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PERSONALIZING LEARNING WITH MOBILE TECHNOLOGY IN SECONDARY EDUCATION

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ABSTRACT

Personalizing learning with technology in secondary schools might be a way to diffuse innovations in both technology and education at the same time. In the current study, personalizing learning with technology is studied from three perspectives: teacher, learner and technology. Data about the implementation and evaluation of the interventions in school were gathered by interviews with teachers and students, teacher logbooks and teacher and student questionnaires. Moreover, test and questionnaire data were collected on achievement, school motivation and self-regulation of more than 4800 students. Effects of 35 personalizing learning interventions with mobile technology in 27 secondary schools in the Netherlands were examined. Generally, three types of personalizing learning interventions seem to increase student achievement: 1) a comprehensive approach across the school organization and programs; 2) personalizing learning with teachers differentiating either convergently or divergently, and 3) learner-control interventions in which students have control of surface aspects such as pacing, sequencing and practicing within limits set by teachers or programs. Too much emphasis on learner control instead of teacher control does not seem to benefit cognitive outcomes. The conclusions with respect to students' motivation and self-regulation are less clear-cut.

KEYWORDS

Personalizing Learning, Mobile Technology, Secondary Education, Learner Control, Teacher Control

1. INTRODUCTION

The increasing use of technology in society in combination with attention for constructivist learning orientations requires secondary schools to change to more suitable learning and teaching practices. Yet innovations in teaching with technology have entered the school sporadically: most classroom teachers use the technology to do what they always have done and choose those activities that will help them accommodate their own perspectives on teaching and learning (Liu, 2011). Many schools have integrated laptops and other digital tools into daily practice, but it is unclear if those devices are being used in ways that best maximize their potential (Greaves, et al. 2010). Despite increased prevalence and use of computers in schools, research on the effectiveness has yielded mixed results (Machin et al., 2007). This problem motivated the Dutch government to setup a tender to stimulate secondary schools to diffuse innovations in both technology and education at the same time. Schools were invited to submit their proposals to receive funds to develop and implement various school-based innovations on personalizing learning with technology. The objective of this study is to provide insights into the effects of the various approaches to personalizing learning with technology in secondary schools.

2. PERSONALIZING LEARNING WITH TECHNOLOGY

In contrast to traditional classroom instruction based on teacher-centered approaches, the use of technology allows educators to empower students to take control of their own learning. Learner control is the degree to which students can direct their own learning experiences (Shyu and Brown, 1992), including path, pace, and

instructional approach. Such control could include choices at the curriculum level (sequence of instructional materials), the opportunity to choose how long to focus on a learning objective (pacing), or the ability to select and sequence a variety of review strategies (choice of practice items or amount of review material; Niemiec et al., 1996). As a result of making their own instructional decisions while learning, students would be more likely to explore tactics for different situations. In other words, students would learn how to better learn in the future. This belief is still prevalent today: many educators agree that personalizing learning is a key priority (Marshall et al., 2009). Although giving a student control over their learning has theoretical and intuitive appeal, its effects seem neither powerful nor consistent in the empirical literature base. A meta-analysis of 18 studies by Karich, et al (2014) .found - consistent with previous research (Niemiec et al., 1996)- near zero effects for all components of instruction (pacing, time, sequence, practice, review). Thus, there does not seem to be an advantage to giving the learner control over any particular instructional component. Yet programs that offered a comprehensive approach had larger effects than practice-based applications, suggesting that educators should consider more comprehensive programs that provide the learner with a unique experience beyond what is commonly received in their classroom. Moreover, studies with behavioral variables had larger effects than measures of academic achievement, which suggests that providing learner control within educational technology may enhance engagement, but may not increase student skills.

In personalizing learning with technology, learner-control is not the only dimension to be considered; technology in itself can control students' learning process to some extent (Vandewaetere et al., 2011; Karich et al., 2014). Therefore, we distinguish between three actors influencing student learning: learner, teacher and technology.

Personalizing learning from the perspective of *learner* includes learning across five aspects of program design: pacing, sequencing, time allotment, choice of practice items, and choice of review items (Niemiec et al., 1996). Pacing indicates how quickly teachers present the content to the learner. Sequencing denotes how teachers order information, such as when particular objectives or tasks are presented in relation to other objectives or tasks. Time allotment referred to the amount of time teachers give to the learner to complete the content in its entirety for a particular session. Practice items indicate the type and amount of practice on a particular objective, whereas review items are typically presented at the end of a lesson as a check for understanding. As mentioned above, effects of learner control are ambiguous with small effects mostly found on learners' motivation and learning behavior (Corbalan et al., 2006; Karich et al, 2014). Yet just adding learner control to an existing learning environment does not always lead to learner behavior regulating their learning (Azevedo et al., 2008); students need some guidance or practice in learner control to increase their regulative behavior (Authors, under review).

Personalizing learning from the perspective of *teachers* means that teachers determine what learners need to learn based on learner characteristics and adapt the content and their way of teaching (Tomlinson et al., 2003). Teachers analyze learner characteristics such as achievement, motivation and learning behavior in order to adapt their teaching to what is needed for individuals or groups of students. Although research on personalizing learning from the teacher perspective has a long history (e.g., Snow, 1992), studies show ambiguous findings with respect to effects on cognitive, affective and behavioral measures (Vandewaetere et al., 2011). Personalizing learning from the perspective of *both teacher and learners* is called shared-control (Corbalan et al., 2006). This model combines the two approaches to personalizing learning: Program-controlled instruction, in which an instructional agent (e.g., computer, teacher) makes instructional decisions and learner-controlled instruction, in which learners makes such decisions.

Personalizing learning from the perspective of *technology* refer to the adaptive qualities of the technology that is used to support teaching and learning (Vandewaetere et al., 2011). Empirical findings suggest that the use of adaptive technology in computer-based assessments has a positive impact on students' achievements in various school subjects (e.g. Faber, Luyten and Visscher, 2017), but not all findings are consistent. Findings about the frequency of using these adaptive environments suggest that greater usage of the system by both teacher and students is associated with better student performance.

3. METHOD

The purpose of the current study is to provide insights into the effects of personalizing learning with technology in secondary education, from the teacher, learner and technology perspective. The following research question guided our study:

"What are the effects of personalizing learning with technology on students' achievement, motivation for school and self-regulating behavior?"

3.1 Research Design and Participants

In total, data were collected about 42 interventions in 34 secondary schools (with 6045 students). Seven schools (with one intervention each) were excluded from the final analyses as these school interventions could not be categorized as focused on either teacher, learner or technology. So, data included in this study are from 35 interventions in 27 secondary schools (with 4808 students). The research design mostly included a setup of an experimental condition (the intervention on personalizing learning with technology) and a comparison condition. The latter can be students in another, but similar school (SCHOOL), in the same school, but in another year group (YEAR), in the same school and year group, but in another class (CLASS), in the same class (STUDENT) or the same student for another school subject (WITHIN). In some cases, no reference condition was used (ONE-GROUP). In all cases, a pre-test post-test design has been used. For an overview of the research design of each intervention, see Table 1, 2, 3 and 4. The research was carried out following the guidelines for research ethics and integrity of Utrecht University.

3.2 Interventions on Personalizing Learning with Technology

Interventions in personalizing learning with technology were categorized into three clusters: 1) teacher perspective, 2) learner perspective and 3) technology perspective. Mobile technology (laptops, tablets, smart phones) was used in combination with an electronic learning environment supported by different Learning Management Systems.

Personalizing learning from a *teacher perspective* can be clusters at two levels of differentiating between individual students: 1) at the school level with different streams of schooling like the Dutch system of secondary education, which is called external differentiation, and 2) at the class level which is called internal differentiation (Berben and Van Teesling, 2014). The interventions examined in this study refer to internal differentiation. Internal differentiation by a teacher means that teachers monitor the content, the process and the assessment of student learning based on ability, motivation and learning behavior of their students (Tomlinson et al., 2003). If the learning goal is the same for the whole group of students, internal differentiation is called convergent differentiation; if learning goals within a group of students are different, international differentiation is called divergent differentiation. Finally, convergent differentiation (having the same learning goal for all students) requires thoughts about group constellation during group work with either students with the same ability level (homogeneous groups) or students with different ability levels (heterogeneous groups). In sum, personalizing learning from a teacher perspective have been categorized as 1) divergent (DIV), 2) convergent with homogeneous groups (CON-HO), or 3) convergent with heterogeneous groups (CON-HE).

Personalizing learning from a *learner perspective* refers to the degree students can control program aspects such as pacing, sequencing, time allotment, practicing and reviewing (Karich et al., 2014). A low degree of learner control (LOW) means that learners controlled pacing, whereas other program aspects have been set. High degree of learner control (FULL) means that all or almost all program aspects were controlled by the learner. In-between position (MODERATE) on the degree of control means that students controlled at least pacing, combined with some other program and task aspects, mostly within the limits set by the teacher or program. Low learner control was frequently combined with learner control of surface task characteristics (e.g., various tasks at the same ability level or various forms of testing the same content); full learner control was frequently combined with learner control of structural task characteristics (e.g., various tasks at different ability levels or various sources with variety of information; Corbalan et al., 2011).

Personalizing learning from a *technology perspective* refers to students completing computer-based assessments with either adaptive technology (ADAPTIVE) or non-adaptive technology (NON-ADAPTIVE).

3.3 Measures

Data about the implementation and evaluation of the interventions in school were gathered by interviews with teachers and students, teacher logbooks and teacher and student questionnaires. Although not all these were collected in all cases, in each case evaluation data have been collected from both teachers and students.

Student achievement was measured by student scores on regular exams of the particular school subject related to the interventions.

Student motivation was measured by the Situational Motivation Scale (SiMS; Guay et al., 2000). This questionnaire contains 16 items that are focused on why students are currently engaged in a particular activity concerning a school subject that is object of study. The items are clustered into four scales: 1) intrinsic motivation (example item: "because I think that this activity is interesting"), 2) identified motivation (example item: "because I am doing it for my own good"), 3) external regulation (example item: "because I am supposed to do it", and 4) A-motivation (example item: "I do this activity, but I am not sure if it is worth it"). Students scored each item on a 5-point Likert type scale with 1= does not apply at all and 5= does apply to a great extent. All scales showed satisfying reliability.

Student self-regulation was measured by a questionnaire with 32 items developed by Vandevelde et al. (2013). These 32 items can be clustered into 6 aspects of self-regulation: 1) task orientation (example item: "Before I start my schoolwork, I read the instructions carefully"), 2) planning (example item: "Before I start my schoolwork, I decide what to do first and what later", 3) Persistence (example item: "I carry on until I finish my schoolwork"). 4) self-efficacy regulation (example item: "I am good at connecting new things to what I already know"), 5) product evaluation (example item: "After finishing my school work I go over my answers again", and 6) process evaluation (example item: "I ask myself: 'Have I done it the right way?'). Students scored each item on a 5-point Likert type scale with 1= does not apply at all and 5= does apply to a great extent. All scales showed satisfying reliability.

3.4 Analyses

In the designs with a comparison group, analyses of covariance have been used with the both conditions as factors and one the effect measures (achievement, motivation or self-regulation) as dependent variable. Pre-test scores on the effect measures and background information of the students such as gender, age, and ability level (if available) were used as covariates. In cases of a one-group-only design, t-tests have been performed on the pre-test and post-test scores.

4. FINDINGS

4.1 Personalizing Learning from a Teacher Perspective

The findings for the cluster of interventions that focus on a teacher perspective on personalizing learning are summarized in Table 1.Schools differed in the way they implemented personalizing learning from a teachers perspective with convergent differentiation in seven schools, divergent differentiation in three schools and a combination of both types of differentiation in one school. In all interventions, teachers designed their own educational materials (sometimes together with colleagues), provided instruction and guided the learning process of their students. Students worked individually or in small groups on assignments with guidance of their teacher (all interventions with convergent differentiation and the one of school 18).

In general, the effects of the interventions on student achievement, motivation and self-regulation are mixed. The effects on student achievement are positive in all cases, with divergent as well as convergent interventions. No achievement effects were measured of the interventions with convergent differentiation with homogeneous groups. The findings with respect to students' motivation are difficult to interpret, although interventions with convergent differentiation with homogeneous groups seem to lead to negative

effects. In school 17, the degree in which student groups were guided by the teachers varied a lot. Interventions with solely divergent differentiation do not show an effect on student motivation. The findings with respect to student self-regulation only show one positive effect, in school 11. Comparing both schools in which all three effects have been measured (school 10, DIV, and school 11, CON-HE) the intervention in school 11 shows effects on all three measures. The main difference between both interventions is the way of personalizing learning. In school 10, poor-performing students received additional instruction and high-performing students additional tasks; in school 11, students choose their own pacing and sequencing of materials sharing the same learning goal.

Table 1. Personalizing Learning from a Teacher Perspective

School	Research Design	$N_{students}$	Personalizing learning	Technology	Achievement	Motivation	Self-regulation
8	CLASS	362	CON-HE	iPads	n.a.	0	0
9a	CLASS	114	CON-HE	iPads	+	0	n.a.
10	CLASS	106	DIV	iPads	+	0	0
11	CLASS	50	CON-HE	iPads	+	+	+
12	YEAR	104	CON-HE	iPads	n.a.	n.a.	0
13	CLASS	92	DIV	iPads	+	0	n.a.
14	CLASS	563	BOTH-HO	iPads	n.a.	+	n.a.
15	CLASS	234	CON-HO	Laptops	n.a.	+/-	n.a.
16	YEAR	195	CON-HE	Laptops	n.a.	-	n.a.
17	ONE-GROUP	257	CON-HO	No	n.a.	-	n.a.
18a	ONE-GROUP	34	DIV	iPads	n.a.	0	0

Note. 0= no effect; += positive effect, -= negative effect, +/-= mixed and n.a.= not applicable (i.e .not measured). For categories of the research design and personalized learning interventions, see Method section.

4.2 Personalizing Learning from a Learner Perspective

The findings for the cluster of interventions that focus on a learner perspective on personalizing learning are summarized in Table 2.Schools differed in the degree learners controlled aspects of the program and learning tasks. In two interventions (22, 23), students only controlled pacing. In four interventions (26a, 26b, 28, 29b) students controlled pacing and sequencing of the various assignments. In one intervention (20), pacing was combined with a choice of practicing items. All these interventions were categorized as low learner control. All interventions coded as moderate combined learner control of pacing with other aspects, without learner control of structural program aspects. The exception was intervention 11, in which students could choose between tasks with different functionalities (memorizing, analyzing, understanding). Finally, all other interventions were categorized as full control with learner control of most program and tasks aspects.

With respect to the effect on achievement four significant effects were found; two in interventions categorized as moderate and two in other interventions that –although not categorized as such- resembles the moderate ones. More significant effects were found with respect to student motivation, negative, positive and ambiguous, and spread over all kinds of interventions. Finally, with respect to self-regulation, only one positive effect was found (school 22, categorized as low).

Table 2. Personalizing learning from a learner perspective

School	Research design	$N_{students}$	Personalizing learning	Technology	Achievement	Motivation	Self-regulation
19	YEAR	170	FULL	BYOD	n.a.	-	0
20	STUDENT	234	LOW	BYOD	n.a.	n.a.	0
21	CLASS	63	FULL	Laptop	n.a.	-	0
22	WITHIN	111	LOW	No	n.a.	+/-	+
23	WITHIN	37	LOW	iPads	n.a.	0	0
24a	YEAR	315[1]	MODERATE	iPad	0	0	0
24b	YEAR	241[1]	FULL	iPad	+	-	0
25	WITHIN	223	FULL	Laptops	n.a.	+	n.a.
26a	CLASS	240[2]	LOW	Laptops	+	0	n.a.
26b	CLASS	240[2]	LOW	Laptops	0	0	n.a.
26c	CLASS	240[2]	MODERATE	Laptops	0	0	n.a.
27	CLASS	86	MODERATE	BYOD	n.a.	0	0
28	YEAR	426	LOW	BYOD	n.a.	0	0
18b	ONE-GROUP	34[4]	MODERATE	iPad	n.a.	+	0
29a	YEAR	123[3]	MODERATE	iPad	+	+	+/-
29b	YEAR	123[3]	LOW	iPad	0	+	+/-
9b	CLASS	106	FULL	CC	0	+	n.a.
30	CLASS	173	MODERATE	CC	+	+	n.a.
31	YEAR	157	FULL	BYOD	n.a.	0	0

Note. [1] the same control group with 176 students; [2] sharing the same 240 students; [3] sharing the same 123 students; [4] sharing the same 34 students with intervention 18a; BYOD = Bring your own device; CC= Computer Classroom; 0= no effect; += positive effect, -= negative effect, +/-= mixed and n.a.= not applicable (i.e .not measured). For categories of the research design and personalized learning interventions, see Method section.

4.3 Personalizing Learning from a Technology Perspective

The interventions with respect to personalizing learning by technology refer to the use of computer-based assessment as a support of students' learning processes. In the interventions, all aspects of a curriculum (pacing, sequencing, time allotment, practice items and review items) were personalized, either by the technology or the learner, as part of regular classes in a particular topic. Students can choose how much effort they put into completing assignments, and technology determines the other parts - if adaptive technology has been used. Adaptive technology also provided students with feedback about their performance (embedded analytics). In intervention of school 32 and 34a, non-adaptive technology has been used. In intervention 33, 34b and 34c, student receive feedback about their performance (embedded analytics) and teachers are able to get an overview of their students' performance (extracted analytics). In school 33, in-between feedback for students included information about the correct response as well as information on what students still had to learn. In intervention 34 and 36a, only information after completion of the computer-based assessments was available.

No effects on student achievements were measured as none of the school intended to use these computer-based assessment to improve student achievement (see Table 3). With respect to student motivation, no effects or negative effects were found. These negative effects coincide with a low satisfaction of the students with the intervention: for both interventions, students were more satisfied with the regular classes on that topic; they did not see the additional value of practicing with computer-based assessments. With respect to self-regulation, only two significant effects are found: one positive and one negative in school 34. In intervention 34b, teachers use extracted analyses for their classroom instruction with various forms of feedback and instruction (plenary, small-group and individual settings); in intervention 34c. students have the possibility to ask teachers for feedback - which they generally did not do.

Table 3. Personalizing Learning from a Technology Perspective

School	Research design	$N_{students}$	Personalizing learning	Technology	Achievement	Motivation	Self-regulation
32	YEAR	133	NON-ADAPTIVE	iPad	n.a.	0	0
33	STUDENTt	83	ADAPTIVE	Mixed	n.a.	-	0
34a	YEAR	77	NON-ADAPTIVE	Mixed	n.a.	-	0
34b	ONE-GROUP	46	ADAPTIVE	Laptop	n.a.	0	+
34c	ONE-GROUP	52	ADAPTIVE	Laptop	n.a.	0	-

Note. Mixed= students complete assignments on paper and on their laptop or tablet; 0= no effect; += positive effect, -= negative effect, +/-= mixed and n.a.= not applicable (i.e .not measured). For categories of the research design and personalized learning interventions, see Method section.

5. CONCLUSION

The evaluation of personalizing learning interventions in 27 schools from three perspectives (teacher, learner and technology) leads to a number of conclusions and practical implications. Generally, three types of personalizing learning interventions seem to increase student achievement: 1) a comprehensive approach across the school organization and programs; 2) personalizing learning with teachers differentiating either convergently or divergently, and 3) learner-control interventions in which students have control of surface aspects such as pacing, sequencing and practicing within limits set by teachers or program. Too much emphasis on learner control instead of teacher control does not seem to benefit cognitive outcomes. The non-linear relationship between the degree of learner control and cognitive outcomes might also be an explanation for empirical evidence in other studies (Karich et al., 2014).

The conclusions with respect to student motivation are less clear-cut. Similar interventions, either teacher- or learner-controlled, led to different effects. One explanation could be the relationship between learners' autonomy, competence and relatedness influencing student motivation as indicated in the self-determination theory (Ryan and Deci, 2000). Providing students with control of program and task aspects should probably combined with differentiating between students who differ in competence.

With respect to students' self-regulation, only a few effects were found. We provide two explanations for this lack of effects. First, the interventions examined in this study might be too much focused on either teacher control or learner-control; a more balanced approach of personalizing learning might be more effective for students' self-regulative skills. Secondly, the interventions of this study were not focused on increasing students' self-regulation in particular. A more comprehensive approach in which a broach range of metacognitive skills of students are addressed, might lead to more positive effects (Authors., under review).

A final critical reflection refers to the variety of the interventions examined in the current study. Even interventions that are similar in the way learner or teacher control was implemented vary on all kinds of program and task details, the length of an intervention, and the range of implementation. More research on underlying mechanisms of the interventions is necessary to provide a deeper understanding of possible benefits of personalizing learning in secondary education.

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