) further elaborate on the not well defined usage of learning style and cognitive style: "Whilst cognitive style is a bipolar dimension, learning style entails many elements and are usually *not* 'either-or' extremes. One either has or does not have the element in one's style, similarly, the absence of one element does not necessarily imply the presence of the opposite element" (p. 194).

2.1.1 Empirical Findings on Learning Styles

Although, terminological shortcomings in learning/cognitive style research have been made explicit for several decades and the benefit of taking such styles into account when designing instruction seems to be obvious – at least from a theoretical perspective – scientists still argue about its practical efficacy. Regarding various empirical studies on learning styles, results still draw an unclear picture about the "true" relevance of the concept.

An in-depth literature review revealed numerous contradicting results of research on learning styles. The following investigations and reviews all support the benefit that arises from considering learning styles when designing instruction (e.g., Dunn et al., 2009, Schmeck, 1988, Hayes and Allison, 1993, Hayes and Allison, 1996, Riding and Grimley, 1999, Bajraktarevic et al., 2003). The scope of the instructions observed in these studies provides a wide range from traditional training situations to hypermedia learning environments. In contrast, other studies and reviews disagree with the aforementioned (e.g., Kavale and Forness, 1987, Snider, 1992, Cook et al., 2007, Gilbert and Swainer, 2008, Martin, 2010). Analogous to the contradicting studies, the investigated learning environments and instructional settings also range from traditional classroom to multimedia learning environments. Thus, as already mentioned, the picture about the "true" relevance of learning styles remains unclear. Positive effects of taking learning styles into account when designing instruction are still questionably.

2.1.2 Index of Learning Styles (ILS)

The Index of Learning Styles (ILS; Felder and Silverman, 1988) was "designed to capture the most important learning style differences among engineering students and provide a good basis for engineering instructors to formulate a teaching approach that addresses the learning needs of all students" (Felder and Spurlin, 2005, p. 103). The model shares commonalities with other popular learning style approaches, e.g., the Learning Style Inventory (LSI; Kolb, 1984) or the Myers-Briggs Type Indicator (MBTI; Lawrence, 1994).

With regard to the theoretical assumptions made above, the ILS is explicitly said not to include 'either-or categories' of its bipolar dimensions. All scales are to be understood as continua, which means that a student's cognitive preference to learning on a given ILS scale may be either fairly well balanced, moderately, or strongly distinctive for one or the other pole of the scale. The four bipolar ILS dimensions can be described as follows (Felder and Silverman, 1988):

- **Active – Reflective.** Active learners tend to gather and understand information best if they engage with it actively and try things out, e.g., by debating, bringing something to application, or via teaching-back. Reflective learners prefer to think about new things respectively information for themselves first. The motto of active learners is "Let us try and see how it works", whilst reflective learners pursue the principle "Let me first think carefully about it".
- **Sensual – Intuitive.** Sensing learners tend to do well in learning facts and to follow established approaches and procedures when solving problems. They are more goal-oriented, carefully and patiently, but avoid complex issues or surprises. Intuitive learners on the other hand prefer to explore different possibilities and relationships and innovative approaches. The can better grasp new concepts, work usually faster and more innovative and have less difficulty with abstract concepts and mathematical expressions. However, they tend to avoid rote learning, repetition, routines and fixed schemes.
- **Visual – Verbal.** Visual learners remember more of what they have seen, e.g. pictures, diagrams, flow charts, films, demonstrations, etc. Instead, verbal learners prefer linguistically based learning that is written and spoken information or declarations. However, it should be noted at this point, that regardless of the deviation of a person, the combination of visual and verbal information is most conductive.
- **Sequential – Global.** Sequential learners tend to understand better by learning in logical linear steps, where each step is the logical consequence of the previous step. In contrast, global learners rather tend to make big steps and gather different material and information quasi-random and without the recognition of contexts and relationships, but suddenly, they understand the whole context.

2.2 Designing Model-Based Learning Environments

2.2.1 Mental Models as a Basis for Analyzing Problem Solutions

A mental model is an idiosyncratic representation of a fact or a thing, of ideas or more generally an ideational framework about something interesting in the world. Mental models, as types of representations, rely on language and use symbolic pieces and processes of knowledge to construct a heuristic for a situation. The theory of mental models follows the constructivist assumption that human knowledge is always fragmentary and thus regarded as dynamic, because it is constantly expanded and/or modified (Johnson-Laird, 1983, Pirnay-Dummer et al., 2012). Hence, mental models function as internal models of the outside world and produce subjective plausibility (Ifenthaler and Seel, 2011).

With regard to problem solving processes, studies show a strong correlation between effective mental modeling and the solution of complex problems (Jacobson, 2000). According to Dörner (1976) problems are characterized by means of three components: 1.) an unsatisfying actual state, 2.) a desired target state, and 3.) a barrier which currently inhibits the mental transformation of the actual to the target state. The bigger this barrier is the more complex the problem is regarded. The definition of problem solving processes clarifies the importance of mental models for successful problem solving. Funke (2003) states that problem-solving thinking is characterized by filling the gaps within an action plan that cannot be accomplished routinely. For that purpose a mental model is constructed which bridges the way from the initial to the goal state (Ifenthaler and Seel, 2011).

Ifenthaler (2010, 2008) describes the externalization of internal cognitive structures as a deliberate communication process of mental models. Whenever the observation of knowledge representation is essential, externalization is necessary, because direct access is not possible. Accordingly, methods to measure knowledge representations result from the conscious communication of mental models, e.g., via thinking aloud, text writing, constructing graphs, knowledge or concept maps (Ifenthaler, 2010). This results in the differentiation between internal knowledge representations and external, so called *re-representations* (Ifenthaler, 2010). The re-representations are communicated on the basis of the mental representations and adequate sign and symbol systems (Shute et al., 2009, Seel, 1999). Accordingly, the solution to a phenomenon in question which is represented by an individual mental model, and consecutively the re-representation of this model as a result of a communication process allows the investigation of individual problem solutions (Ifenthaler, 2010).

2.2.2 Preflection – a Pendant to Reflection

Expert self-regulated learners are said to be effective in actively influencing and adjusting all learning processes of the three key-components of learning: cognition, metacognition, and motivation (Schiefele and Pekrun, 1996, Bransford et al., 2000). Metacognitive processes are attributed to play a superior role, because metacognition can serve as a tool to regulate the further dimensions of learning and consequently optimize their specific aspects with regard to the goals set (Leutner and Leopold, 2003).

Zimmerman's model of self-regulation (2008, 2000, 1998) suggests a cyclic-reflective understanding of self-regulation. Three phases are identified analogous to an input-output-system, where each result of an action sequence affects the following. At the beginning of a learning cycle stands the forethought phase. Pintrich (2000) adds "planning and activation" to the label of that initial stage of each self-regulated learning cycle. In general, it can be characterized as preactional phase, followed by the actional and post-actional phase. Consequently, the learning phase of action is enclosed by a preparatory and a post-processing phase. In terms of metacognition, the differentiation between prospective and retrospective monitoring (Nelson and Narens, 1994) can be applied to the surrounding phases, represented by two psychological constructs: *Reflection* is primarily characterized to refer to something experienced (Pintrich, 2000), thus suiting the postactional phase, whereas *preflection* is relating to future events and based on prospective thoughts, thus suiting the preactional phase. The latter, hence, is to be understood as the pendant to reflection. In regard to what Dewey (1933) described when introducing the concept of reflection – humans learn more from reflection on their own experience than from the experience itself – preflection can be characterized as reflection's inverted counterpart: a tool for optimizing subsequent experience, respectively problem-solving and learning processes. Accordingly, preflection involves the activation of central learning relevant structures (e.g., content knowledge, strategies, values, interest, etc.) that are prospectively regarded to be beneficial for future performance.

2.2.3 Prompts as an Instructional Intervention in Self-Regulated Learning Environments

External instructional interventions have to be used at the right time and the right extent, so that the self-regulatory learning process is not disturbed, but rather supported. Instructional designers need to develop learning environments implementing an appropriate level of external- and self-control which poses not an easy challenge. Therefore, research has gained big interest in investigations of demand-oriented support and assistance interventions (*scaffolds*). One specific form of scaffolds are formed by instructional cues, so called *prompts*. Within the context of self-regulated learning they are regarded as effective, because they serve as a "short-time intervention" (Bannert, 2009) and only represent a minimal external control mechanism.

Davis (2003) and Ifenthaler (2012) differentiate between two forms of prompts: *generic* and *directed*. Generic prompts follow the principle "stop and think". A generic prompt encourages learners to interrupt the current learning or problem solving processes for a moment and reflect. Here, the object of reflection is left completely open. There are no specific issues highlighted or instructed by the prompt.

Directed prompts, on the other hand, follow the principle "stop and think about ...". Davis (2003) states that the more specific directed prompts should be more effective than general, unspecific prompts, if they were adequately implemented in the learning or problem-solving environment. It is assumed here that individuals who do not have the necessary knowledge and skills required for the desired deliberations – reflective or preflective – need an additional instruction along with the prompt. Directed prompts include such an instruction, for example, in form of to complete sentences. Ifenthaler (2012) alternatively found generic prompts to be more efficient compared to directed prompts, because they leave a certain amount of autonomy for self-regulative acting. Still, Ifenthaler (2012) agrees on Davis' (2003) argument that directed prompts may be more efficient for learners that do not already have a specific set prior knowledge and skills.

2.3 Research Questions and Hypotheses

The contrasting views within the community of educational psychology as well as the contradictory empirical results on the effects of taking learning styles into consideration when designing instruction led us to the present study. The objective is to investigate the influence of students' learning styles on the effectiveness of instructional interventions (metacognitive prompts within a problem-based learning environment). Regarding the theoretical foundation of learning styles, we assume that reflective students as well as students with a propensity for verbal learning develop higher quality problem solutions and perform better in retrieving declarative knowledge than the active type of students and students with a preference for visual learning. The reasons for these assumption are that (1) active learners tend to profit from actively doing something, e.g., discussing, applying information, teaching back, or trying it out; reflective learners gain much more from introspective processing and thoroughly thinking something through before trying it out (Kolb, 1984) and (2) the fact that the learning environments' metacognitive prompts plus the problem solving itself happen basically verbal. Thus, the following hypotheses are addressed: The more reflective and verbal the learners are, the higher the quality of their developed problem solutions (Hypothesis 1). The more reflective and verbal the learners are, the better they perform in retrieving declarative knowledge (Hypothesis 2).

3. METHOD

3.1 Participants and Design

A total of N = 56 undergraduate students (42 female and 14 male) from a German university took part in the experiment. Their average age was 22.73 years (SD = 3.83). They were all enrolled in an introductory course on research methods and were asked to participate in an experiment to meet the course requirements. Participants were randomly assigned to two experimental groups (GP = generic prompt, n_1 = 28; DP = directed prompt, n_2 = 28). Participants in the GP group received a general prompt to conduct a phase of preflection on the subsequent problem-solving task. Participants in the DP group received instructional to-complete-sentences in order to prompt preflective thoughts.

3.2 Materials

3.2.1 Problem Scenario and Prompts

The prompts were embedded in a problem-based self-regulated learning environment where participants were asked to help their mother who was moaning about dorsalgia and concerned about having a herniated disk. A partially illustrated article on the spine's and spinal cord's anatomy and functionalities as well as the reflex circuit was used as learning content.

Generic and a directed prompts were developed accordingly. The generic prompt included a general suggestion for a preactional phase of forethoughts, planning, and activation on the subsequent problem solving process and according self-regulation mechanisms (*please use the following ten minutes to optimize your upcoming problem solving process through well-thought-out planning and preparation*). In contrast, the directed prompt was designed more specific. In total it contained eleven to-complete-sentences in order to induce the specific processes of prospective considerations and preactional self-regulation (e.g., *activation of prior knowledge: About the substantive subject area of the problem I already know that…; goal setting: To achieve the main objective I'll set the following sub goals…*).

3.2.2 Domain Specific Knowledge Test

The knowledge test included eleven multiple-choice questions with four possible solutions each (1 correct, 3 incorrect). Two versions (pre- and post-test) of the domain-specific knowledge test were administered (in which the eleven multiple-choice questions appeared in a different order). It took about eight minutes to complete the test.

3.2.3 ILS

A German translation of the Index of Learning Styles (ILS; Felder and Spurlin, 2005) was used to assess the students' individual learning styles. Each of the four ILS dimensions consists of eleven items. Each item possesses two response possibilities (*a* or *b*) that either correspond to one extreme of a dimension's continuum (e.g., *active* vs. *reflective*). Felder and Spurlin (2005) report correlation coefficients for the ILS-scales of three test-retest studies with values between .72 and .87 at a four weeks interval, .60 and .78 at seven months, and .51 and .68 at eight months.

Regarding the validity of the ILS, it is to report that both exploratory factor analysis with an eight-factor solution, as well as a feedback analysis of the sample with approval levels of 80 percent for the Sequential-Global scale and over 90 percent for the economies of scale Active-Reflective, Sensing-Intuitive, Visual-Verbal seem to prove the validity of the ILS (Litzinger et al., 2007).

3.3 Procedure

First the participants completed the domain-specific knowledge test, a demographic data and the ILS questionnaire. Then they were introduced to the problem-scenario and the groups received their specific prompts to preflect. The learning material was handed out 10 minutes afterwards. Participants worked for 30 minutes on the solution of the problem. After a total of 40 minutes for solving the problem, including the induced phase of preflection, participants were asked to represent their solution of the problem as a written text. Finally, the post-version of the domain-specific knowledge test was completed.

3.4 Analysis

3.4.1 HIMATT

HIMATT (Highly integrated Model Assessment Technology and Tools; Pirnay-Dummer et al., 2010) allows an automated analysis of the text-based problem solutions. A detailed description of the seven measures of HIMATT, which include four structural and three semantic measures, is provided by Ifenthaler (2010). High reliability and validity measures have been reported for HIMATT (Pirnay-Dummer et al., 2010).

3.4.2 Reference Model

In order to quantify the qualities of the participants' problem solutions an expert solution was used as a reference model for our statistical analysis. The text-based reference model was worked out within the same problem-based learning environment by an orthopedic specialist and apprenticed physiotherapist.

4. RESULTS

Table 1 describes the distribution of learning style tendencies of all four ILS-scales for the 56 participants of our experiment. The distribution is in line with reports from other studies that used the German translation (Derntl and Graf, 2009) as well as the English version of the ILS (Felder and Spurlin, 2005).

Table 1. Distribution of learning style preferences

active	reflective	sensing	intuitive	visual	verbal	sequential	global
36	20	39	17	47	9	28	28
64.3 %	35.7 %	69.6 %	30.4 %	83.9 %	16.1 %	50 %	50 %

On the declarative knowledge test, participants could score a maximum of eleven correct answers. They scored an average of M = 3.23 correct answers (SD = 1.53) in the pretest and an average of M = 6.16 correct answers (SD = 1.68) in the posttest. The increase in correct answers (not normally distributed) was significant, $Z = -6.049$, $p < .001$, $r = -.808$ (strong effect).

For testing our hypotheses, we computed an ILS main score for each participant using the according numeric relatives of both hypotheses-relevant ILS-scales, active-reflective and visual-verbal. Then, experimental groups were segmented into three sub-groups via percentiles (GP: active-visual n_{1a} = 9, non-distinct n_{1b} = 4, reflective-verbal n_{1c} = 16; DP: active-visual n_{2a} = 17, non-distinct n_{2b} = 0, reflective-verbal n_{2c} = 11). To check hypothesis 1, the qualities of problem solutions were investigated by independent t-tests respectively Mann-Whitney-tests, if HIMATT measures were not normally distributed.

For the GP group t-tests revealed no significant effect for GRM, $t(23) = .424$, $p = .675$; STM, $t(23) = 1.344$, $p = .192$; GAM, $t(23) = 1.463$, $p = .157$; PPM, $t(23) = -.729$, $p = .473$. Additionally, the Mann-Whitney-tests showed no significant effect for SFM, $U = 60.5$, $p = .514$; CCM, $U = 63.0$, $p = .610$; BPM, $U = 63.0$, $p = .610$. For the DP group t-tests revealed no significant effect for SFM, $t(26) = -.391$, $p = .699$; GAM, $t(26) = -1.046$, $p = .305$; CCM, $t(26) = -.445$, $p = .660$; PPM, $t(26) = -.100$, $p = .921$; BPM, $t(26) = -.365$, $p = .718$. Additionally, the Mann-Whitney-tests showed no significant effect for GRM, $U = 68.0$, $p = .225$; STM, $U = 64.5$, $p = .172$. Accordingly, no significant differences of the quality of problem solutions between reflective-verbal and active-visual learners could be identified in either experimental group. Therefore, hypothesis 1 is rejected.

Secondly, we assumed that the increase in declarative knowledge for subjects with a preference for reflective and verbal learning is superior compared to others. For the GP group (knowledge increase not normally distributed) the Mann-Whitney-test revealed no significant differences between reflective-verbal and active-visual learners, $U = 51.5$, $p = .238$. For the DP group (knowledge increase normally distributed) t-test revealed no significant differences between reflective-verbal and active-visual learners, $t(26) = -1.083$, $p = .289$. Accordingly, we reject hypothesis 2.

5. DISCUSSION

A consideration of the orientation of the applied HIMATT measures (structural vs. semantic) shows that in average the subject performed ways better on the structural than on the semantic level of the posed problem. This suggests that, although a minimum of necessary complexity could be obtained, the subjects were not able to use sufficiently correct concepts as well as to create semantically correct relationships within their solution to the problem. For higher quality results they should have increased their usage of correct concepts and propositions.

Contrary to our hypotheses, the more reflective and verbal study groups did not differ significantly from the more active and visual subjects, neither in the quality of their developed problem solutions nor in their increase in declarative knowledge. Accordingly, we conclude that the matching of our instructional scaffolds respectively both the suiting generic and directed prompts did not work beneficially for their target group. Therefore, either the prompts or the dimensions of the Felder-Silverman learning style model have to be questioned in terms of validity.

Regarding the first two critical aspects, we have to mention that our experimental design with its strict time schedule could be one reason for the fact that the consideration of learning styles did not transfer into higher quality problem solutions and an increase in declarative knowledge. But at the same time, one could assume that a matching respectively mismatching between the type of the developed self-regulated problem-solving environment as well as the embedded instructional support (generic/directed prompts) on the one hand, and the present learning styles (either more distinctive reflective-verbal or active-visual) on the other hand, still would result in differences regarding our dependent variables.

6. CONCLUSION

Given that generic and directed prompts have been found to be an important instructional method for self-regulated learning in problem-solving environments (Ifenthaler, 2012, Davis, 2003, Wirth, 2009), we put in question if learners really benefit from taking learning/cognitive styles into account when designing instruction. Based on our empirical finding, one would have to answer »No« to that question.

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