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'The best app is the teacher' Introducing classroom scripts in technology-enhanced education

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Abstract A quasi-experimental study was set up in secondary education to study the role of teachers while implementing tablet devices in science education. Three different classroom scripts that guided students and teachers' actions during the intervention on two social planes (group and classroom level) are compared. The main goal was to investigate which classroom script leads to the best results regarding progress in domain-specific knowledge and inquiry skills. Besides student achievement, students' experiences towards the role of the teacher and students' perceptions towards learning with tablets within the three conditions were investigated.

In the first condition, the classroom script included learning activities that were balanced between the group and the classroom level. In the second condition, the learning activities occurred predominantly on the group level. The third condition entailed the classroom script as the control condition in which the learning activities were situated only on the classroom level, with the tablet used in a traditional way or as *'book behind glass'*. Results show that students perform better on domain-specific knowledge in the conditions where the teacher intervened on the classroom level. Regarding the acquisition of inquiry skills, students performed best in the condition where the learning activities were balanced between the group and the classroom level. Moreover, students who perceived more structure achieved better. These results indicate that the role of the teacher cannot be ignored in technology-enhanced learning. Moreover, these results seem to suggest that one of the best apps remains the teacher.

Keywords classroom scripts, inquiry learning, science education, student outcomes, tablet devices, technology-enhanced learning.

Introduction

Since the upcoming introduction of tablet devices in education, these tools are considered by international researchers (e.g., Clark & Luckin, 2013; Sung, Chang, & Liu, 2016) as promising tools for technology-enhanced learning (TEL) in education. Moreover, it is claimed that technology such as tablet devices can be easily adopted in classroom instruction and has the potential to change teaching and learning practices (Enriquez, 2010; Twining & Evans, 2005). Moreover, these tools can facilitate the shift from the traditional classroom setting, where the student is seen as a passive consumer of educational knowledge, to a classroom in which learners are considered active participants and where collaboration and sharing information in a resource-rich environment are given precedence (Pelgrum, 2001). In line with these benefits, a recent report of the OECD (2015) pointed at the strong association between the use of technology and the opportunities for student-oriented practices. Furthermore, technology can facilitate students to actively construct knowledge from an inquiry approach (Slotta & Linn, 2009). However, research is lacking concerning the role of the teacher while implementing technology such as tablet devices to promote student-centred learning approaches. Therefore, in

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this study, we focused on the role of teachers in TEL by implementing three macro- or classroom scripts.

Inquiry-based learning

Following this student-centred approach, where students are encouraged to actively be involved in learning, the term 'inquiry-based learning' can be introduced. Inquiry-based learning can be seen as opposed to more traditional approaches, which tend to emphasize the memorizing of factual information (Raes, Schellens, & De Wever, 2013). Moreover, students have to actively construct knowledge by formulating hypotheses, searching and interpreting data (Mäkitalo-Siegl, Kohnle, & Fischer, 2011). Several researchers showed that (e.g., Alfassi, 2004; Slotta & Linn, 2009) this method is more effective and leads to better learning outcomes compared with a frontal teaching context. However, the debate in the science education community discussing the effectiveness of direct instruction versus learning through inquiry, or finding a balance between direct instruction and inquiry learning is still on-going. On the one hand, learning with direct instruction can provoke rote learning, which could harm students' motivation and acquisition of non-transferrable knowledge. On the other hand, learning through inquiry entails some difficulties. Research of Kirschner, Sweller, and Clark (2006) shows that minimal guidance during inquiry-based activities is insufficient. Without guidance, students could have false starts of the learning process and do not understand the content (Schauble, 1990). In this light, the knowledge integration (KI) perspective on science learning can be introduced and can be defined as the process of incorporating new information into a body of existing knowledge by guiding students to engage in inquiry (Linn & Eylon, 2011). According to the KI approach, students may have multiple, conflicting and often confusing ideas about science.

The role of the teacher during technology-enhanced learning

It can be argued that the use of technology during classes has several benefits, such as increased motivation (Ciampa, 2013), fostering engagement during learning (Falloon, 2014) and support of student-centred didactical approaches (OECD, 2015). In addition, previous research suggests that gender and age may have a significant impact on TEL (Chen & Macredie, 2010; Montrieux, Vanderlinde, Schellens, & De Marez, 2015). However, merely implementing technology into classes does not necessarily lead to a radical change of the didactic teaching methods of teachers (Montrieux et al., 2015). Several previous studies (Karsenti & Fievez, 2013) even show that most of the teachers do not succeed in applying the aforementioned potential of introducing mobile devices in the classroom, which consequently does not result in changing teaching and learning practices. In a previous study (Montrieux et al., 2015), we concluded that teachers make use of tablets in their classrooms as *'book behind glass'* tools. It was observed that teachers still manage conservative practices by taking up a stringent role in front of the classroom and giving traditional courses with a tablet computer. On the one hand, research of Ifenthaler and Schweinbenz (2013) can partly explain this as they indicate that the majority of the teachers do not know how tablet devices can be used as an innovative tool to facilitate learning and instruction and consequently use it in the way they use their traditional tools which are books and worksheets. Mäkitalo-Siegl et al. (2011), on the other hand, indicate that many teachers also hold a 'replaced-by technology' mind-set which in contrast makes that students are left to their own devices and can result in students that get overwhelmed by the complexity or the frustration that can sometimes arise in doing inquiry (Sierens, Vansteenkiste, Goossens, & Soenens, 2009; Tabak & Reiser, 2015).

In that context, it has been stressed that more research is needed in order to investigate how teachers should act when implementing tablet devices to have a positive impact on learners' experience (Li, 2010). Empirical research that can inform teachers about how to implement tablet devices to optimize the learning effects in authentic classroom is lacking (Burden, Hopkins, Male, Martin, & Trala, 2012; Clark & Luckin, 2013; Falloon, 2014; Ifenthaler & Schweinbenz, 2013; Twining & Evans, 2005).

Despite the limited available research (Haßler, Mayor, & Hennessy, 2015; Sung et al., 2016), we can build on limited previous research, focusing on the role of the teacher in computer-supported learning (Kollar, Wecker, Langer, & Fischer, 2011, 2013; Mäkitalo-Siegl et al., 2011; Raes & Schellens, 2015). These studies stress the pivotal role teachers' play when it comes to technology integration in the classroom and confirm the concept of ‘classroom orchestration’ (Dillenbourg, 2013), a pedagogical approach of TEL that emphasizes attention to the challenges of the use of technology into the classroom and with a focus on supporting the teachers’ role within it. In 2013, the European Network of Excellence in Technology-Enhanced Learning (STELLAR) highlighted orchestration as one of its ‘Grand Challenges’ (Roschelle, Dimitriadis, & Hoppe, 2013). Moreover, Roschelle et al. (2013) claim that the introduction of this concept is an effort to do meaningful research by acknowledging the complexity and variability of classrooms and the mediating role of the teacher. When introducing technology in the classroom, some stress that the role of the teacher cannot be ignored but needs to be redefined ‘from the sage on the stage to a guide on the side’ (Carey, 2008). However, Dillenbourg (2009) noticed that by learning with technology, putting teachers ‘on the side’, would not enhance learning. Slotta and Linn (2009, p.119) suggest that web-based inquiry learning can only improve KI if the teacher acts as ‘the leader from within’. Moreover, student-centred learning and constructivism are often being confused with a minimization of the role of the teacher, this while the teachers have instead of the guide on the side a central role in orchestrating multi-level activities.

Scripting the role of the teacher

Previous studies (e.g., Ifenthaler & Schweinbenz, 2013) show that teachers are not used nor prepared for embedding inquiry-based form of learning with tablet technology in their curriculum. The little amount of available studies (Kollar et al., 2011, 2013; Mäkitalo-Siegl et al., 2011; Raes & Schellens, 2015) put forward a classroom script or macro-script to guide the teacher across different social levels. Following Vygotsky (1978), learning activities can occur on the individual level, on the group level and finally on the classroom level. To define the activities on the different levels, previous research has introduced the concept of ‘macro or classroom scripts’ (Dillenbourg & Hong, 2008). In contrast with micro scripts – that emphasize the activities of individual learners – classroom scripts are pedagogical models or scenarios that structure a sequence of activities taking place on the individual, the group or the class level. This with the aim of enhancing productive learning activities (Dillenbourg & Jermann, 2007). Providing such classroom scripts could be a facilitator of the implementation and could foster successful orchestration. Research focusing on how classroom scripts can support the teachers’ role in inquiry-based science learning is thus needed (Edelson, Gordin, & Pea, 1999). However, Cress (2008) mentions the issue that empirical research in TEL research has not yet adopted widespread.

Focus and research questions of this study

In line with the previous studies and building on the aforementioned gaps, this quasi-experimental study designed and compared three classroom scripts to study how teachers can implement tablet devices in the classroom and how they can manage students’ activities and their own activities to get the best results. Three macro or classroom scripts, comparing the activities on the different social planes, have been implemented during a 4-h intervention in secondary science classes to investigate under which conditions students achieve the best results on domain-specific knowledge and inquiry skills. Besides students’ achievement, the role of the teacher within the different conditions was investigated. Finally, students’ perceptions towards learning in their assigned condition were measured. In addition to the main questions, the impact of students’ characteristics is taken into account during the analyses:

Following research questions were put forth in this study:

Research question 1: What is the impact of the intervention on

A) **Domain-specific knowledge**?
B) **Inquiry skills**?

Research question 2: What are the **perceptions** of the students towards **the role of the teacher** within the different conditions/macro scripts?

Research question 3: What are the **perceptions** of the students towards **the learning approach used in the assigned condition**?

Based on the available research, it is hypothesized that students who learn in an inquiry-based way with simultaneous teacher interventions will experience more teacher support, which, in turn, will result in better domain-specific knowledge and inquiry skills. In addition, these students will evaluate the intervention as the most positive.

Method

Context and participants

This study was conducted in the context of a pioneering secondary school in Flanders where tablet devices (iPads) were implemented into the classroom organization. Since the beginning of the school year 2012, all students and teachers have a personal tablet to use in both class and home environments. Based on this introduction of tablets, it was possible to conduct an intervention study during February–March 2014 in authentic classroom settings with 139 students (grade 9 and 10) from nine classrooms and their science teachers (n = 3). Each teacher gave classes in the three different conditions. The average age of the students was 16 years, 50.4% were girls. In addition, 80% of the students followed the general-oriented track, whereas 20% of the pupils followed the technical-oriented track.

Design and procedure

As depicted in Figure 1, based on the social planes, a quasi-experimental study was conducted in science education. Moreover, three macro scripts were implemented as three conditions. In the first condition (C1), activities alternated between group level (inquiry tasks in pairs) and class level (plenary instruction by the teacher). Moreover, both group and class level activities are sequenced. In the second condition (C2), students worked on inquiry tasks in pairs without the plenary guided instruction; the group level is central. These student pairs could only use the instructions provided in the learning material, and they could ask the teacher individual questions. In the third condition (C3), the control condition, plenary instruction with the tablet used as *'book behind glass'* was given (without applications, without searching on the Internet). Nine participative classes were randomly assigned over these three conditions. The study consisted of three intervention sessions of each 50 min. Before the intervention (25′), all students (N = 139) were asked to complete an online survey with the online survey tool 'Qualtrics' on their personal tablet devices. The didactical approach depended on the condition students were assigned to. Following Dillenbourg and Jermann (2007) and Kollar and Fischer (2013), the teachers were provided with this macro script that functioned as a protocol to guide the intervention. These outlined goals and predefined learning activities are guidelines on how the lessons should proceed. The script that is used during the intervention can be found in Appendix A. In addition, Master students of Educational Sciences were involved during the intervention to control the intervention, to guide teachers through the pre-mentioned macro scripts and observe the lessons during the intervention. Finally, after the intervention, students were asked to complete the online posttest (25′).

Students in the three conditions had to master the same amount of new content (glands, communication between

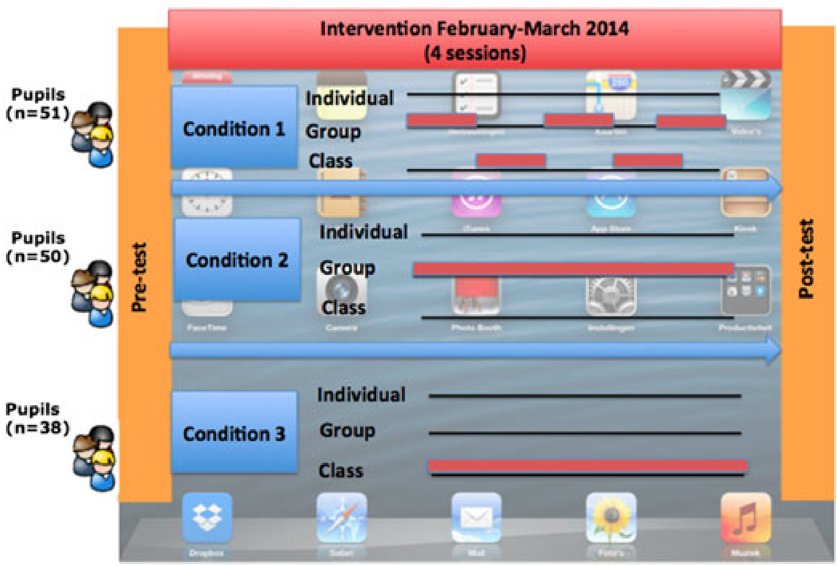

Figure 1 The Procedure of the Intervention [Colour figure can be viewed at wileyonlinelibrary.com]

animals and energetic reactions) during the intervention. However, students in the inquiry-based conditions *(condition 1 and 2*, see Figure 1) received learning material adapted to the opportunities of tablet devices. Moreover, applications such as Lino (an online stickies service), Popplet (an application to capture and organize information), Show me (an application to record voice-over whiteboard tutorials and share them online), Drillster (an adaptive learning tool that gives immediate feedback) and Socrative (an application to engage and assess pupils during learning) were used in *condition 1 and 2*. These apps aimed at active knowledge construction among students. Besides the adapted version of the traditional learning material, the content in *condition 1 and 2* was transformed into three mini-inquiry quests. Each mini-inquiry task was based on the same structure and involved the steps of the inquiry cycle as described by Bruce and Davidson (1960) (formulating the research question and hypothesis generation, data collection, and reporting and reflection). Because each lesson consisted of 50 min, adopting mini-inquiry tasks running the different steps of inquiry seemed to be efficient because students were able to run the inquiry learning steps three times. For students in *condition 3*, the same learning content has been developed, but without the steps of inquiry learning or applications. Moreover, these students could only follow the course, instructed by the teacher and could take notes with their tablet. In other words, in this condition, the tablet devices are implemented as '*book-behind*-glass'.

Measurement and analysis

The students completed pre- and post- questionnaires that consisted of several sections partly based on existing scales (Table 1). Students' background characteristics comprised gender, age and academic track. Achievement level was calculated by the mean on their exam results for science, whereas students were divided into high versus low achievers.

Table 1. Structure of the Pre- and Posttest Questionnaire

• Students' background characteristics • Domain-specific knowledge • Inquiry skills • TASQ	• Students' background characteristics • Domain-specific knowledge • Inquiry skills • TASQ • Evaluation questions towards the learning approach • Final open question

The pre- and posttest to measure domain-specific knowledge consisted of five items, which were a balanced mix between open-ended questions and multiple-choice questions. The open-ended questions were scored by means of a rubric (Linn & Eylon, 2011). A scoring rubric was created for capturing progressively more sophisticated levels of KI in student responses. Research on KI items shows that items scored using the KI rubric form meet all the criteria for item response theory models. See Appendix B for an example of the rubric and scores of the domain-specific content knowledge. To check the inter-reliability, two independent raters who were both trained to use the rubrics coded the answers. Regarding all items, Krippendorff's alpha ranged from .77 (pretest) to .83 (posttest), which means that there is an excellent interrater agreement (Hayes & Krippendorff, 2007).

Next, and in line with previous research of Raes et al. (2013), the science inquiry skills were measured (both in pre- and posttest) by providing students an abstract of an academic magazine (see Appendix C). Students were asked to formulate an adequate research question and to generate a hypothesis, and they also had to describe how the researchers of the study investigated this research question. Finally, the scores were summed up to one global score for inquiry skills. Two independent raters who were trained to use the proposed rubrics coded the answers of the students regarding the steps of inquiry learning. The first rater coded the answers of all students. To check the inter-reliability, the second rater independently coded 30% of the answers (N = 42). Krippendorff's alpha ranged from .92 (pretest) to .84 (posttest), which means that there is a very good interrater agreement (Hayes & Krippendorff, 2007).

Besides the variables mentioned above, students' experiences towards the role performance of their teacher were measured by means of the scale 'structure' of the existing questionnaire 'Student Report of Teacher Context' (TASQ), developed by Belmont, Skinner, Wellborn, & Connell (1988). This variable can be divided into two constructs: Help/Support and Adjustment/Monitoring. See Table 2 for the operationalization of the scales. The scales were rated on a 5-point Likert scale (1 completely disagree – 5 completely agree), and the Cronbach's alphas were satisfying (ranging from .78 to .81).

Table 2. Questions of TASQ (Belmont et al., 1988)

Constructs of TASQ	Example questions
Help/support	My teacher shows me how to solve problems for myself. If I can't solve a problem, my teacher shows me different ways to try to. My teacher doesn't help me, even when I need it. Even when I run into problems, my teacher doesn't help me. My teacher doesn't seem to know when I need help.
Adjustment/ monitoring	My teacher makes sure I understand before he/she goes on. My teacher checks to see if I'm ready before he/she starts a new topic. My teacher doesn't check to see if I'm keeping up with him/her. My teacher doesn't know when I'm ready to go on. My teacher doesn't check to see if I understandbefore he/she goes on.

The posttest ended with two evaluation questions, rated on a 5-point Likert scale (1 completely disagree – 5 completely agree). The first evaluation question, containing 11 questions, was based on the questionnaire of Burden et al. (2012), whereas students' attitudes towards learning with the tablet in their assigned condition were measured (e.g., 'I learned more by this learning approach compared to the other courses', 'I prefer this kind if learning compared with the lessons before the intervention'). The second evaluation question entailed six questions whereas the students could state if they prefer more the traditional way of learning or the inquiry-based learning with tablets. The Cronbach's alphas were satisfying (ranging from .66 to .85).

Given the design and the hierarchical structure of the experiment (different levels: classroom – group – individual student), a multilevel analysis is appropriate (Cohen, Manion, & Morrison, 2011). However, first analyses showed no significant differences between the different levels. Only significant variances on the student level could be found. Based on these findings, data was analysed from a one level perspective with the statistical package SPSS. In particular, using stepwise regression, univariate and linear regression analyses are presented. The significance level was .05 for all analyses.

Next to quantitative data, also qualitative data was gathered. Moreover, at the end of the questionnaire, the students were asked in an open question to express their remarks about the didactical use of tablets during the course. The answers of the students were categorized into positive and negative perceptions towards the condition students were assigned to. These data were used to add nuance and contour to the study, enriching it beyond what quantitative analysis can offer. In addition to this data, all the lessons were videotaped, and the Master students provided detailed logbooks of the intervention.

Results

Research question 1

Concerning research question 1a), we focused on the impact of the condition on pupils' achievement of **domain-specific knowledge**. ANCOVA was conducted. Based on the backward method, all predictors were taken into the model (pretest score, condition, gender, age, achievement level and academic track). Due the fact that only the variables pretest score ($F(1,105) = 12.78$, $p = .001$), condition ($F(2,105) = 3.84$, $p = .03$), gender ($F(1,114) = 6.66$, $p = .010$), age ($F(1,105) = 21.18$, $p = .000$) and an interaction effect of condition and academic track ($F(1,105) = 4.88$, $p = .03$) were making a statistically significant contribution, the other predictors 'achievement level' and 'academic track' have been removed from the model ($p > .05$).

The results showed that the condition variable has a significant impact on students' achievement ($F(2, 114) = 8.88$, $p = .00$). *Post hoc* comparisons using the Bonferroni test indicated that the mean score for the students who worked without plenary instruction (C2; Mpost = 48.36, $SD = 2.61$; Mpre = 19.36, $SD = 10.02$) was significantly lower (mean difference = 14.51; $p = .001$) compared to the score of students in the control condition (C3; Mpost = 62.87, $SD = 2.43$; Mpre = 15.17, $SD = 14.14$). In addition, a significant difference between the mean score of condition 1 (Mpost = 58.50, $SD = 2.45$; Mpre = 20.85, $SD = 13.23$) and condition 2 (mean difference = 10.14; $p = .013$) was measured. Finally, no significant difference between condition 1 and 3 could be found ($p > .05$).

These results suggest that the role of the teacher is important; students who followed classes with teacher-led interventions (C1 and C3) performed significantly better compared to students who worked without any help of the teacher (C2). However, based on descriptive data, students in the third condition performed the best. These findings indicate that students learn best in the old-fashioned way (C3), followed by condition 1. Condition 2, which does not provide teacher guidance, seems to disadvantage students. Next to condition, gender (F(1,114) = 6.66, p = .011) and age (F(1,114) = 25.55, p = .000) have a significant effect on domain-knowledge: pupils of grade 9 performed better (M = 63.98, SD = 2.17) compared to pupils of grade 10 (M = 47.47, SD = 2.00); and girls (M = 58.76, SD = 1.99) performed in general significant better on the test compared to boys (M = 51.87, SD = 2.10). However, no interaction effects between these predictors and condition ($p > .05$) could be measured. Finally, a significant interaction effect between condition and academic track can be noticed (F(2,114 = 3.84, p = .024). However, because of the limited amount of students in the technical oriented track, only a comparison between condition 1 and condition 2 can be reported. Results show that students from a technical-oriented track performed significantly better in the condition with a teacher (C1) whereas there is no significant difference ($p > .05$) between condition 1 and 2 concerning students of the general-oriented track.

As an answer to research question 1b), results show that condition has a significant impact on enhancing **the inquiry skills**. Specifically, the skill 'formulating an adequate research question' (with maximum score of '2') was significant (F(1,119) = 3.90, p = .02). In order to compare the results over the three different conditions, appropriate follow-up contrasts show that students in condition 1 scored better (M = 1.97, SD = .06) compared to students in condition 2 (M = 1.75, SD = .06) (no plenary teacher feedback on the formulated research question) or condition 3 (M = 1.79, SD = .07) (no inquiry-based tasks). Moreover, contrasts show a significant difference between condition 1 and 2 (p = .010) and a significant difference between condition 1 and 3 (p = .044). No significant differences were observed between condition 2 and 3 ($p > 0.05$). In other words, students who worked in an inquiry-based manner with teacher interventions (C1) have gained more inquiry skills compared to students who worked in an inquiry-based manner without plenary teacher interventions (C2) or students of the control condition (C3). However, the mean scores are high in the different conditions. No significant effects between students' characteristics and inquiry skills could be found ($p > .05$).

Research question 2

In order to answer the second research question: 'What are the perceptions of the students towards **the role of the teacher** within the different macro scripts?' first, linear regression analyses were applied. Results showed a significant relation (F(1,126) = 18.90, $p < .05$) between the level of experienced structure and the posttest scores. Students, who experienced more structure during the intervention, achieved better results.

Based on the analysis of variance (ANOVA), a significant effect of condition towards perceiving structure (the construct adjustment/monitoring) (F(2,105) = 3.34, $p < .05$) was found. Students in condition 1 (M = 2.70, SD = .08), followed by students in condition 3 (M = 2.67, SD = .10), whereby the teacher had a predefined role, perceived more structure during the course, compared to students in condition 2 (M = 2.39, SD = .10). Focusing on the background characteristics, no effects could be found ($p > .05$).

To complement these findings, qualitative data from the final question showed that students complained about the minimal guidance of their teacher in the second condition: *'I prefer the teacher in front of the classroom instead of having to learn individually'* (Student C2, 9th grade); *'I understand the content better with classical instruction'* (Student C2, 9th grade); *'I prefer courses instructed by the teacher'* (Student C2, 10th grade). Moreover, almost every comment emphasized the need for additional feedback from the teacher, who structures the content and gives an overview of the content. More details are explained under research question 3 and Table 7.

Research question 3

Finally, pupils' **perceptions towards learning with tablets** were investigated. Using multivariate ANOVA (MANOVA), with the 11 items such as dependent variables and condition as independent variable, results show a significant impact of condition towards the evaluation of using tablets (Wilks' Lambda = .66, F(22,232) = 2.48, p = .000). Moreover, two items: *'I would like to have more courses with the iPad just like in the intervention'* (F(2,) = 8.47, p = .000) and *'I learned more on this way of teaching with the iPad'* (F(2,) = 6.62, p = .002) were significant (Table 3).

Concerning the first item, the Bonferroni test indicated that only condition 2 differs significantly from condition

Table 3. Descriptives of Evaluation Items

Item	C1 (Group- and class level) *M*(*SD*)	C2 (Group level) *M*(*SD*)	C3 (Class level) *M*(*SD*)
'I would like to have more courses with the iPad just as in the intervention'	3.04 (.15)	2.36 (.15)	3.21 (.17)
'I learned more on this way of teaching with the iPad'	2.67 (.14)	2.26 (.14)	3.03 (.16)

1 (mean difference = .68, p = .004) and from condition 3 (mean difference = .84, p = .001). No significant difference between condition 1 and 3 could be measured ($p > .05$). In other words, these results revealed that there is no difference in appreciation towards the didactical approach during the intervention for students who were assigned to the first and third condition. It is obvious that student assigned to the second condition did not appreciate the didactical approach of learning on an inquiry-based manner positively, without classical interventions. No relations with background characteristics could be found. This tendency is also reflected for the second item: '*I learned more by this way of teaching with the iPad*'. Students from the second condition gave significantly lower scores compared to condition 3 (mean difference = −.77, p = .001), whereas there is no significant difference between condition 1 and 3 ($p > .05$). Only the background variable 'age' was significant ($F(1,96) = 4.22$ $p = .04$) whereby students from 9th grade are more positive ($M = 2.87$, $SD = .14$) compared to the students of 10th year ($M = 2.44$, $SD = .13$).

Besides the 11 evaluation items, students' preference towards learning on a '*book-behind-glass* method or by inquiry-based method was measured (see Table 4 for the descriptives).

Table 4. Descriptives of Preferences Towards a Particular Didactical Method

Item	Preference towards inquiry-based method *M*(*SD*)	Preference towards book-behind-glass method *M*(*SD*)
Condition 1 (Group- and class level)	3.20 (.74)	3.22(.69)
Condition 2 (Group level)	2.92(.84)	3.41 (.77)
Condition 3 (Class level)	3.48(.49)	3.27(.54)

Using MANOVA, condition is significant (Wilks' Lambda = .89, $F(4,250) = 3.63$, $p = .007$). Moreover, as depicted in Table 6, students of condition 2 were the most negative towards the inquiry-based learning approach compared to students of the first condition. Furthermore, they reported the most positive towards learning in the '*book-behind-glass*' method. In addition, the background characteristics 'gender' and 'age' are significant. In general, boys show more preference towards the inquiry-based method ($M = 3.33$, $SD = .10$) compared to girls ($M = 3.05$, $SD = .10$), and younger students show more preference towards the inquiry-based method ($M = 3.40$, $SD = .10$) compared to the older students ($M = 3.07$, $SD = .10$).

Based on the qualitative data, when focusing on ***condition 1*** (n = 51 students), 20 students expressed positive feedback on learning in an inquiry-based manner. When focusing on the 25 negative comments, the students reported both the rapidness of the intervention and the difficulty to learn in an independent way frequently. When making a distinction between the grades, students of grade 9 were more positive (13 positive comments and 4 negative comments) about condition 1 as compared with students of grade 10 (7 positive comments and 21 negative comments). In Table 5, some examples of students' quotes are formulated.

Inquiry learning requires more time in order to process the same amount of content, as compared with classical

Table 5. Examples of Quotes of Students Concerning Condition 1 (Inquiry Activities Alternated Between Group Level and Class Level)

Positive quotes	'I learned more because I am actively involved during the course' (C1, 9th grade)'I was more motivated to learn' (C1, 9th grade)
Negative quotes	*'I learn better when the teacher offers me the information instead of when we have to search information by ourselves'* (C1, 10th grade)*'I prefer the course as before because I am used at it'* (C1, 10th *grade*)

courses in which teachers instruct the content and where learners are passive consumers. Because the same content over the three conditions in three lessons is programmed, there was a lot of time pressure among the students in the inquiry-based conditions 1 and 2. Consequently, students were under pressure and had no time enough to investigate the content deeply (Table 6).

When zooming in onto the comments in ***condition 2***, students are sceptic about this mode of learning (17 positive comments and 32 negative comments; 9th grade: 12 positive and 15 negative comments; 10th grade: 5 positive comments and 17 negative comments). While positive aspects such as the active involvement and the fun factor to learn with applications are mentioned, the majority of the comments were rather negative. Most of the negative comments involved the need of structure by the teacher (Table 7).

Looking at the ***3rd condition***, most of the students state that they did not found any difference with the course before the intervention (Table 8). Moreover, they confirm that they are used to have classes with the *book-behind-glass* format.

Table 6. Examples of Quotes of Students Concerning the Time Pressure

'I would perform better if it went a little slower' (C1, 10th grade)
'I felt less pressure before this intervention' (C1, 9th grade)
'The inquiry-tasks were fun, but we were pressured to make the tasks quickly (C1, 10th grade)

Table 7. Examples of Quotes of Students Concerning Condition 2 (Inquiry Activities on Group Level Without the Plenary Guided Instruction)

Positive quotes	'It was more fun to learn' (C2, 9th grade)'I remember better the content because I had to search the Information' (C2, 9th grade)
Negative quotes	*'I prefer classical interventions in which we do not need to adapt this new learning approach' (C2, 9th grade)'I understand the content better when the teacher intervenes to summarize' (C2, 9th grade)* *'We should have teacher-led instruction instead of self-study' (C2, 10th grade)*

Table 8. Examples of Quotes of Students Concerning Condition 3 (Control Condition)

'Nothing has changed' (C3, 9th grade)
'There is almost no difference' (C3, 10th grade)

Discussion and conclusion

This study focuses on the implementation of tablet devices in education (Falloon, 2014; Ifenthaler & Schweinbenz, 2013; Sung et al., 2016). Building on limited previous research (Kollar et al., 2011, 2013; Mäkitalo-Siegl et al., 2011; Raes & Schellens, 2015), we focused on the role of teachers in computer-supported learning by implementing three macro- or classroom scripts. In this script, activities on two social planes (group and classroom level) (Vygotsky, 1978) were implemented during a 4-h intervention in secondary science classes. The main goal was to investigate under which classroom script/condition students achieve the best results in domain-specific knowledge and inquiry skills. Besides achievement, students' experiences towards the role of the teacher and student's perceptions towards learning with tablets within the three conditions were investigated.

In the first condition, the learning activities were balanced between the group (collaborative) and the classroom level (teacher-led interventions). In the second condition, the learning activities occurred predominantly on the group level. The third condition was the control condition in which the learning activities were situated only on the classroom level, with the tablet used in a traditional way or as *'book behind glass'*. Based on the available research, we hypothesized that students who learn in an inquiry-based way but with teacher interventions (condition 1) would experience more support, which would result in better domain-specific knowledge and inquiry skills (Alfassi, 2004; Slotta & Linn, 2009). In addition, it is expected that students evaluate the intervention the most positive. The results of RQ1a show that students achieved better scores on domain-specific knowledge if they followed classes with teacher-led interventions (condition 1 and condition 3). Condition 2, which does not provide teacher guidance, seems to disadvantage students, as their achievement scores were significantly lower. This is in line with findings by Kirschner et al. (2006). It is remarkable that high scores were also achieved in the most traditional use of the tablet device. Possible explanations could be: 1) Students are not used to learn on an 'inquiry-based' manner because their courses with the tablets were previously dominated by the ‘book-behind-glass’ method, which is in line with the results of our previous study (Montrieux et al., 2015). 2) Students reported in the survey that they do not feel the need to change this ‘traditional’ didactic principle, as it permits them to process information in the shortest time span. 3) Students in this study are not used to be ‘actively involved’, that is, being compelled to a constant effort throughout the whole course. Students clearly have the natural tendency towards being the ‘passive consumer’ of knowledge. As a result, the ‘new’ learning approach that demands constant active involvement caused strong opposition from the students, who preferred a passive role of listening to a lecturing teacher.

Another reason for this finding lies in the fact that there was a lot a time pressure during the intervention. The results show that learner-centred and inquiry-based methods are actually even more time consuming compared to traditional methods, because students have to actively construct knowledge (Mäkitalo-Siegl et al., 2011). Students reported that time pressure has led to frustration and to the impossibility to learn the new content thoroughly. Furthermore, it could be overly ambitious to assume that 4 h would change the mind-set of students to appreciate the added value of the learner-centred didactical approach. Focusing on the background characteristics, girls do significantly outperform boys at the domain-specific knowledge test, a finding that is in line with research of Chen and Macredie (2010). In addition, students from technical-oriented tracks need more teacher support and are disadvantaged in the condition with no classical interventions.

Regarding RQ1b, the current study found that students in the first condition outperformed on the inquiry test compared to the other conditions. Furthermore, this study shows that the tablet is an appropriate tool to foster learner-centred approaches, which is in line with previous research (Clark & Luckin, 2013; Montrieux et al., 2015). As stated by Slotta and Linn (2009), educational technology – and in this case using different tablet applications – could have a positive effect on the learning experience in which students actively construct knowledge. However, claiming on the results in condition 2, this is only valid when the teacher intervenes on the classroom level (Mäkitalo-Siegl et al., 2011; Raes & Schellens, 2015).

Regarding RQ2 that focuses on the role of the teacher, we can conclude that students who experienced more structure scored better on the achievement tests. This is reflected in the results where both students in condition 1 and 3 perceived to have more structure compared to the students in the second condition in which the activities occurred predominantly on the group level.

In the qualitative results of RQ3, it is clear that students were positive about working in condition 1 and 3 (with a predefined role of the teacher). On contrary, almost every student in condition 2 reported the need of classical interventions by the teacher. In addition, this study shows that background characteristics cannot be ignored. Students of younger age are significantly more positive towards the assigned intervention, compared to the older students. In other words, it seems that younger students are more positive towards the more learner-centred approach, whereas the older students are sceptical and rely on traditional learning. Finally, boys seem to have more preference towards the ‘inquiry-based’ method compared to girls. These results are in line with previous research (Montrieux et al., 2015; Chen & Macredie, 2010). This might suggest that learner-centred approaches should be implemented at the early school career.

In sum, the outcomes of the three research questions reveal the same message: technology cannot replace a teacher, who has to orchestrate (Dillenbourg, 2009) the learning activities in order to support learner-centred learning during TEL. Moreover, this study specifies the role of the teacher when they would be implementing tablet devices, in order to have a positive impact on learners’ experience.

However, the hypothesis that the first condition will be the best condition with regard to achievement, inquiry skills and perceived benefits has only been partly met. As described above, besides the higher scores for inquiry learning for students in the first condition compared to the other conditions, both the students in the first and third condition scored equally for domain-specific achievement and had the same positive attitudes towards the classroom script.

The three research questions confirm the pivotal role of teachers during TEL (Kollar et al., 2011, 2013; Mäkitalo-Siegl et al., 2011; Raes & Schellens, 2015). From our experiences, we conclude that the often-used metaphor concerning the changed role of the teacher as ‘guide on the side’ needs to be nuanced (Carey, 2008). Rather, it should be understood as ‘the leader from within’ Slotta and Linn (2009, p.119). The positive relation between experiencing structure and higher achievement scores reflects this stance.

Given the sample size and the fact that this study is embedded in an authentic classroom setting, the results of this study should be interpreted with some caution. Further research should take the above-mentioned issues such as time pressure and duration of the intervention into account. Next to this, regarding the measurement instruments used in this study, inquiry learning is measured via a students' interpretation of an abstract. Further research should explore new ways to measure inquiry skills, such as implementing a simulated inquiry-task during the testing. In addition, it is possible that the difference between the first and third condition could lie in the fact that although students in the first condition had less time to see the content, they have learned it more deeply, because they actively constructed knowledge (Slotta & Linn, 2009). This is in contrast to the traditional approach, with students being passive consumers. Finally, it remains difficult to control the actual application of the scripts by the teacher. To counter this, we used classroom scripts that outlined the intervention, and there were in each class Master students present at the time of the intervention. However, the variation between teachers cannot be controlled fully; it is one of the challenges of doing research into authentic classroom settings.

Practical implications can be formulated. First, according to our findings, the ideal cocktail is a balance between learner-centred learning and traditional, teacher-led learning, or so-called 'blended learning'. Second, it is clear that the teacher cannot be ignored and should be moved away from the 'replaced by technology' – mindset which makes students get overwhelmed by the complexity or the frustration that can arise in doing inquiry (Sierens et al., 2009; Tabak & Reiser, 2015). Putting forward a classroom script can be helpful to guide teachers to orchestrate (Dillenbourg, 2009) the use of tablets during science inquiry. Additionally, software tools could be introduced that support teachers to monitor real-time learning in the classroom (Sung et al., 2016). However, besides knowing that teacher interventions are necessary, the next step is to discover how and when the teacher should intervene. Should the teacher act proactive by organizing classroom interventions when teachers feel the need? Or should the teacher act reactive by organizing classroom interventions based on the need reported by students? Further research should extend this. Third, the variable timespan for the intervention opens venues for further research. In this study, there was a restricted intervention time of 4 h, including taking the questionnaires. When implementing a new didactical approach such as inquiry-based learning with the use of technology, both teachers and students need to be habituated to this new didactical approach. We suggest organizing a long-term intervention, such as implementing the intervention during the whole course.

In sum, these results confirm the importance of the teacher within technology-enhanced inquiry learning. Plenary teacher-led class interventions were found to positively affect students' inquiry skills and perceived provision of structure. The absence of teacher's class interventions appeared to disadvantage students. Further research should focus on how to integrate tablet devices adequately during learning activities instead of using them as a *'book behind glass'* tool, to have an optimal impact on both domain-specific knowledge and inquiry skills and to overcome the reported time constraints. This study supports the current focus of researchers in the field on the complex role of the teacher in a TEL environment (Kollar et al., 2011, 2013; Mäkitalo-Siegl et al., 2011; Raes & Schellens, 2015). Furthermore, these results show that besides the way tablet devices are implemented, it remains the teacher who determines the success of learner-centred learning with tablets. In fact, when deciding on using tablet devices to promote leaner-centred learning, keep in mind that tablets are a mean, not a goal, and that *'the best app remains the teacher'*.

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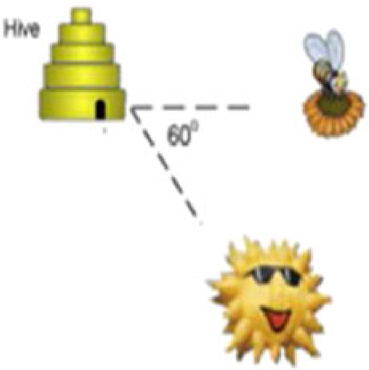
Appendix A: Teacher script in condition 1 (Activities alternated between group level (inquiry tasks in pairs) and class level (plenary instruction by the teacher)

Steps of Mini-inquiry 1	Social Plane	Activity of the students	Activity of the teacher
1.Generating research question and hypothesis	Class level	Listening to the teacher	The teacher shows the student an introduction movie on ‘glands’ and ask the students to think about an **adequate research question** and **hypothesis.**
	Group level	Brainstorming in pairs	
	Class level	Class discussion	The different research question and hypothesis made by the students are discussed.
2. Data collection	Class level	Listening to the teacher	The teacher give students the assignment to make the exercise on the tablet **to find more information** to be able to answer their research questions.
	Group level	Students learn in pairs by findings information using the tools on tablet (Internet, link to movies, watching pictures) They report findings on the tablet (by using the app Popplet) Students use the application Drillster to practice gained knowledge	The teacher is available for questions.
3. Reporting and reflection phase	Class level	Listening to the teacher Classical discussion Writing the fill-in box	The teacher summarizes the most important findings, together with the students.
	Group level	Students give an answer to their research question and reflection to the tablet if their hypothesis was right or wrong.	The teacher was available for questions.
	Class level	Class discussion	The teacher and students discuss **the answers and reflection upon the research cycle.**

Appendix B: Examples of rubrics where scores are visualized

Question	Possible answers	Score
'A hormone is always related to an exocrine gland'(total score: 2)	True	0
	False	1
	I don't know	0
	+ Explanation	1
	'Endrocrine'	
' How does the bee going to dance to show others the location of the food resource?' (total score: 2)	Downstairs	0
	Upstairs	1
	To the left	1
	To the right	0
		
' You turn on the stove and boil an egg. What kind of energetic reactions are occurring?' (total score: 3)	This is an exo-energetic reaction	0
	This is an endo-energetic reaction	0
	This is both an endo and exo energetic reaction	1
	This is not an endo or exo energetic reaction	0
	I don't know	0
	+ Explanation 'Exo = fire'	1
	endo = boiling egg	1

Appendix C: An example of a rubric for measuring inquiry skills

Abstract: 'Using educational games is more beneficial for students instead of learning by paper and pencil'.

Question	Score	Description
What is an appropriate research question for this abstract?	2	The student has given no answer or an incorrect research question
	1	The research question is partly right but not clearly formulated
	0	The student has given an appropriate and clearly described research question