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Personalizing learning with mobile technology in a secondary school in the Netherlands: Effects on students' autonomy support, learning motivation and achievement

Wilfried Admiraal & Lysanne Post
Leiden University, the Netherlands

Ditte Lockhorst
Oberon Consultancy and Research, the Netherlands

Monika Louws & Liesbeth Kester
Utrecht University, the Netherlands

Abstract: Personalizing learning with technology in secondary schools is a way to empower students to take control of their learning. The more learners can direct their own learning experiences, including path, pace and instructional approach, the more they may learn what they want and need to learn. In a quasi-experimental design, data about the implementation and evaluation of three interventions in one secondary school in the Netherlands have been gathered with student questionnaires and regular exams. In these three interventions, each lasting one entire school year, teachers attempted to support their students' autonomy in decisions during their learning process. Effects on students' perceived autonomy support, learning motivation and their achievement have been examined. One intervention – the one with the highest scores on perceived autonomy support – shows small positive effects on students' learning motivation and their achievement. Learner control over structural aspects of the curriculum, such as students' autonomy to choose their tasks for practicing and reviewing and the way to complete them, is a possible effective way of designing personalizing learning in secondary education. In future research, more attention should be addressed to which combination of autonomy supportive activities might be effective. These effects might also be different for different student groups, based on, for example, their learning preferences and abilities.

Keywords: Autonomy support; Learning motivation; Personalizing learning; Secondary education; Student achievement; Tablets

Introduction

Research on the effectiveness of technology in schools has yielded mixed results, although a tendency has been found for positive learning outcomes of students (Hassler, Major, & Hennessy, 2016; Sung, Chang, & Liu, 2016). Many schools have integrated digital tools into daily teaching practice, but it is unclear if those devices are being used in ways that best maximize their potential (Hassler et al., 2016; Lin, 2017). Tablets seem to be particularly suitable to support personalizing learning, as it is owned by an individual learner and can be full of materials and applications that address learners' needs. Yet personalization can take many forms – whether that is through ownership of the device, the design of individualized learning activities or choices of support and tools. Personalizing learning can have positive effects on educational outcomes and well-being (Wei, Zhang, He, & Bobis, 2020; Yu, Li, Wang, & Zhang, 2016) and on students' autonomous forms of motivation in particular (Hagger, Sultan, Hardcastle, &

Chatzisarantis, 2015; Zhou, Ntoumanis, & Thogersen-Ntoumani, 2019). The more learners can direct their own learning experiences, including path, pace and instructional approach, the more they may learn what they want and need to learn. The objective of this study is to contribute to insights into the effects of approaches to personalizing learning with mobile technology in secondary education on students' perceived autonomy support, learning motivation and achievement.

Personalizing Learning with Technology

Greater affordability of mobile devices, such as laptops, tablet, smart phones and e-readers, along with rapid development and expansion of wireless Internet connections in schools, has led to an increasing use of mobile technology in secondary schools (Kearney, Schuck, Burden, & Aubusson, 2012). By combining computing power, portability, wireless communication and context sensitivity mobile technology can enhance student learning in a number of ways (Clark & Luckin, 2013; Sung et al., 2016): 1) flexible and adaptive learning and teaching, 2) situated and authentic learning, and 3) personalized learning in which learning is customized for the interests, preferences and capabilities of the learners. Whilst there are some minor concerns raised about distracting influence of mobile technology (Herodotou, 2018), misuse (Culén & Gasparini, 2012; Ifenthaler & Schweinbenz, 2013) and a lack of skills of some students (Dündar & Akçayir, 2014; Henderson & Yeow, 2012), most research report on increased motivation, enthusiasm, interest, engagement, and self-regulation, creativity and improved learning and productivity (Hassler et al., 2016; Heflin, Shewmaker, & Ngyuen, 2017; Huang, Yang, Tosti, Chiang, & Su, 2016). Other researchers report mixed findings and emphasize the moderating role of teaching methods, which explained most variance in students' motivation for learning with tablets (Fabian, Topping, & Barron, 2018; Sung et al., 2016). These mixed findings imply that more insights is needed how teachers can use tablets in class to improve students' learning motivation and achievement. In a study on schools in rural Kenya, Heinrich, Darling-Aduana and Martin (2020) identified prerequisites and supporting factors for successful technology integration. In addition to factors related to the particular rural context in Kenya, a more general supporting factor indicates to offer more professional training to teachers on how to handle tablets in class for multiple learners, each working on a single device.

A theory on motivation such as the Self-Determination Theory (Ryan & Deci, 2020) can help to understand which classroom climate can stimulate students' learning motivation and achievement. Two main motivational classroom climates can be distinguished that either promote or counteract students' motivation for learning and their achievement. *Autonomy supportive classroom climate* refers to "ways to nurture, support and increase students' inner endorsement of their classroom activity" (Reeve & Jang, 2006 p. 210). By contrast, in a *controlling motivational climate,* teachers pay little attention to their students' inner motivational resources and encourage students to adopt expected behaviors by using incentives, more directive language, and controlling modes of communication (Bennett, Ng-Knight & Hayes, 2017; Reeve & Jang, 2006). Personalizing learning is a teaching approach that implements an autonomy supportive classroom climate as it is focused on customizing learning for the interest, preferences and capabilities of students.

A meta-analysis of 18 studies by Karich, Burn and Maki (2014) found - consistent with a previous literature review (Niemiec, Sikorski, & Walberg, 1996) - near zero effects for all components of instruction of personalizing learning (pacing, time allotment, sequence, practice, review). Yet programs that offered a comprehensive approach have 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 report larger effects than measures of academic achievement, which suggests that personalizing learning with educational technology may enhance engagement, but may not increase students' knowledge and skills (Karich et al., 2014).

This Study

Research on personalizing learning with technology gives a mixed picture of its benefits for students. Researchers argue that is not the technology that makes sure students' personalized learning happens; it should be more about how much autonomy support students perceive (cf. Sorgenfrei & Smolnik, 2016). Yet not much evidence-based information is available about ways of personalizing learning with technology and about its effects on students' perceived autonomy support, learning motivation and achievement. The purpose of the current study is to contribute to insights into effects of personalizing learning with technology in secondary education on students' perceived autonomy support, their motivation for learning and their achievement. The following research questions guided our study:

1. What is the effect of personalizing learning with technology on students' perceived autonomy support and autonomy supportive activities?
2. What is the effect of personalizing learning with technology on students' motivation for learning?
3. What is the effect of personalizing learning with technology on students' achievement?
4. How are students' personalizing learning, autonomy support and learning motivation related?
5. How are students' personalizing learning, autonomy support and achievement related?

Method

Research design and participants

Data have been collected about interventions with personalizing learning with mobile technology in three school subjects in one secondary school in the Netherlands. The research design has been set up with an experimental condition (the three interventions with personalizing learning) and a control condition, with in total 242 student participants. Students of the control condition are from the same school and year group, but from another class. The intervention lasted one complete school year. The research is carried out following the guidelines for research ethics and integrity of Utrecht University, which was principle responsible for the research project.

Personalizing learning interventions

In four student groups (three groups of Grade-7 students and one group with Grade-8 students), laptops for each student have been introduced to support personalizing learning during one school year in three school subjects: English language, Geography and Math. Four groups of students (two groups of

Grade-7 students and two groups of Grade-8 students) form the control condition.

For English language, students used their laptops to learn Grammar and Listening skills at their own ability level, which has been set by the teacher. Students completed additional tasks at their own ability level to practice their skills. Students also used their method book in addition to the materials on their laptop. In the control condition, students also learned Grammar and Listening skills at their own ability level, but only used their method book. The use of laptops in the intervention made it easier for students to carry out assignments and tasks at their own ability level.

For Geography, students used their laptops to do tasks at their own pace, which they set at the beginning of each lesson. In addition, in some lessons students worked on additional tasks when they had completed the previous ones. The teaching format included mainly individual work on tasks; most instruction was included in the digital materials. Students only used materials on their laptop. In the control condition, students only used their method book with an equal mix of plenary instruction and individual and group work.

For Math, students used their laptops to do tasks at their own pace, which they set at the beginning for each module (which is a series of lessons). During the first semester, some students took tests at their own ability level; in the second semester all students took the same tests. Students in the experimental condition only used materials on their laptop; students in the control condition used desktop PCs. Actually, the only difference in instruction between experimental and control condition is the use of laptops.

To implement the intervention with personalizing learning, instructional decision have been made across five aspects of program design: 1) pacing, 2) sequencing, 3) time allotment, 4) choice of practice items, and 5) choice of review items (cf. 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 refers 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. In Table 1, the implementation of the interventions in the three schools subjects is summarized. The main difference between the school subjects refer to relatively more autonomy in the interventions with English language (in choice of both practicing and reviewing items), compared to Mathematics (only choice of practicing items) and Geography (practicing and reviewing items are fixed and set by the teacher).

Measures

At the beginning and the end of the school year student questionnaires have been administered to measure students' perceived autonomy support and their learning motivation. Data about achievement have been measure by students' school report for the particular school subject and retrieved from the school's monitoring system. Data about the implementation of the interventions in school are gathered by individual interviews with five participating teachers at the end of the school year. In this teacher interview, the interviewer (one of the

authors) asked open questions during 30 minutes regarding the implementation of personalizing learning and the role of technology in the intervention.

Perceived autonomy support and autonomy support activities: Students from both conditions completed an online questionnaire twice: at the beginning of the school year and at the end. At both times, perceived *Autonomy support* has been measured consisting of a cluster of eight items (with Cronbach's α= 0.69 for English, 0.72 for Geology, and 0.73 for Mathematics), based on the adapted short Teacher as Social Context Questionnaire student-report (Belmont, Skinner, Wellborn, & Connell, 1988). This variable refers to the extent to which students perceive autonomous choices in their learning process. Example items are "My teacher takes note of my opinion" and "My teachers gives me many options how to study". Each item was scored on a 5-point Likert type scale, from *1*= does not apply at all to *5*= does perfectly apply. Descriptive statistics are presented in Table 2.

Table 1.

Characteristics Of The Three Interventions In Terms Of Instructional Decisions (Niemiec et al., 1996).

	English language	**Geography**	**Mathematics**
Pacing	Student	Student	Student
Sequencing	Student	Student	Student
Time allotment	Within one lesson	Within one lesson	Within one module
Choice practicing items	Student; difficulty level set by the teacher	Fixed	Student
Choice reviewing items	Student; difficulty level set by the teacher	Fixed	Fixed
Technology	Laptops	Laptops	Laptops

At time 2, students from both conditions also completed items on their evaluation of autonomy supportive activities in the particular school subjects during that school year. Students reported on their perception of frequency of eight different autonomy support activities: *Planning* (the extent to which students plan their work), *Tasks* (the extent to which they are allowed to choose their tasks), *Sequence* (the extent to which they are allowed to set the sequence of completing tasks), *Group mates* (the extent to which they are allowed to choose their group mates in collaborative learning), *Sources* (the extent to which they are allowed to select sources they used for completing their work), *Task completion* (the extent to which they are allowed to choose the way they completed their work), *Ability level* (the extent to which they are allowed to decide for the difficulty level of the tasks they work with), and *Pacing* (the extent to which they work following their own pace). These items are scored on a 5-point Likert type scale referring to frequency, with *1*= never; *2*= 1-2 times per month; *3*= 1 time per week; *4* =more than 1 time per week; *5*= each lesson. Students could also indicate whether this particular item did not apply for that school subject. Second, students completed two items on how satisfied they are about 1) the autonomy

support activities and 2) the use of laptops (both with a short explanation). These latter items are scored on a 10-point scale, with 10 as highest score. The descriptive statistics are summarized in Table 2.

Students' learning motivation: At both pre-test and post-test, students' motivation for learning has been measured with a Dutch translation of the 16-items questionnaire Situational Motivation Scale (SIMS, Guay, Vallerand, & Blanchard, 2000). Each item has been adapted to focus on the particular school subject of the current study. Each item is scored on a 5-point Likert type scale with from *1*= does not apply at all to *5*= does perfectly apply. Four types of learning motivation with four items each have been distinguished. *Intrinsic motivation* refers the extent to which students are motivated for school because of the pleasure and satisfaction this gives them. Example items are "I do my best for <school subject>, because I think these are interesting" and "I do my best for <school subject>, because it feels good to work on these". *Identified motivation* refers to the extent to which students 'internalized' former external goals and reasons, resulting in the extent to which students think their efforts are their choice or are important. Example items are "I do my best for <school subject> for my own good" and "I do my best for <school subject>, because it is an important activity for me". *External motivation* refers to the extent to which students work for school to receive benefits or to avoid negative consequences. Example items are "I do my best for <school subject>, because it is expected from me to do so" and "I do my best for <school subject>, because I think I have to do it". *A-motivation* refers to the extent to which students are not aware why they work for school and how they can influence their own work. Example items are "I do not see what <school subject> brings me" and "I do work on <school subject>, but I cannot see it is worth the effort". The reliability and validity of the scales are established in the original study of Guay et al. (2000). The satisfying reliability is confirmed at the post-test in the current study with Cronbach's α of 0.88 (Intrinsic motivation), 0.75 (Identified motivation), 0.79 (External motivation) and 0.83 (A-motivation). The descriptive statistics are summarized in Table 3.

Student achievement: Student achievement is measured by student average scores on regular exams (i.e. school report) of the school subject (English, Geography or Math). Pre-test scores are based on the school report of period 1; post-test scores for the same school subjects are based on the school report of period 4, which is the final period of the school year. In the Netherlands, school report scores ranges from 1 to 10, with 10 as highest score. The descriptive statistics are summarized in Table 4.

Analyses

To examine effects on perceived autonomy support (research question 1), first repeated measures analyses of variance have been performed for each school subject, with both conditions as between-subjects factor, time (pre-test vs post-test) as within-subjects factor and students' perceived autonomy support as dependent variable. Second, to examine effects on autonomy support activities, mixed-method analyses of variance have been performed, for each activity, with both conditions as between-subjects factor, school subject as within-subjects factor and the particular autonomy support activity as dependent variable. Thirdly, paired-samples t-tests are used to test the differences in satisfaction between the three school subjects.

To examine effects on students' learning motivation (research question 2), repeated measures analyses of variance have been performed, for each school subject and learning motivation scale, with both conditions as between-subjects factor, time (pre-test vs post-test) as within-subjects factor and each learning motivation scale for the particular school subject as dependent variable.

To answer research question 3, similar analyses have been performed as described with answering research question 2, but now with achievement in the particular school subject instead of learning motivation scales. The statistic η^2 (proportion explained variance) is used as indication of effect size.

To answer research question 4, regression analyses have been performed, for each school subject and each motivation scale separately, with the eight autonomy support activities and their interaction with condition as predictors and each learning motivation scale for the particular school subject as dependent variable. The pre-test score on each of the eight autonomy support activities has been inserted as co-variate.

To answer research question 5, similar analyses have been performed as described with answering research question 4, but now with achievement in the particular school subject instead of learning motivation scales. The statistic sr^2 (squared semi-partial correlation) is used as indication of effect size.

Findings

Effects on students' perceived autonomy support and autonomy support activities

Students' evaluation of the personalizing learning intervention is summarized in Table 2. The change in perceived Autonomy support, which indicates the extent to which students have experienced that they have been supported in their autonomy to make curricular choices during the intervention period, differs per intervention. For English language, a significant difference in increase in feelings of autonomy support is found between students from the experimental and control condition ($F(1,164)= 5.069$; $p= 0.026$; $\eta^2= 0.03$), with a small increase for the experimental condition and a decrease in scores for students from the control condition. For both Geography ($F(1,164)= 2.126$; $p= 0.147$) and Math ($F(1,134)= 3.453$; $p= 0.065$), no significant difference in change in Autonomy support between both conditions have been found.

The interaction effects Condition by School subject show that for Sequence ($F(2,352)= 3.257$; $p= 0.040$; $\eta^2= 0.02$) and Ability level ($F(2,352)= 13.209$; $p< 0.001$; $\eta^2= 0.07$), the Math experimental condition generally shows *higher* scores and the Geography experimental condition *lower* scores, compared to their peers in the control condition; for English language, both conditions show similar scores.

Table 2.

Means Scores On Perceived Autonomy Support And Time 2 Evaluations Of Autonomy Support Activities And Satisfaction With Standard Deviations Within Brackets.

	English		Geography		Math	
	Exp.	Control	Exp.	Control	Exp.	Control
Perceived autonomy support						
Time 1	3.37 (0.42)	3.30 (0.44)	3.08 (0.39)	3.09 (0.54)	3.22 (0.53)	3.16 (0.60)
Time 2	3.40 (0.45)	3.16 (0.49)	2.75 (0.54)	2.91 (0.56)	3.40 (0.43)	3.14 (0.56)
Autonomy support activities						
Planning	2.27 (1.28)	2.35 (1.40)	1.91 (1.11)	2.30 (1.38)	2.10 (1.40)	2.28 (1.42)
Tasks	1.91 (1.35)	2.08 (1.44)	1.57 (1.22)	2.13 (1.44)	2.68 (1.59)	2.62 (1.53)
Sequence	3.23 (1.60)	3.33 (1.52)	2.90 (1.74)	3.43 (1.64)	**3.77 (1.46)**	**3.65 (1.42)**
Group mates	2.51 (1.37)	3.01 (1.27)	**3.58 (1.46)**	**3.05 (1.42)**	3.37 (1.35)	3.09 (1.31)
Sources	**3.51 (1.43)**	**3.35 (1.50)**	**4.14 (1.26)**	**2.98 (1.48)**	**3.43 (1.50)**	**3.24 (1.47)**
Task completion	2.17 (1.52)	2.67 (1.39)	**3.24 (1.57)**	**2.66 (1.49)**	2.87 (1.52)	2.74 (1.47)
Ability level	2.35 (1.40)	2.25 (1.39)	1.59 (1.13)	2.27 (1.56)	**2.88 (1.59)**	**2.52 (1.47)**
Pacing	3.99 (1.39)	3.89 (1.35)	3.66 (1.59)	3.80 (1.49)	4.32 (1.13)	4.15 (1.25)
Satisfaction						
Autonomy support	6.97 (1.90)	n.a.	5.49 (2.03)	n.a.	6.86 (2.09)	n.a.
Laptops	6.46 (1.79)	n.a.	6.63 (2.45)	n.a.	7.53 (2.16)	n.a.

Note. Exp.= Experimental condition; Control= control condition; n.a.= not applicable. Items of Perceived autonomy support and Autonomy support activities are scored on a 5-point Likert type scale, with 5 as highest score. The two items of Satisfaction are scored on a 10-point scale, with 10 as highest score. Printed bold= significant difference with Experimental condition with higher scores than Control condition; Printed underlined= significant difference with Experimental condition with lower scores than Control condition.

Finally, for Group mates ($F(2,352)= 6.691$; $p= 0.001$; $\eta^2= 0.04$) and Task completion ($F(2,352)= 3.378$; $p= 0.035$; $\eta^2= 0.02$), the Geography experimental condition generally shows *higher* scores and the English language experimental condition *lower* scores, compared to their peers in the control condition; for Math, both conditions show similar scores. No effects have been found for Tasks and Pacing.

With respect to student satisfaction, students evaluate the Geography intervention the lowest on the extent to which students' autonomy has been supported, compared to English language ($t=(91)= 6.625$; $p< 0.001$) and Math ($t=(91)= 5.594$; $p< 0.001$). Students

rate the use of laptops generally higher, with the highest scores for Math intervention, compared to English language (t=(91)= 4.303; p< 0.001) and Geography (t=(91)= 4.203; p< 0.001). More specifically, although students appreciate the freedom of choice and possibility to work at their own pace in the Geography intervention, they indicate in their explanation of their scores that they experienced hardly any differentiation in content and difficulty level, resulting in a relatively low satisfaction score for autonomy support for this school subject. Students evaluate differentiation of difficulty level in the English language and Math interventions more positively. With respect to the use of laptops, positive evaluations are mainly focused on the possibility to search for information (Geography), to practice (English), and working on a laptop continually (and not having to carry books). Notably, students report one specific negative point regarding the use of laptops in all three interventions. That is, they experienced technical problems with websites, Wi-Fi, and laptops.

Effects on students' learning motivation

In Table 3, the pre- and post-test scores for the four motivation scales are summarized. Only two of the repeated measures analyses of variance show significant effects of the condition on students' learning motivation, both for the intervention with English language. Students from the experimental condition show a larger increase in external motivation compared to students from the control condition (F(1,169)=5.885; p= 0.016; η^2= 0.03). With respect to A-motivation, students from the experimental condition show a small decrease and students from the control condition a large increase in scores (F(1,169)=7.405; p= 0.007; η^2= 0.04). No other effects with respect to students' learning motivation have been found.

Effects on students' achievement

In Table 4, the pre- and post-test scores for student achievement are summarized. The results of the repeated measures analyses of variance show mixed findings. For English language, students from the experimental condition show a smaller decrease in their school report score than students from the control condition (F(1,221)= 6.791; p= 0.010; η^2= 0.03). For Geography, the effects is the other way around: students from the experimental condition again show a small decrease in school report scores, but students from the control condition show an increase in their scores F(1,220)= 5.319; p= 0.022; η^2= 0.02). No significant effects have been found for the Math intervention.

Relationship between autonomy support activities and learning motivation

In Table 5, the results of the regression analyses with the four learning motivation scales as dependent variables have been summarized for the three school subjects. As none of the eight autonomy support activities show a significant relationship with Identified motivation for English language and Math and with External motivation for Geography and Math, the results with respect to these learning motivation variables are not included in the table.

Table 3.

Means Scores On Learning Motivation At Time 1 And 2 With Standard Deviations Within Brackets.

	English		Geography		Math	
	Exp.	Control	Exp.	Control	Exp.	Control
Intrinsic						
Time 1	3.95 (0.83)	3.20 (0.92)	2.76 (0.84)	2.77 (1.00)	3.42 (0.94)	2.96 (1.11)
Time 2	3.30 (0.93)	3.16 (0.91)	2.49 (0.80)	2.60 (0.99)	3.07 (1.06)	3.00 (0.98)
Identified						
Time 1	3.73 (0.68)	3.86 (0.66)	3.14 (0.78)	3.12 (0.80)	3.74 (0.77)	3.60 (0.70)
Time 2	3.82 (0.77)	3.79 (0.71)	2.97 (0.76)	3.04 (0.89)	3.71 (0.87)	3.50 (0.77)
External						
Time 1	**3.08 (0.92)**	**3.29 (0.89)**	3.20 (0.88)	3.20 (0.95)	3.23 (0.90)	3.35 (0.90)
Time 2	**3.41 (0.89)**	**3.30 (0.91)**	3.37 (0.83)	3.30 (0.87)	3.43 (1.01)	3.28 (0.93)
A-motivation						
Time 1	**1.92 (0.72)**	**1.79 (0.77)**	2.49 (0.92)	2.55 (0.95)	1.96 (0.71)	2.12 (0.87)
Time 2	**1.89 (0.78)**	**2.02 (0.83)**	2.77 (0.92)	2.83 (0.92)	2.16 (0.99)	2.31 (0.95)

Note. Exp.= Experimental condition; Control= control condition. Items are scored on a 5-point Likert type scale with 5 as highest score. Printed bold= significant difference with Experimental condition with higher scores than Control condition.

Table 4.

Means Scores On Student Achievement At Time 1 And 2 With Standard Deviations Within Brackets.

	English		Geography		Math	
	Exp.	Control	Exp.	Control	Exp.	Control
Student achievement						
Time 1	**7.10 (1.01)**	**7.20 (0.97)**	6.97 (1.00)	6.23 (0.91)	7.22 (1.54)	6.88 (1.34)
Time 2	**6.72 (0.93)**	**6.56 (0.91)**	6.89 (0.52)	6.38 (0.64)	6.90 (1.12)	6.62 (1.06)

Note. Exp.= Experimental condition; Control= control condition. Both pre- and post-test scores are relevant school reports with grades ranging 1 to 10, with 10 as the highest score. Printed bold= significant difference with Experimental condition with higher scores than Control condition; Printed underlined= significant difference with Experimental condition with lower scores than Control condition.

For English language, some autonomy support activities are positively related to controlled forms of motivation, with positive relationships with External motivation (Sequence, sr^2= 0.03) and A-motivation (Planning, sr^2= 0.03 and Tasks, sr^2= 0.04). The only difference between both conditions has been found with Group mates (sr^2= 0.04), with a stronger positive relationship between the extent to which students could choose their group mates in collaborative learning and intrinsic motivation for the experimental condition than for the control condition. The significant relationships can be understood as weak relationships (cf. Cohen, 1988). All relationships are corrected for the relevant pre-test scores on learning motivation.

For Geography, three autonomy support activities show a significant relationship with autonomous forms of motivation, although in a different way. Task completion (sr^2= 0.03) and Pacing (sr^2= 0.05) are positively related to Intrinsic and Identified motivation, respectively, and Tasks (sr^2= 0.03) is negatively related to Identified motivation. The three interaction effects - showing differences between the two conditions- also show mixed findings. The positive relationship between Task completion and Intrinsic motivation is caused by a significant relationship for the Control condition (r= 0.33), whereas the Experimental condition show a near-zero correlation (r= 0.04; sr^2= 0.04). Tasks and Identified motivation are positively correlated in the Experimental condition (r= 0.22), and a near zero correlation for the Control condition (r=-0.03; sr^2= 0.03). Finally, a similar pattern has been found of Ability level with A-motivation with a positive correlation for the Experimental condition (r= 0.20) and near zero correlation for the Control condition (r= 0.02; sr^2= 0.03).

For Math, two significant relationships have been found. First, the more students were allowed to pace their activities (Pacing), the lower their score on A-motivation (sr^2= 0.04). Secondly, the relationship between Group mates and Intrinsic motivation is stronger for the Control condition (r= 0.21), compared to the Experimental condition (r= 0.09; sr^2= 0.03).

Table 5. Results Of The Regression Analysis With Learning Motivation.

	English			Geography			Mathematics	
	Intrinsic	External	A-	Intrinsic	Identified	A-	Intrinsic	A-
	B (SE)	*B (SE)*	*B (SE)*	*B (SE)*	*B (SE)*	*B (SE)*	*B (SE)*	*B (SE)*
Autonomy support activities								
Planning	0.04 (0.06)	0.01 (0.07)	**0.12 (0.06)**	0.11 (0.07)	0.11 (0.07)	-0.04 (0.08)	0.07 (0.07)	0.01 (0.07)
Tasks	-0.06 (0.07)	0.08 (0.08)	**0.18 (0.07)**	-0.15 (0.09)	**-0.18 (0.09)**	0.04 (0.10)	0.08 (0.09)	-0.02 (0.09)
Sequence	0.06 (0.07)	**0.16 (0.07)**	-0.04 (0.06)	-0.03 (0.06)	-0.06 (0.06)	-0.03 (0.06)	0.02 (0.07)	0.02 (0.08)
Groupmates	0.03 (0.07)	-0.08 (0.08)	0.01 (0.07)	0.10 (0.07)	0.12 (0.07)	-0.02 (0.08)	0.12 (0.09)	-0.06 (0.10)
Sources	0.10 (0.07)	-0.08 (0.07)	-0.06 (0.06)	0.05 (0.09)	0.08 (0.08)	-0.05 (0.10)	-0.08 (0.08)	0.11 (0.09)
Task completion	-0.03 (0.10)	-0.08 (0.11)	-0.04 (0.10)	**0.21 (0.09)**	0.11 (0.09)	0.21 (0.11)	0.05 (0.08)	0.03 (0.08)
Ability level	-0.07 (0.11)	-0.04 (0.12)	0.6 (0.11)	-0.05 (0.10)	-0.11 (0.10)	-0.05 (0.06)	-0.00 (0.09)	0.06 (0.10)
Pacing	0.06 (0.07)	-0.05 (0.07)	-0.03 (0.06)	0.03 (0.06)	**0.14 (0.05)**	0.03 (0.13)	0.08 (0.07)	**-0.20 (0.08)**
Interaction condition with								
Planning	0.02 (0.09)	-0.01 (0.10)	-0.03 (0.09)	0.01 (0.11)	-0.08 (0.11)	0.03 (0.13)	0.03 (0.11)	-0.18 (0.11)
Tasks	0.06 (0.12)	-0.11 (0.13)	-0.09 (0.11)	0.21 (0.14)	**0.27 (0.13)**	0.01 (0.16)	-0.02 (0.12)	0.04 (0.12)
Sequence	-0.04 (0.08)	-0.10 (0.09)	-0.03 (0.08)	0.04 (0.08)	0.05 (0.08)	0.06 (0.09)	0.03 (0.10)	-0.08 (0.11)
Groupmates	**0.23 (0.10)**	-0.03 (0.10)	-0.00 (0.09)	-0.05 (0.09)	-0.01 (0.09)	-0.05 (0.10)	**-0.23 (0.11)**	0.15 (0.12)
Sources	-0.12 (0.09)	0.13 (0.09)	0.06 (0.09)	-0.07 (0.11)	-0.08 (0.11)	0.12 (0.12)	0.05 (0.11)	-0.10 (0.12)
Task completion	0.03 (0.12)	0.12 (0.13)	0.03 (0.12)	**-0.28. (0.11)**	-0.11 (0.11)	0.07 (0.12)	-0.00 (0.11)	0.01 (0.12)
Ability level	0.04 (0.14)	-0.03 (0.15)	-0.12 (0.13)	0.06 (0.16)	0.10 (0.16)	**-0.40 (0.18)**	0.11 (0.12)	-0.16 (0.13)
Pacing	-0.05 (0.09)	0.06 (0.09)	0.03 (0.08)	0.09 (0.08)	-0.06 (0.08)	-0.01 (0.09)	0.04 (0.09)	0.16 (0.10)
Model summary								
R^2	0.37	0.27	0.20	0.33	0.26	0.19	0.40	0.22
F (df)	6.77 (17, 150); *p*< 0.001	4.71 (17, 150); *p*< 0.001	3.42 (17, 150); *p*< 0.001	5.87 (17,149) *p*< 0.001	4.43 (17,149) *p*< 0.001	3.31 (17,149) *p*< 0.001	7.33 (17,148) *p*< 0.001	3.69 (17,148) *p*< 0.001

Note. SE= standard error; Interaction= interaction effect autonomy support activity * condition with control condition = 0. Covariates are not included in this table. Only motivation scales with at least one significant effect are included. Significant effects are printed bold.

Relationship between autonomy support activities and achievement

In Table 6, we have summarized the results of the regression analyses for the three school subjects, with student achievement as dependent variable, the ability-test score as co-variate and the eight autonomy support activities and interaction Condition by Autonomy support activity as predictors.

Table 6.

Results Of The Regression Analyses With Student Achievement.

	English		Geography		Math	
	B (SE)	sr^2	*B (SE)*	sr^2	*B (SE)*	sr^2
Covariate						
Time 1 Achievement	**0.75 (0.05)**	**0.56**	**0.39 (0.04)**	**0.41**	**0.42 (0.05)**	**0.30**
Autonomy support activities						
Planning	-0.09 (0.05)		**-0.08 (0.04)**	**0.03**	0.01 (0.06)	
Tasks	-0.05 (0.05)		0.01 (0.03)		-0.02 (0.07)	
Sequence	0.10 (0.06)		-0.01 (0.03)		0.10 (0.08)	
Group mates	-0.06 (0.06)		0.06 (0.04)		-0.03 (0.09)	
Sources	0.06 (0.06)		0.00 (0.04)		-0.03 (0.07)	
Task completion	-0.10 (0.06)		-0.03 (0.05)		-0.04 (0.08)	
Ability level	-0.03 (0.05)		-0.01 (0.04)		-0.01 (0.07)	
Pacing	-0.01 (0.06)		-0.03 (0.04)		0.07 (0.09)	
Interaction condition with						
Planning	0.07 (0.06)		**0.10 (0.04)**	**0.03**	-0.01 (0.08)	
Tasks	0.07 (0.06)		-0.01 (0.04)		0.03 (0.09)	
Sequence	-0.06 (0.07)		-0.03 (0.05)		-0.14 (0.11)	
Group mates	0.08 (0.08)		-0.06 (0.05)		0.07 (0.11)	
Sources	**-0.17 (0.08)**	**0.03**	0.05 (0.06)		0.10 (0.11)	
Task completion	014 (0.07)		-0.03 (0.06)		0.01 (0.10)	
Ability level	0.04 (0.06)		0.03 (0.05)		0.01 (0.10)	
Pacing	-0.00 (0.07)		0.02 (0.05)		-0.04 (0.11)	
Model summary						
R^2	0.56		0.52		0.29	
F (df)	13.82 (17, 157); $p<0.001$		12.02 (17, 155); $p<0.001$		5.14 (17,154); $p<0.001$	

Note. SE= standard error; sr^2= squared semi-partial correlation. Interaction= interaction effect autonomy support activity * condition with control condition = 0. Significant effects are printed bold.

Only three significant relationships between autonomy support activities and student achievement have been found, indicating weak relationships with a sr^2 of 0.03. For the intervention with English language, an interaction effect between Source and achievement have been found that indicates a small negative correlation for the experimental condition (r= -0.10) and a zero correlation for the control condition (r= -0.00). For Geography, two effects with respect to Planning have been found. First, the more students made a planning of their time and work, the *lower* their achievement. This negative relationship is even stronger for students from the experimental condition (r= -0.25) than students from the control condition (r= -0.22). No significant relationships have been found for the intervention with Math.

Discussion and Conclusion

Personalizing learning with technology in secondary schools can be a way to empower students to take control over their learning. Our expectation was that the more learners can direct their own learning experiences, including path, pace and instructional approach, the more they learn what they need to learn and what they want to learn. In a quasi-experimental design, questionnaire data and exam records have been gathered about the implementation and evaluation of the interventions with personalizing learning in one secondary school in the Netherlands. The aim of the interventions was to provide students with opportunities to regulate their own learning and support their autonomy in order to personalize their learning and make it more worthwhile.

One of the three interventions, English language, shows a significant increase in perceived autonomy support. This one is also the one that allows students the most autonomy to choose the items for practicing and reviewing, in addition to pacing and sequencing, compared to the other two interventions. Yet the differences between the three interventions do not show in the evaluation of the autonomy support activities: all three interventions show relatively high scores for students' freedom to choose their own sources and relatively low scores for making a time planning, compared to the control condition. In addition, the Geography intervention shows relatively high scores on students' freedom to choose their group mates and to complete tasks the way they want, and the Math intervention shows scores on the autonomy to choose the sequence of tasks and to do task at different ability levels, compared to the control condition and the other school subjects.

Furthermore, the effects of the intervention on students' learning motivation and achievement are mixed as well, with the one with the highest autonomy support (English language) as the most positive one. These mixed findings with respect to motivation and achievement are in line with findings from previous studies showing no effects of the use of tablets in learning (Lin, 2017), but are in contrast of findings of studies on autonomy support showing positive findings on motivation and achievement (Wei et al., 2020; Zhou et al., 2019).

Finally, various relationships are found between the perceived autonomy support activities, on the one hand, and learning motivation and achievement, on the other hand. The eight autonomy support activities show different relationships with learning motivation, either positive or negative. This means that student perceived some of the autonomy support activities as demotivating and others as motivating. A reason for

these differential outcomes might be that some of the autonomy support activities were not perceived as autonomy supportive by the students, such as the extent to which students made a work planning (Planning) and the chance to do tasks at your own ability level (Ability level). These activities might have been evaluated as teacher pressure instead of autonomy supportive (cf. Reeve & Jang, 2006; Bennett et al., 2017) as teacher controlled the planning and difficulty level of the tasks. Overall, the freedom to do your work at your own pace (Pacing), to do the tasks you want (Tasks) and the way you want (Task completion) and to choose your own group mates in collaborative learning (Group mates) seem to be autonomy support activities that do show a positive relationship with either students' learning motivation or their achievement.

Personalizing learning approach

The mixed findings confirm the conclusions of Sorgenfrei and Smolnik (2016) in their review of 54 empirical studies on learner control and effectiveness of e-learning. In their conceptual model of the relationship between learner control interventions and learner achievement, they emphasized the role of *perceived* learner control as well as the differential influences on this relationship of both learner characteristics and teaching approach. In the current study, one intervention (English language) shows a positive relationship with achievement, another (Geography) a negative. This finding suggests that not all teaching approaches that are directed to enhancing learner control and students' personalized learning activities might be effective. These findings are also in line with the review studies of Karich et al. (2014) and Niemiec et al. (1996), who reported many near zero-effects of personalizing learning interventions on student achievement. Learner characteristics as well as teaching approach with various selections or combinations of personalizing learning activities might have a differential effect on student achievement.

The use of technology

In the model of Sorgenfrei and Smolnik (2016) technology is not explicitly addressed and can be included in the environmental context that moderates the relationship between perceived learner control and student achievement. In the current study, laptops have been used to facilitate access to materials and independent and collaborative work of the students. Yet the way and intensity technology has been used is different between the interventions. From the student evaluations, it appears that students see benefits of using tablets for learning because of practicalities: it makes it easier to find and use internet resources, it allows repeating the same speaking skill over and over, and all materials are included in one device, which means students do not have to carry their books to school. These evaluative findings confirm the conclusion from Hassler et al. (2016) that many schools have integrated digital tools into daily practice, but that those devices are not always being used in ways that best maximize their potential. We can conclude that future research should point out how teaching with technology can support not only personalized learning in which learning is customized for the interests, preferences and capabilities of the learners, but also flexible and adaptive learning and teaching as well as situated and authentic learning (Clark & Luckin, 2013; Sung et al., 2016).

Limitations and directions for future research

Differences between autonomy supportive activities, students, and teaching approaches might explain the mixed findings of the current study. A first limitation we should address is the small sample size, which led to low power of our statistical tests and therefore does not allow robust interpretations. A second limitation refers to the limited variety of data that have been collected with student questionnaires and school administration. No data have been collected *during* the school year, such as class observations, completed tasks of the students or logs from the learning environments. This kind of data could have provided a deeper insight in the implementation and evaluation of the three interventions and autonomy support activities. In addition, with more data on student characteristics and teaching approaches, more advanced analyses might also be possible to, for example, examine the moderating role of student characteristics (cf., Graça, Calheiros, & Barata, 2013) and teacher characteristics (cf., Bennett et al., 2017) on the effects of autonomy support activities on students' learning motivation and learning outcomes. Also, larger sample sizes will make it possible to examine the mediating role of learning motivation between autonomy support and student achievement, following other studies on autonomy support (cf., Zhou et al, 2019). Although we realize that more elaborated data collection and more advanced statistical analyses require large research efforts, in this way future research on autonomy support, learning motivation and achievement can further contribute to understanding the effectiveness of teachers' autonomy support.

Conclusion

This study on effects of personalizing learning interventions on students' perceived autonomy support, learning motivation and achievement has contributed to our understanding of personalizing learning with technology in secondary education. Although the findings are mixed, it seems that learner control over structural aspects of the curriculum, such as students' autonomy to choose their tasks for practicing and reviewing and the way to complete them, are possible effective ways of designing personalizing learnings. Future research can further this understanding by examining other ways and levels of learner control, beyond the freedom to do tasks at your own pace and search and select learning materials.

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Corresponding Author Contact Information:

Author name: Wilfried Admiraal

Department: ICLON Graduate School of Teaching

University, Country: Leiden University, the Netherlands

Email: w.f.admiraal@iclon.leidenuniv.nl

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