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Differential impact of learning path based versus conventional instruction in science education

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ABSTRACT

Learning paths have the potential to change the teaching and learning interaction between teachers and students in a computer-supported learning environment. However, empirical research about learning paths is scarce. Previous studies showed that the low adoption of learning paths can be linked to the lack of knowledge on the part of teachers about learning path design and its implementation. In the present study, which was undertaken in the context of a biology course in secondary education, 496 14- to 15-years old secondary school students in Flanders were assigned to either learning path based or conventional instruction during classroom activities. The aim was to analyze the differential impact of the instructional formats on learning outcomes, considering variations in group setting and group composition. Given the focus on science learning, gender was also considered. Multilevel analysis was applied, and the results show empirical evidence for superior performance for both boys and girls in the learning path condition as compared with that in the conventional condition. In addition, when girls collaborate, they perform best within same-sex groups, whereas boys achieve better results in mixed-gender groups. The implications of the findings are important for tackling the gender gap in science learning. The findings can lead to guidelines for teachers who want to implement learning paths within an optimal learning environment design.

1. Introduction

In a study of 376 teachers from 70 secondary schools, De Smet and Schellens (2009) observed that 96% of the participating schools used a learning management system (LMS), but only 10% of the participating teachers actively used the learning path module. They concluded that, despite the high adoption level of LMSs within schools, the low adoption rate of learning paths suggests that teachers are unfamiliar with how learning paths can be designed and implemented.

As a result, De Smet, Schellens, De Wever, Brandt-Pomares, and Valcke (2014) studied the design and implementation of learning paths in an LMS. The impact of optimizing a learning path with guidelines derived from the cognitive theory of multimedia learning (CTML; Mayer, 2003) was studied within the context of a biology course. In addition, individual versus collaborative use and gender differences were considered when examining the impact on learning outcomes. It was found that students provided with a learning path optimized with the CTML guidelines, especially when working alone,

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outperformed students in other conditions. However, the impact of collaborative learning was less obvious, more specifically for females. These results demonstrated that collaboration in a learning path does not automatically lead to better learning.

De Smet et al. (2014) described a learning path as "the LMS functionality to order a number of learning objects in such a way that they result in a road map for learners. Within a learning path, learning steps are structured in a general way (as a navigation map or a table of contents) or in a very specific sequenced way (e.g., 'complete first step 1 before moving on to step 2')" (p. 2). The most important building blocks of a learning path are the learning objects. Kay and Knaack (2007) defined them as "interactive web-based tools that support the learning of specific concepts by enhancing, amplifying, and/or guiding the cognitive processes of learners" (p. 6). Learning paths can be created with authoring tools (e.g., eXe and Xerte) or can be programmed by software developers.

This paper aims to support and extend previous learning path research. Building on the observation that optimizing learning paths based on the CTML guidelines was beneficial for student learning outcomes, we decided to adopt this design approach for a follow-up study. In addition, we build on research about collaborative learning. We expect students studying a learning path in a collaborative way to attain significantly higher learning outcomes as compared with students learning individually. However, previous studies are less conclusive as to the beneficial effect of collaborative learning. Possible causes are group composition (Resta & Laferrière, 2007), the role of gender within group composition (Johnson & Johnson, 1996), and the tendency of women to be less active in certain group settings (Felder, Felder, Mauney, Hamrin, & Dietz, 1995). This brings us to the central research problem: do learning paths have a beneficial impact on learning outcomes when students learn in a collaborative way? We especially considered the role of gender and group composition. Since most teachers have not yet adopted learning paths (De Smet & Schellens, 2009), we implemented a design wherein conventional instruction is the control group and learning path based instruction is the experimental group.

In the next sections, we first present the theoretical base underpinning the hypothesized differences between conventional instruction and learning paths, the rationale in relation to collaborative versus individual study based on learning paths, and the impact of group composition. We also focus on gender because it is of prime importance when investigating collaborative learning (as discussed above) and also because our study is set up in the domain of science learning, where it is considered a key variable.

2. Theoretical and empirical framework

2.1. Learning paths and their potential to promote learning performance

The present study focuses on the impact of learning paths. The latter represent a specific functionality, made available via LMSs (also referred to as virtual learning environments, digital learning environments, course management systems, or electronic learning environments). LMSs give educators tools for creating an online course website and provide access to enrolled students (Cole & Foster, 2007). Most LMSs provide a number of specific tools and functionalities to support learning. Dabbagh and Kitsantas (2005) distinguished 4 categories of web-based pedagogical tools: collaborative and communication tools (e-mail, discussion forums, and chat tools); content creation and delivery tools (upload course content and learning paths); administrative tools (course information, functions, interactions, and contributions); and assessment tools (tools to post grades etc.).

From a theoretical perspective, the potential benefits of learning paths are built on (1) the assumptions related to the CTML and (2) the assumptions related to instructional technology conceptions.

Most learning objects in a learning path have various functionalities and features (e.g., content, context, appearance, animation, behavior, and structure); therefore, the rationale for using learning paths is heavily based on their multimedia nature. CTML, as postulated by Mayer (2001, 2003), represents a framework for determining the instructional design of multimedia learning materials and presents practical guidelines for creating such materials. For instance, the audiovisual elaboration of certain learning objects builds on the dual channel assumption that states that learners have different channels (auditory versus visual) that allow them to simultaneously process complex knowledge (Baddeley, 1992, 1995; Paivio, 1978, 1991). Exploitation of these different channels allows the study of increasingly complex learning content. CTML also stresses the active learning assumption (Mayer, 2005). The (interactive) learning objects guarantee that learners are actively engaged in processing a multimedia environment. The cognitive processes that are involved select (visual/audio), organize (mental representation), and integrate (visual, audio, and prior knowledge). The latter processes are consistent with evidence-based cognitivist learning principles that foster schema development and subsequent learning performance (see Marzano, Pickering, & Pollock, 2001).

The sequencing of learning objects along a "path" can, theoretically, also be linked to "programmed instruction" principles as previously defined by Skinner and to principles found in the "teaching machines" of Pressey (1927, 1960) and Skinner (1954, 1958). Both programmed instruction and teaching machines reflect a systematic build-up of learning materials by following carefully defined steps. Moving from one step to the other depends on successful mastery of the previous step. Skinner refers to the "operant condition" as the mechanism for grounding learning. Emurian (2005) concluded that step-by-step instructional design as found in programmed instruction is especially helpful when students access a new knowledge domain "because it provides study discipline", guarantees "structured rehearsal", and requires learners to attain a high achievement level. McDonald, Yanchar, and Osguthorpe (2005) added that programmed instruction was found to be most