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Supporting pre-service teachers in designing technology-infused lesson plans

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Abstract The present study compared the effectiveness of two types of just-in-time support for lesson planning. Both types contained the same technological information but differed regarding pedagogical and content information. The first type presented this information separately (i.e., separate support); the second type presented this information in an integrated way (i.e., integrated support). In an experimental design pre-service biology teachers received either the integrated support ($n = 26$) or separate support ($n = 27$). They were instructed to create a technology-infused lesson plan and justify their design decisions. Results showed that pre-service teachers who used the integrated support had more integrated pedagogical and content-related justifications and higher quality lesson plans than the group who received separate support. Both groups had few technology-related justifications, and technology integration was of low quality. These findings confirm the alleged superiority of integrated support over separate support, and suggest that additional guidance is needed for pre-service teachers to fully integrate technological, pedagogical and content information during lesson planning.

Keywords lesson design, lesson plan, pre-service teachers, teacher support, TPACK.

In the last decade, an abundance of technological tools and applications have been developed and tested in educational practice. Research reviews have shown that technology-enhanced learning can increase students' understanding of and engagement with the subject matter on condition that the technology is adequately implemented (e.g., Smetana & Bell, 2011; Hew & Cheung, 2013). An important goal for teacher education therefore is to prepare pre-service teachers for the appropriate use of such technologies in the classroom. Several researchers developed technology-integration courses that taught pre-service teachers about the use of technology by having them design technology-infused lessons (e.g., Abbitt, 2011; Voogt, Fisser, Pareja, Tondeur, & van Braak, 2013). These courses employed the Technological, Pedagogical And Content Knowledge (TPACK) framework, a descriptive model that portrays the knowledge teachers should possess to effectively use technology in the classroom (Mishra & Koehler, 2006).

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The TPACK framework visualized in Figure 1 contains three basic elements: (1) content knowledge about the subject matter; (2) pedagogical knowledge about teaching methods; and (3) technological knowledge about common instructional aids such as the blackboard, and innovative technologies such as webquests, e-portfolios and educational games. Integration of these elements results in four intersections. The first concerns pedagogical content knowledge (PCK) about how teaching methods and subject matter can be aligned. Technological pedagogical knowledge (TPK) represents teachers' understanding of how the affordances of technology match the characteristics of teaching methods, whereas technological content knowledge (TCK) denotes how technologies fit the subject matter. Finally, technological pedagogical content knowledge (TPACK) involves the combination of

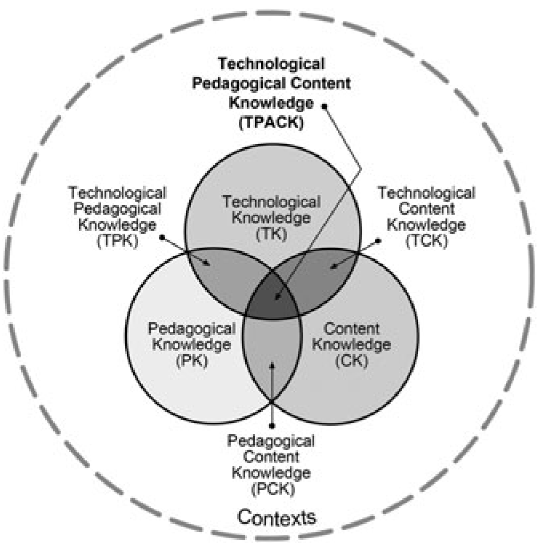

Figure 1 Technological Pedagogical and Content Knowledge Framework (TPACK). Reproduced by Permission of the Publisher, © 2012 by tpack.org

particular technologies, content and pedagogies (Mishra & Koehler, 2006).

The TPACK framework has mainly been used to describe teachers' technology integration efforts in the context of lesson design practices. These studies have shown that, although pre-service teachers are confident about their knowledge of the three basic TPACK elements and their intersections, many of them still experience difficulties in applying this knowledge when actually designing a lesson (e.g., So & Kim, 2009; Pamuk, 2012; Maeng, Mulvey, Smetana, & Bell, 2013). A possible reason for these difficulties is that pre-service teachers are insufficiently supported in designing technology-infused lessons. Providing pre-service teachers with tailor-made, just-in-time support during the lesson design process may help them to more effectively integrate technology in their lesson plans.

Several recent studies implemented support aimed at pre-service teachers' TPACK development. This support can roughly be classified as pertaining to the basic TPACK elements, their intersections or the core TPACK component. Support on the basic TPACK elements aims to increase teachers' knowledge of technology, content and pedagogy per se. Studies examining this type of support generally show that pre-service teachers improve in their ability to make pedagogy, content and technology-related decisions (Chittleborough, 2014), and gain confidence in all seven TPACK components (Çalik, Özsevgeç, Ebenezer, Artun, & Küçük, 2014; Chittleborough, 2014).

Support on the TPACK intersections aims to assist teachers in the *integration* of pedagogy, content and/or technology. Koh and Divaharan (2011), for example, found that support for TPK deepens pre-service teachers' reflections about this component. Other studies showed that pre-service teachers who received support for PCK (Ozgun-Koca, Meagher, & Edwards, 2010) and TPK (Koh & Chai, 2014) became more confident in their knowledge of all seven TPACK components.

Finally, support on the core TPACK component aims to assist teachers in *fully* integrating the three basic elements. Researchers advocating this type of support argue that TPACK should not be divided into different parts, but call for 'specific instruction targeting exclusively the development of TPCK [i.e., TPACK]' (Angeli & Valanides, 2009, p. 158). Studies offering TPACK training activities showed that pre-service teachers improved their TPACK by engaging in lesson design tasks (Angeli & Valanides, 2009), design justifications and lesson observations (Bell, Maeng, & Binns, 2013; Maeng et al., 2013), and journal reflections (Chang, Chien, Chang, & Lin, 2012).

Research comparing different types of TPACK-based support is scant. One exception is the study by Walker *et al*. (2012), who compared the effectiveness of technology support and technology-and-pedagogy support in a lesson designing course for in-service teachers. Results showed that support for technology-and-pedagogy yielded more profound pedagogical lesson planning decisions; scores for the other six TPACK components were not statistically compared between the groups. However, the focus of this study was on in-service teachers, who are more versed in pedagogical reasoning than pre-service teachers (Borko & Livingston, 1989). Therefore, definitive conclusions regarding TPACK-based support for pre-service teachers cannot be made.

Recent research by the authors examined in-service and pre-service teachers' preferences for just-in-time pedagogical and content support accompanying a technology-infused lesson plan (Janssen & Lazonder, 2015). Teachers had a forced choice between either separate and elaborate support on pedagogy and content, or support that presented this information in a condensed and integrated fashion. Pre-service teachers were expected to prefer the separate support as it addressed their incomplete and fragmented pedagogical and content knowledge, but the results proved otherwise. Similar to the in-service teachers, most pre-service teachers chose the integrated support that, in their view, would assist them in integrating pedagogical and content knowledge (i.e., PCK). Still, as this study only addressed teachers' preferences it is yet unknown which type of support is most effective in actual lesson planning.

The present study compared the relative effectiveness of integrated and separate pedagogical and content support. The study revolved around the design of a technology-infused lesson plan. Planning is pivotal to teachers' instructional thinking process. When planning a lesson, a teacher adapts the curriculum to his/her understanding, the specific classroom situation and students' knowledge and preconceptions (Clark & Peterson, 1984). In teacher education, lesson planning is established practice because, for novice teachers in particular, adequate lesson planning is crucial for successful classroom practice (Clark, 1988). Lesson planning also provides important learning opportunities in that it requires aspiring teachers to explicitly consider and integrate pedagogy, content and technology (Koehler & Mishra, 2005; Angeli & Valanides, 2009; Koehler et al., 2011). More specifically, teachers need to think about *what* pedagogical, content and technological information is needed, and *when* it should be integrated. And in justifying their design decisions, teachers need to consider *how* and *why* this information should be integrated (Kramarski & Michalsky, 2010).

Lesson planning tasks have traditionally been used to assess pre-service teachers' professional knowledge. For example, Blömeke *et al*. (2008) tapped teachers' pedagogical knowledge by open-ended questions on lesson planning, and Jacobs, Martin, and Otieno (2008) created a science lesson plan analysis instrument to track pre-service teachers' pedagogical knowledge. Concerning teachers' technology integration, assessment of lesson plans mainly focused on teachers' TPACK (e.g., Kramarski & Michalsky, 2010; Graham, Borup, & Smith, 2012; Krauskopf, Zahn, Hesse, & Pea, 2014). These studies showed that a lesson plan is a valid means to measure teachers' technology integration because it conveys teachers' knowledge of pedagogy, content and technology, *and* their understanding of how the three elements interact. This interaction can be determined by analysing how often pedagogy, content and technology are combined in teachers' design justifications. For example, Graham *et al*. (2012) showed that the number of TPACK-related justifications increased throughout a technology-integration course. Similar findings were reported by Koh and Divaharan (2011), who found that training on the pedagogical applications of the whiteboard increased the number of justifications related to TPK in pre-service teachers' course reflections.

However, the mere integration of pedagogical, content and technological information could be a poor indicator of the actual quality of a lesson plan. In line with Abell (2008), quality assessments should consider how deep and how well pedagogy, content and technology are integrated. Work in this direction has started to emerge. For example, Harris, Grandgenett, and Hofer (2010) developed a rubric that measured technology, pedagogy and content interactions in lesson plans on a 4-point scale ranging from 'no fit' to 'strong fit'. However, they did not specify *how* pedagogy, content and technology should fit together.

The present study built on these ideas by using a quality measure for lesson plans based on the correctness and specificity of the integration of pedagogy, content and technology. The study compared the effectiveness of two types of support by examining both the *number* of integrated statements in pre-service teachers' justifications and the *quality* of their lesson plans.

Pre-service teachers in the *separate support* condition received separate and elaborate information about pedagogy and content, which according to the TPACK framework would match their actual support needs. The support materials specified *what* information pre-service teachers required on these subjects (cf. Kramarski & Michalsky, 2010). Pre-service teachers assigned to the *integrated support* condition received ancillary materials that matched their preference for PCK support. The support linked content information to pedagogical information, thus implicitly prompting *when* the two could be combined (cf. Kramarski & Michalsky, 2010). Furthermore, as the integrated support was geared towards the PCK level, pre-service teachers receiving this information were expected to have basic knowledge of pedagogy and content. The information given was therefore a condensed version of the pedagogical and content information in the separate support.

Specific hypotheses were proposed for both outcome measures. Consistent with pre-service teachers' support preferences (Janssen & Lazonder, 2015), design justifications in the integrated support condition were expected to contain more PCK-related statements than the justifications given in the separate support condition. Likewise, the quality of PCK in the lesson plans of pre-service teachers in the integrated support condition was assumed to be superior to that of the lesson plans designed in the separate support condition.

In addition, the integrated support might enhance instances of TPACK-related statements in pre-service teachers' lesson plans and justifications. With the pedagogical and content information already combined, adding technology seems like a small step. However, research by Angeli and Valanides (2009) showed that specific support on the TPACK level is required to increase pre-service teachers' TPACK. Therefore, an open research question was formulated to examine whether the number of TPACK-related justifications would differ between conditions, and how the two types of support would contribute to the quality of TPACK in the lesson plans.

Method

Participants

The sample comprised 54 pre-service biology teachers (21 males, 33 females). They came from four cohorts of two teacher education institutes and were enrolled in the teacher education programme for an average of 4.63 months ($SD = 3.32$). Within these four cohorts, six pre-service teachers attended the bachelor programme, 17 pre-service teachers were in the master programme, and 31 pre-service teachers in the post-graduation programme.

Per cohort and programme, participants were randomly assigned to either the condition with separate support ($n = 27$) or integrated support ($n = 27$). One participant in the integrated support condition reported that she had not used the support materials during the experiment and was therefore removed from the sample.

Materials

Lesson planning materials

Participants had to design the final lesson of a three-lesson high school biology project about glucose–insulin regulation. They received the following materials: (1) student resources, (2) lesson plan assignment, (3) lesson plan template and (4) support materials. *Student resources* concerned an instructional text about glucose–insulin regulation and a matching System Dynamics model (developed by students in Mulder, Bollen, de Jong, & Lazonder, 2016), both of which served to contextualize the lesson. These resources were already addressed in the first and second lesson of the project; the resources pivotal to the third lesson were an assignment about the effects of eating a pizza on glucose–insulin regulation and a matching reference model (visualized in Figure 2).

The participants' *lesson plan assignment* described the context and materials used, and instructed participants to design the third lesson on glucose–insulin regulation (content) using the inquiry-based teaching approach (pedagogy), and the System Dynamics modelling software (technology). It also asked participants to justify the decisions made in designing the lesson plan.

Participants' design efforts were guided by a *lesson plan template*: a blank fill-out form in which participants could specify basic organizational information (lesson title, domain, topic, etc.) and describe the introduction, body and closure of the lesson they designed. Participants were instructed to describe the student and teacher activities, the subject matter and the tools.

Support materials consisted of background information regarding (1) technology, in the form of a tutorial that guided participants step-by-step through the SCYDynamics model editor (Mulder et al., 2016), and (2) content and pedagogy, depending on the participants' condition presented in a separate or integrated way. In the separate support, pedagogical and content information was presented in two chapters (1206 words). The content information detailed the glucose–insulin regulation process. Main concepts were presented such that teachers could easily relate these concepts to the variables in the model. For example: '…So in the model, the overall glucose release depends on both the normal glucose release and the glucose release caused by eating food.' Pedagogical information described the main phases of the inquiry-based learning process: orientation, hypothesis generation, experimentation, drawing conclusions, and planning and monitoring (see De Jong, 2006). For example: 'During experimentation, students can test their hypotheses by specifying and adapting variables.'

The integrated support presented the pedagogical and content information in an interrelated and compact way (547 words). This information was presented in the same sequence as in the separate support materials. In each paragraph, content information about glucose–insulin

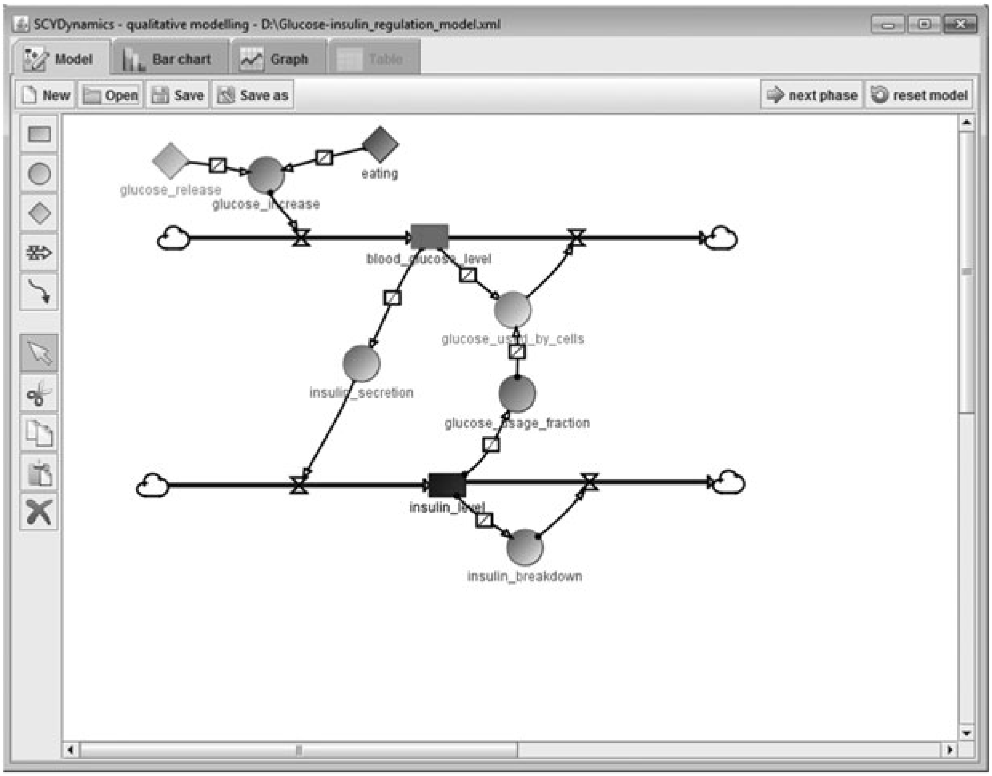

Figure 2 Model Editor Tool with the Glucose–Insulin Regulation Reference Model

regulation was purposefully integrated with pedagogical information about inquiry-based learning. For example: 'During experimentation, students can test their hypotheses by specifying and adapting variables. When eating a pizza, the overall glucose release in the model should depend on both the normal glucose release and the glucose release caused by eating food.' Basic explanatory information on pedagogy and content was excluded, resulting in information that merely aimed to support the integration of both elements.

Pre-service teachers in both conditions needed to tailor the given information to the lesson they were designing, and had to decide for themselves *how* and *why* to integrate pedagogy, content and technology.

Evaluation and background questionnaire

The evaluation questionnaire aimed to assess whether participants held different views on the support materials they received, as this could affect their actual use of these materials. The seven items addressed the main features of the support materials, that is, the amount of information, integration of pedagogy and content, concreteness, theoretical rigour and transparency. For example: 'This source contains too much information' (i.e., amount of information), and 'This source fits to the way I prepare and teach my own lessons' (i.e., concreteness). Participants could indicate to what extent they agreed with a statement on a 5-point Likert scale ranging from 'I completely disagree', to 'I completely agree'.

The background questionnaire assessed participants' prior knowledge of technology, pedagogy and content so that possible a priori differences could be controlled for when comparing the lesson plans created in both conditions. This questionnaire contained three items that assessed participants' knowledge of inquiry-based learning, glucose–insulin regulation, and Information and Communication Technologies (ICT) relative to their peers. These questions were answered on a 5-point Likert scale ranging from 'much less' to 'much more'. Two additional items concerned the number of inquiry-based lessons taught, and the number of lessons given about glucose–insulin regulation; another seven items asked participants to rate the use of basic and advanced ICT tools in their teaching (e.g., word processors, respectively, modelling software). Items were scored on a 5-point Likert scale ranging from 'never' to 'more than 4 lessons'.

Procedure

The study was conducted as part of a regular teacher preparation programme. All participants attended a 30-min introductory session, which was immediately followed by a 60-min experimental session. During the introductory session participants were introduced to the study and System Dynamics Modelling. They completed a model editor tutorial to familiarize themselves with the System Dynamics Modelling language and the operation of the modelling tool.

In the experimental session, participants were instructed to individually design their lesson using the lesson planning materials for their condition. They were asked to provide elaborate information on what they would teach, how they would teach it, and which tools they would use. In this way, participants were prompted to explain the planning of the lesson as well as to provide information regarding content, pedagogy, technology and their relations. After the instructions, participants received the assignment and support materials and started designing their lesson plan. They could use the support materials at any point during the design process (i.e., just-in-time). After participants finished their lesson plan, they filled out the evaluation and background questionnaire.

Data analysis

Participants' lesson plans were analysed on learning activities, justifications and lesson plan quality. First, it was determined whether participants attended to the support materials and whether pedagogical, content and technological information was included in their lesson plans. Lesson plans were segmented into learning activities, that is, events that engaged students in a new task within the lesson. These learning activities were classified according to the steps of the inquiry cycle (i.e., orientation, hypothesis generation, experimentation and drawing conclusions). As these steps were pivotal in both versions of the support material, their occurrence in a lesson plan reflected participants' support usage. Learning activities that were created by participants themselves received the score 'self-devised'. Additionally, each learning activity was scored on the presence of pedagogical, content and technological information (see Table 1).

Next, participants' design justifications were analysed. The information within each learning activity was classified as a justification if it described *why* certain decisions had been made; information that lacked this explanation was classified as descriptive information. The justifications were scored as pertaining to pedagogy, content or PCK; and the justifications were additionally scored as technology, TPK, TCK or TPACK (see Table 2).

In each coding step, the first author and a fellow researcher coded a randomly selected set of 12 (22%) lesson plans to determine inter-rater reliability. Reliability of the segmentation of learning activities and justifications was 82% and 87%, respectively; in the coding process of the remaining steps Cohen's κ ranged from .76 to .98. The first author coded the remaining lesson plans and consulted the second rater when in doubt.

Assessment of lesson plan quality was inspired by the technology-integration quality measure by Krauskopf *et al.* (2014). Consistent with the study's research question, the coding scheme addressed the quality of both

Table 1. Coding Scheme of the Learning Activities in Participants' Lesson Plans

Codes[a]	Description
Classification of learning activities	
Orientation	Students are probed to think about their prior knowledge of the subject.
Hypotheses	Expectations are formulated regarding the results of the testing of the model.
Experimentation	The model is tested by adding or changing variables.
Conclusions	Results are discussed and evaluated upon.
Self-devised	Learning activities that could not be assigned to one of the codes above.
Identification of the basic TPACK elements[b]	
Pedagogy	Processes on how to teach, e.g., instructional strategies, student activities and supervision.
Content	The subject matter or a clear reference to the topic in the student materials.
Technology	Activities or specific terms that refer to the modelling software.

[a]The step 'planning and monitoring' was required throughout the lesson and therefore not classified as a learning activity.
[b]The term 'model' was not assigned to one of the codes because of its generic nature.

Table 2. Coding Scheme of the Justifications in Participants' Lesson Plans

Codes	Description	Example
Pedagogy and content integration		
Pedagogy	Pedagogical information[a] not related to content information.	'In a classroom discussion prior knowledge is activated.'
Content	Content information[a] not related to pedagogical information.	'The goal is that students learn to apply glucose–insulin regulation'
PCK[b]	Pedagogical information is clearly related to content information.	'I will start with a plenary session so that they will mention the terms sugar and carbohydrates.'
Technology integration		
Technology	Technological information[a] not related to pedagogical and content information.	'I use the SCYDynamics model editor because I think it is important to gain insights into technical applications such as modelling'.
TPK[b]	Technological information is clearly related to pedagogical information.	'The SCYDynamics modelling programme helps students to see connections and experiment with them.'
TCK[b]	Technological information is clearly related to content information.	'The SCYDynamics modelling programme shows the effect of eating on the glucose–insulin regulation'.
TPACK[b]	Technological information is clearly related to PCK information (i.e., PCK as defined above).	'Students experiment with the SCYDynamics modelling programme so they can investigate themselves what effect eating has on the glucose–insulin regulation.'

[a]Pedagogical, content and technological information was defined as described in Table 2.
[b]PCK: Pedagogical Content Knowledge, TPK: Technological Pedagogical Knowledge, TCK: Technological Content Knowledge, TPACK: Technological Pedagogical and Content Knowledge.

PCK and TPACK in the lesson plans (see Table 3). The coding focused on *how* and *why* participants integrated pedagogy and content into PCK, and technology, pedagogy and content into TPACK. The correctness and specificity of this information were used to determine the quality scores. In each lesson plan, PCK and TPACK received a separate score that could range from 0 (incorrect integration) to 3 (specific integration).

The same two raters coded 18 randomly selected lesson plans (30%) on PCK and TPACK quality. Weighted kappa (κ) was computed to indicate inter-rater reliability. This coefficient is preferred in case of ordinal data because it takes the order of scores into account, in this case from 1 to 3 (Fleiss, Levin, & Paik, 2003). The κ for PCK was .66, and the κ for TPACK was .67. The first author coded the remaining lesson plans and consulted the second rater when in doubt.

Results

Prior knowledge and experience

The background questionnaire that captured participants' prior knowledge and experience yielded ordinal data that were analysed by Mann–Whitney *U*-tests. Results showed that the level of prior knowledge about inquiry-based learning, glucose–insulin regulation and ICT did not differ significantly between the two conditions (all $p > .1$).

Concerning experience, 18 participants in each condition (67.92%) had taught in fourth and/or fifth grade of pre-university education (i.e., the classes for which the lesson plan was intended). Furthermore, participants in both conditions had taught an average of two inquiry-based lessons during their internships and most of them (58%) had not yet taught about glucose–insulin regulation. No significant differences were found between conditions on these measures ($p > .1$). Only three participants from the integrated support condition and one from the separate support condition had used modelling software in class. However, most participants had some experience with related applications such as animations (96%), simulations (50%) and mind-mapping software (64%).

Lesson plans

Participants' lesson plans contained approximately 650 words; the minor difference between the integrated support condition ($M = 648.46$, $SD = 152.44$) and the

Table 3. Coding Scheme of the Quality of PCK and TPACK in Participants' Lesson Plans

Code	Description	Examples
Incorrect[a]	PCK: Integration of pedagogy and content is incorrect or essential information is missing.	PCK: Asking students about diabetes in their family is impertinent and will not help activate their prior knowledge in any way.
	TPACK: Integration of technology with pedagogy and content is incorrect or essential information is missing.	TPACK: The target model will not be shown during the closing part of the lesson; this will strengthen students' misconceptions.
Practical	PCK: Integration of pedagogy and content is based on practical considerations.	PCK: Students are working together on the pizza assignment so that they do not have to ask the teacher.
	TPACK: Integration of technology with pedagogy and content is based on practical considerations.	TPACK: Because of a lack of available laptops students work together.
General	PCK: The students' learning process is considered, but the advantage of pedagogy for the specific content is not clear.	PCK: A plenary discussion will be held to reveal students' knowledge of glucose–insulin regulation.
	TPACK: The students' learning process is considered, but the advantage of technology for learning/teaching about the specific content is not clear.	TPACK: The modelling software is used to help students in learning about glucose–insulin regulation.
Specific	PCK: The students' learning process is considered and the advantage of pedagogy for the specific content is clearly described.	PCK: By introducing the context of eating a pizza students learn about glucose–insulin regulation in light of their own experiences.
	TPACK: The students' learning process is considered and the advantage of technology for learning/teaching about the specific content is clearly described.	TPACK: Modelling software visualizes the glucose–insulin regulation process. In this way, students gain knowledge in the dynamic relations of glucose–insulin process.

[a]This category was dismissed because there were no instances of incorrect integration in participants' lesson plans.

separate support condition ($M = 651.81$, $SD = 193.33$) was not significant, $F(1, 52) = .01$, $p = .95$.

As normality tests indicated that all other data was positively skewed and/or sharply peaked, Mann–Whitney tests were used to examine possible differences between conditions. Results showed that the total number of learning activities in the lesson plans did not differ across conditions (see Table 4). Most of these activities could be traced back to the available support materials; in both conditions, one learning activity on average was conceived by the participants themselves. Table 4 further shows that every learning activity contained pedagogical information, and over 60% also contained information on content and/or technology. Here too, no significant differences were found between conditions.

Participants also had to justify the design of their lesson plan. Participants in the integrated support condition gave 5.15 justifications on average ($SD = 2.89$); the number of justifications in the separate support condition was slightly higher ($M = 6.48$, $SD = 3.72$) but this difference was not statistically significant, $U = 276.00$, $z = -1.34$, $p = .18$. Justifications were further classified as pertaining to pedagogy, content and their integration, and the integration of technology.

Table 4. Occurrence of Learning Activities in the Lesson Plan

	Integrated support ($n = 26$)		Separate support ($n = 27$)				
	M	SD	M	SD	U	z	p
Number of learning activities							
Support-related	3.04	1.08	2.63	0.97	265.50	−1.59	.11
Self-devised	1.19	1.17	1.11	1.05	342.00	−0.17	.87
Total	4.12	0.99	3.74	0.81	277.00	−1.40	.16
Type of information (%)							
Pedagogical	100.00	0.00	100.00	0.00	351.00	0.00	1.00
Content	60.32	21.30	71.98	26.08	320.50	−0.56	.57
Technological	76.15	24.14	64.88	24.75	327.00	−0.43	.67

The percentages of these justifications were compared across conditions. As shown in Table 5, participants who received integrated support had comparatively more justifications containing PCK-related statements than participants from the separate support condition; the effect size was moderate, $r = -.33$. The percentage of pedagogy-related statements also differed between conditions, albeit not to a statistically significant degree.

The quality of the lesson plans was determined from the level of PCK and TPACK. The quality of PCK within the lesson plans differed significantly between conditions, $U = 246.00$, $z = -1.99$, $p = .05$, $r = -.27$. Participants in the integrated support condition scored higher on PCK quality (*Mdn* = 2, mean rank 31.04) than participants in the separate support condition (*Mdn* = 2, mean rank: 23.11). Regarding TPACK, the quality of the lesson plans developed in the integrated support condition was higher (*Mdn* = 1, mean rank: 30.23) than that of the lesson plans in the separate support condition (*Mdn* = 1, mean rank 23.89), but this difference was not significant, $U = 267.00$, $z = -1.79$, $p = .07$.

The quality of PCK did not significantly correlate with the number of PCK justifications in both conditions, Spearman's $\rho = .14$, $p = .49$ (integrated support), and $\rho = .21$, $p = .29$ (separate support). However, the quality of TPACK significantly correlated with the number of TPACK justifications, $\rho = .59$, $p < .001$ (integrated support) and $\rho = .45$, $p = .02$ (separate support).

Opinion of the support materials

Scores on the evaluation questionnaire were used to assess how participants perceived the quality of the support materials they received. Because these scores were at the ordinal level, Mann–Whitney *U*-tests were used to analyse possible cross-condition differences. As shown in Table 6, a significant difference was

Table 5. Pedagogy, Content and Technology Integration Statements

	Integrated support (*n* = 26)			Separate support (*n* = 27)					
	M	*M* %	*SD* %	*M*	*M* %	*SD* %	*U*	*z*	*p*
Pedagogy and content									
Pedagogy	2.08	35.80	23.44	3.56	46.50	27.24	254.50	−1.73	.08
Content	0.23	6.70	14.68	0.37	4.29	8.63	343.50	−0.18	.86
PCK[a]	2.42	51.56	27.48	2.04	35.16	24.25	218.00	−2.38	.02
Technology-related									
Technology	0.04	0.96	4.90	0.07	1.27	4.64	339.50	−0.51	.61
TPK[b]	0.54	11.87	17.74	0.74	11.68	14.51	337.00	−0.88	.38
TCK[c]	0.12	3.27	10.86	0.19	1.61	4.67	348.00	−0.10	.93
TPACK[d]	0.62	14.78	23.98	0.56	8.90	16.81	307.00	−0.89	.38
Miscellaneous	0.38	4.98	9.27	0.44	5.37	10.34	349.00	−0.05	.96

[a]Pedagogical Content Knowledge.
[b]Technological Pedagogical Knowledge.
[c]Technological Content Knowledge.
[d]Technological Pedagogical and Content Knowledge.

Table 6. Participants' Evaluation of the Support Materials

	Integrated support (*n* = 26)		Separate support (*n* = 27)				
Statements	N	*Mdn*[a]	N	*Mdn*[a]	*U*	*z*	*p*
Too much information	26	1	26	2	202.00	−2.63	.01
Too little information	25	1	27	1	256.00	−1.60	.11
Sufficient integration of pedagogy and content	26	3	27	3	326.50	−0.50	.62
Information is transparent	26	2	27	3	339.50	−0.22	.82
Information is related to practice	26	2	27	2	343.00	−0.15	.82
Information is theoretical	25	3	27	3	336.00	−0.03	.98

[a]0 = I completely disagree, 4 = I completely agree.

found regarding the amount of information; participants who used the integrated support did not think that their support materials contained too much information, whereas participants from the separate support condition were neutral about this statement—the effect size was moderate, $r = -.37$. The other scores indicated that participants generally disagreed that they received too little information, and found that the integration of pedagogy and content was appropriate. They were neutral about the transparency of the information and whether it was sufficiently related to practice, but generally agreed that the information was theoretical.

Discussion

The results of this study showed that most pre-service teachers used the just-in-time support they received to design the lesson plans. They generally attended to the steps provided by the support materials, but also created learning activities themselves. This suggests that the support was generally considered useful, and the answers to the evaluation questions support this notion. The difference in text size between the two versions of the support materials apparently did not affect the amount of information in the lesson plans: the number of words and learning activities were comparable between conditions.

Although not all learning activities contained content and technological information (see Table 4), pre-service teachers had ample opportunity to integrate pedagogy, content and technology. Their justifications showed that this was especially the case for pedagogy and content; almost half of the justifications were related to PCK. The effectiveness of the two types of support on the integration of pedagogy and content was reflected in pre-service teachers' lesson plans and justifications. Consistent with pre-service teachers' support preferences (Janssen & Lazonder, 2015), integrated support led to more PCK-related justifications and a higher quality of PCK in the lesson plans than separate support. These results confirm the alleged superiority of integrated support for pre-service teachers' integration of pedagogy and content.

The integrated support did not promote pre-service teachers' integration of pedagogy, content *and* technology. The overall number of TPACK-related justifications was low and so was the TPACK quality of the lesson plans. In fact, pre-service teachers' justifications contained few technology-related statements, which could be because of the separate presentation of the technological information. In view of these findings, providing pre-service teachers' with additional support for the integration of technology with *both* pedagogy and content might be a more fruitful option. Research in this direction shows promising results (e.g., Angeli & Valanides, 2009; Bell et al., 2013). Furthermore, the current study only provided pre-service teachers with descriptions of *what* information was needed regarding pedagogy and content, and *when* this information could be integrated in the lesson. Possibly, also modelling *how* and *why* to integrate technology, pedagogy and content might more effectively support pre-service teachers' technology integration (cf. Kramarski & Michalsky, 2010).

The number of PCK-related justifications was not associated with the quality of PCK in the lesson plans. This suggests that participants could have used different approaches in integrating pedagogy and content. Research on learning approaches distinguishes deep learning aimed at understanding, from surface learning intended for memorization (Marton & Säljö, 1976; Biggs, 1987). Possibly, pre-service teachers who mainly gave a high number of PCK-related statements used a surface approach, while others who primarily considered the quality of PCK used a deep approach to using the support materials. To find out whether this is indeed the case, measures of pre-service teachers' thoughts during lesson planning should be taken into account.

The TPACK-related justifications *did* correlate with the TPACK quality measure. Pre-service teachers scored relatively low on both measures (32 participants gave no TPACK-related justifications, and 35 scored lowest on TPACK quality), but those who gave TPACK-related justifications also scored higher on the quality of TPACK. Still, because of the low scores on both TPACK measures, definitive conclusions cannot be drawn. Further research on the TPACK measures should include lesson plans with more variation in both the number of TPACK-related justifications and the TPACK quality. This could be established by, for instance, including lesson plans of teachers who have more TPACK-related experience, or by offering teachers additional TPACK-specific support.

Pre-service teachers generally converged in their opinion of the support they received; the only difference concerned the amount of information. Pre-service teachers who received integrated support did not agree that they received too much information, whereas the group that received separate support was generally neutral about this statement. As participants in both conditions strongly disagreed that the support contained too little information, it seems that sufficient support was given to pre-service teachers in both conditions—despite the fact that the separate support materials contained twice as many words. Overall, participants in both conditions were equally positive about the support they received. This is consistent with teachers' positive evaluations of the support materials in previous research (Janssen & Lazonder, 2015) and suggests that differences in effectiveness of the two types of support were because of the presentation format rather than the extensiveness or perceived quality of the support materials.

This study has some limitations that could affect the generalizability of its findings. The study focused on pre-service teachers from a postgraduate teacher education programme who fully mastered the topic of the lesson they designed. Although Lederman and Gess-Newsome (1999) pointed out that even with such a background pre-service teachers do not always possess the content knowledge needed to teach biology in secondary education, these pre-service teachers could have benefited from their topical knowledge when using the integrated support. Future research should examine whether undergraduate pre-service teachers with a less profound understanding of the subject matter use the integrated support as effectively. Another issue is that the current study did not focus on actual classroom practice. Although part of pre-service teachers' teaching activities were investigated – a lesson plan is the main data source of teachers' lesson preparation – it is yet unknown how the lesson plan would be used when actually delivering the lesson in class. Further research into teachers' reflections on their classroom practice could shed light on this issue.

The results of this study have at least one implication for the training of pre-service teachers. Support on the level of PCK has a positive effect on the integration of pre-service teachers' pedagogical and content knowledge during lesson planning. Such support should therefore be given on a just-in-time basis during pre-service teachers' technology integration practices. Future research should investigate whether integrated support on the TPACK level could support pre-service teachers in considering technology, content and pedagogy in tandem. The effectiveness of such support is crucial for successful implementation of technology in educational practice.

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