ADJUSTING COGNITIVE LOAD TO THE STUDENT'S LEVEL OF EXPERTISE FOR INCREASING MOTIVATION TO LEARN

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Developing conceptual understanding of statistics requires an instructional format that adjusts cognitive load to the student's level of expertise in order to optimize motivation to learn. Structuring the material to be learned and guiding self-explanation of what is learned will diminish fear and postponing behavior on the part of the student, it will stimulate students to engage in meaningful learning, which will help them to keep an overview and develop conceptual understanding of the subject matter. These aims of education form the pillars of the educational method presented in this paper: the method of propositional manipulation (MPM).

INTRODUCTION

Statistics is inherent in a variety of everyday and work related situations as well as across a wide range of academic domains. An amalgam of student-related factors (i.e., deficiencies in background, negative attitude and motivation, underestimating the importance of the subject matter, and wrong learning strategies), educational factors (i.e., the abstract and cumulative nature of the subject matter, time, technology, and inappropriate instructional methods), and curricular factors leads to the finding that many students develop only superficial understanding as they postpone confrontation with the subject matter until right before the exam (Ben-Zvi & Garfield, 2004, Van Buuren, 2008). Statistics education should consider all these factors. Structuring the material to be learned and guiding self-explanation of what is learned will diminish fear and avoidance behavior on the part of the students, it will stimulate them to engage in meaningful learning (i.e., relating and integrating important elements of the subject matter), which will help them to keep an overview and develop conceptual understanding (Broers, 2009). The method of propositional manipulation (MPM; Broers, 2002, 2009; Broers & Imbos, 2005) addresses all these issues.

PROPOSITIONS AND ARGUMENTS

MPM comprises three steps, the first of which having the instructor to subdivide the subject matter into a limited number of basic propositions that usually constitute slightly new facts or ideas that can be found in statistics literature (for examples, see Broers, 2008). The number of propositions is determined by the instructor, and depends on the size of the topic as well as on the complexity of the learning assignment, which on its turn depends on the complexity of the subject matter. Next, students have to study these propositions in order to focus their attention on a number of important and relevant propositions, while ignoring less relevant or still too complex propositions. The propositions are presented to the student in the form of questions. Once one answered these questions, one can relate and integrate these answers in order to develop cognitive schemata of what is learned. Finally, students are stimulated to self-explain by providing them with a true/false statement that matches their level of expertise and having them relate and integrate the constituent propositions in an argument that proves the statement to be either true or false. This way, the student's cognitive schemata of the subject matter are developed further and gradually they can be integrated with other cognitive schemata in order to develop conceptual understanding of the subject matter.

ASSIGNMENT COMPLEXITY

Keeping the complexity and size of the subject matter constant, the number of questions and the formulation of these questions determine the cognitive load required to perform the assignment. Consider the following statement: "If the sample mean is known, the expected mean can be expressed in a number." Suppose that this statement is accompanied by three underlying questions, being: (1) "What is a sampling distribution?", (2) "What is meant by expected mean?", and (3) "What parameter equals the expected mean?" When confronted with the statement only, the

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student may not be able to answer that the statement in question is false. And even if answering this question, the answer may reflect a rule that was learnt by heart right before the exam, without learning the meaning of the concepts the statement comprises. If the latter is the case, it is very likely that the student will not be able to solve other statements comprising the same propositions. MPM stimulates the student to engage in meaningful learning (Novak, 2002) instead of rote learning, as it stimulates the student to self-explain the elements underlying the more complex statement. Many students, especially those having a non-mathematical background, feel intimidated by the frequently complex, abstract, and even counterintuitive formulae, equations, and ideas they are confronted with when consulting the literature. When confronting them with all these complex things without guiding them to self-explain more elementary things first, many of them will feel helpless and postpone confrontation with the subject matter until right before the exam, and those who initially have the motivation to find their way in this myriad can easily become disoriented by focusing on things that are irrelevant or still too complex. Most students do not think of asking themselves underlying questions, like the three questions in the example above. They need guidance in becoming acquainted with the core concepts and ideas in order to perform more complex assignments. Answers to the underlying questions are easily found in textbooks. Hence, even novice students can find the answers to the questions and, next, reason why the statement above is false. The content of the assignment as well as the (number of) underlying questions can and should be adjusted to the student's level of expertise, in order to avoid expertise reversal effects. By varying in subject matter, in the number of underlying questions, in content of the underlying questions, as well as in the nature of contextual information one can have enormous variation in assignment complexity. Hence, MPM can help both novice students and more experienced students to develop a better understanding of the subject matter.

COGNITIVE ARCHITECTURE

By adjusting the cognitive load–imposed on the students by an assignment–to their level of expertise, MPM seeks to optimize motivation to learn and help them to develop conceptual understanding. MPM unites implications of Cognitive Load Theory (Schnotz & Kuerschner, 2007; Sweller, 1988, 1999; Sweller, Van Merrienboer, & Paas, 1998) and motivation theory (Bruinsma, 2003; Ryan & Deci, 2000). Cognitive load consists of three types of load that are assumed to be additive: intrinsic load, extraneous load, and germane load. Intrinsic load is dependent of task complexity and one's level of expertise. Extrinsic load is load from instructional features. Germane load is load from instructional features and processes enhancing learning, while extraneous load arises from all instructional features that are not beneficial for learning. It becomes evident that extraneous load should be minimized. Optimal instruction can manage cognitive load externally, whereas internal management of cognitive load is a matter of one's own metacognitive and self-regulative competence and strategies of dealing with high cognitive load. Intrinsic load should be manipulated in instructional design by selecting learning assignments that fit to the student's level of expertise (Schnotz & Kuerschner, 2007). The student's level of expertise in combination with the educational objectives determines whether load is intrinsic or extrinsic. Germane load should be in accordance with working memory capacity as well as with the intrinsic load of the learning assignment, which in turn has to be adapted to the student's level of expertise in order to avoid expertise reversal effects (Kalyuga, Chandler, & Sweller, 2001). When the facilitation reduces task difficulty to an extent that is no longer aligned with the student's level of expertise, then the facilitation has instructionally negative effects. When fully guided instructional material is presented to more experienced students, part of the provided instructional guidance may become redundant. In contrast, the same material may be essential for less experienced students. Schnotz and Kuerschner (2007) assume that it is the combination of germane load and intrinsic load rather than germane load alone that allows predicting how much better learning will result from germane load activities. Germane load is likely to be constrained by intrinsic and extraneous load as well as by the student's interest and learning orientations, and by affective and motivational aspects, since one does not automatically invest all cognitive capacity available (i.e., the capacity not used for intrinsic or extraneous load) into learning activities.

OPTIMIZING MOTIVATION TO LEARN

Learning in a domain like statistics is a lengthy process requiring students' motivational states and levels of expertise development to be considered. Research has shown that learning from an intrinsic motivation enhances in-depth learning (Bruinsma, 2003) and increases learning outcomes (Ryan & Deci, 2000). According to Ryan and Deci, for sustained intrinsic motivation three psychological basic needs have to be fulfilled: competence, autonomy, and relatedness. Competence refers to the feeling of being capable to perform an assignment, autonomy refers to the feeling that one is free to follow own interests without being controlled in one's actions, and relatedness comprises a feeling of a social support and a sense of trust in the people around. If intrinsic load is too high, both the need for competence and the need for relatedness may not be fulfilled. If extraneous load is too high or if intrinsic load is too low (i.e., given the student's level of expertise, either the task is too easy or part of the instructions is superfluous, or instructions are too fuzzy), the need for autonomy may not be fulfilled. Although there is no direct empirical support for the latter, statistics education illustrates that for many students the need for competence as well as the need for relatedness are apparently not fulfilled. Especially students having a non-mathematical background feel helpless when confronted with the formulae in the statistics literature (Broers, 2009), and an instructional format minimizing instructional guidance may enhance this feeling of helplessness, because due to cognitive overload (Kirschner, Sweller, & Clark, 2006) they will experience not being capable of performing the assignments confronted with, and the minimized guidance will lead to the experience of not receiving any social support at all. Developing conceptual understanding of statistics requires an instructional format that adjusts cognitive load to the student's level of expertise in order to optimize motivation to learn. MPM enables both instructor and students to structure the material to be learned, stimulates students to seek confrontation with the subject matter by confronting them with less complex elements that by means of (guided) self-explanation can be related and integrated in order to perform more complex assignments and develop conceptual understanding of the subject matter. As cognitive load can be adjusted to the students' level of expertise, all three psychological needs should be fulfilled: the guidance into self-explaining propositions that are important for performing the assignment should fulfill the students' need for relatedness and competence, and since they have to self-explain the relevant subject matter and create their own argument, their need for autonomy should be fulfilled as well.

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