Enhancing Pre-service Math Teachers’ Self-regulated Integration of Professional Knowledge from Multiple Documents

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Abstract

This research investigates pre-service mathematics teachers’ integration of knowledge entities from documents that pertain to the core dimensions of their professional knowledge. The theoretical rational founds on models and methodical approaches on self-regulated learning, its assistance through prompts, and multiple-document comprehension. Results of an experimental study suggest that prompts positively influenced the integration of knowledge entities from multiple documents on teachers’ professional knowledge domains. In contrast to prior multiple document studies, argumentation tasks did not promote knowledge integration compared to unspecific writing tasks. Neither integration prompts nor the type of writing task inhibited knowledge acquisition within professional knowledge dimensions. The results, further analyses, and consequences for future studies are discussed.

Keywords: knowledge integration, multiple-document comprehension, self-regulated learning, prompting, teacher knowledge, teacher education

Theoretical background

Based on the “knowledge as elements” theory it is assumed that novices acquire new knowledge in form of isolated elements before they make connections between originally unrelated knowledge entities and construct a single, more complex, interrelated model (diSessa, Gillespie, & Esterly, 2004). The concept of knowledge integration refers to this “process of linking, connecting, distinguishing, organizing, and structuring ‘models’ of scientific phenomena” (Linn, 2000, p. 783).
Teachers’ “professional knowledge” comprises three core dimensions – content knowledge (ck), pedagogical knowledge (pk), and pedagogical content knowledge (pck) – which are fundamental for their decision making (Shulman, 1986). Hence, it is important that pre-service teachers develop an integrated set of knowledge from these domains. In universities’ teacher training programs, the acquisition of knowledge in these domains is largely separated (Blömeke, 2009; Darling-Hammond, 2006) and often based on reading multiple texts (Kolić-Vehovec et al., 2011) in self-studying phases. However, research on these two factors shows that students struggle to comprehend scientific texts (Snow, 2002) and to implement effective integration processes in multiple-document processing situations (Rouet et al., 1997). And even though the interconnectedness of knowledge is crucial for expert-like behavior, pre-service teachers are largely left on their own when it comes to knowledge integration across ck, pk, and pck. Subsequently, they do not provide well-connected knowledge structures after their university studies (Blömeke, 2009; Darling-Hammond, 2006). As a consequence, the question raises how to assist pre-service teachers when they learn and try to integrate knowledge from multiple documents on ck, pk, and pck in a self-regulated manner.

Self-regulated learning involves actively influencing and adjusting all learning processes of the cognitive, metacognitive, and motivational dimension in all phases of a self-regulated learning cycle (Boekaerts, 1999; Zimmerman, 2002). A means to address difficulties experienced by learners are so-called prompts. Prompts are instructional short time interventions that support learners in activating cognitive, metacognitive, motivational, volitional, and/or cooperative activities and strategies (e.g., Bannert, 2009; Ifenthaler & Lehmann, 2012; Lehmann et al., 2014; Reigeluth & Stein, 1983; Wäschle et al., 2015). Prompts can be differentiated according to their timing and sequencing (Thillmann et al., 2009) and their presentation format (e.g., explicit statements, questions, to-complete sentences, or pictures). Maier and Richter (2014) reported that prompting metacognitive strategies was an effective instructional scaffold to overcome one-sided mental representations that are biased towards belief-consistent text information. However, promoting belief-inconsistent knowledge integration via prompts was moderated by learners’ motivation. Besides, multiple-document comprehension research suggests “that any document-based activity involves the formation of a task model—that is, a representation of the expected outcomes of the reading activity. The task model then drives subsequent processes involved in the search, evaluation and integration of information” (Rouet & Britt, 2011, p. 31). McCrudden and Schraw (2009) support this understanding of students’ processing and their use of multiple documents as a task-oriented process. Moreover, there is evidence that different kinds of writing tasks change the processing...
of multiple documents and the subsequent construction of a model of understanding (Rouet & Britt, 2011; Wiley & Voss, 1999). This finding delivers converging evidence for Scardamalia and Bereiter’s (1987) notion of knowledge-telling in students’ written texts – which relates to the construction of a text model that allows to retrieve more text specific information later on – and knowledge-transforming – where students’ texts go beyond an isolated understanding of each text by linking, distinguishing, and structuring text information to/from each other in the sense of constructing an integrated mental model. Yet, findings on the effect of different writing tasks on knowledge integration (e.g., Wiley & Voss, 1996, 1999) are rarely based on studies with teachers’ professional knowledge domains and their relations to each other as learning content. It remains a desideratum how pre-service teachers’ knowledge integration processes may be instructionally supported in self-regulated learning settings that comprise the use of multiple documents.

Research question and hypotheses

Based on the described theoretical background, there is a need for research on different types of tasks as well as task-complementary scaffolds that enhance pre-service teachers’ self-regulated integration of knowledge when learning with multiple documents. The according research question reads as follows: Are argumentation tasks and prompts effective to enhance knowledge integration processes when learning with multiple documents on teachers’ professional knowledge? Previous studies showed that pre-service teachers did not benefit from prompts in terms of more declarative knowledge acquisition (Lehmann et al., 2014; Wäschle et al., 2015). But prompts enhanced drawing on multiple knowledge domains when evaluating learning tasks (Wäschle et al., 2015) and problem solving in a transfer task (Lehmann et al., 2014). In addition, Wiley and Voss (1996, 1999) showed that argumentation tasks are particularly beneficial for knowledge integration across multiple documents. Accordingly, a general increase of knowledge but no differences based on receiving either integration prompts or no prompts (hypothesis 1a) as well as either an argumentation task or an unspecific writing task (hypothesis 1b) are expected. At the same time, receiving knowledge integration prompts is expected to foster a more integrated comprehension of multiple texts than learning in a self-regulated manner without prompts (hypothesis 2a). Furthermore, we assume that an argumentation task also enhances knowledge integration compared to an unspecific writing task (hypothesis 2b).

Yet unclear is the interplay between tasks and prompts. On the one hand, argumentation tasks inherently “prompt” the integration of information from different sources (Wiley & Voss,
1996, 1999), which puts an additional effect of task-supplemental prompts into doubt. However, since tasks and prompts affect learning at different levels (cf. Bannert, 2009) one may expect that these means are additive. Regarding the latter, we cannot expect an interaction effect between type of task and prompting on pre-service teachers’ knowledge integration when learning with multiple documents (hypothesis 3).

**Method**

**Participants and design.** One hundred pre-service primary school mathematics teachers from a German university participated in the experimental study. Seven participants had to be excluded due to missing data or because they did not engage in the writing task. The remaining ninety-three participants (86 % female) had an average age of 24.70 years ($SD = 4.14$). They had studied $M = 7.10$ semesters ($SD = 1.89$) and provided first practical teaching experience in schools of $M = 4.50$ months ($SD = 4.60$) through internships with having planned and taught $M = 11.19$ lessons independently but under supervision ($SD = 11.73$). All participants were recruited in a lecture on pedagogical diagnostics which was part of their teacher training. They received course credit for participation.

We used a two factorial between-subject design with four experimental conditions. Participants were randomly assigned to either an unprompted self-regulated learning condition with an unspecific writing task (UU; $n_{UU} = 22$), a prompted self-regulated learning condition with an unspecific writing task (PU; $n_{PU} = 25$), an unprompted self-regulated learning condition with an argumentation task (UA; $n_{UA} = 24$), or a prompted self-regulated learning condition with an argumentation task (PA; $n_{PA} = 22$).

**Material.** Knowledge gains were assessed by pre-post-measures in each dimension of math teachers’ professional knowledge. The ck-test comprised nine single-choice questions with four response options each (one correct) and four short answer questions with open text production. The pk-test also comprised nine single-choice questions (four response options each; one correct) and four short answer questions. The pck-test comprised seven single-choice questions (four response options each; one correct) and five short answer questions. All items were generated on the basis of textbook excerpts that are used in teacher education in each domain and served as learning material in the experimental study (see table 1).
Table 1

Description of documents taken from teacher education textbooks and used as learning material.

<table>
<thead>
<tr>
<th>Professional knowledge dimension</th>
<th>Content description</th>
<th>Source</th>
</tr>
</thead>
</table>

Note: Three text documents provided the content to be learned and integrated in a self-regulated manner by future math teachers in the experimental study (Mwords=1946.67; SDwords=238.02; Msentences=120.67; SDsentences=5.51; each on three pages). All documents were slightly adapted to increase the internal validity of the study, e.g., intra-textual references were removed. Further variables that have been found to influence multiple document comprehension and knowledge integration, such as author expertise, document type, and currentness, were maintained constant.

To assess the degree of knowledge integration an intertextual inference verification task (InterVT) was developed. This type of test measures subjects’ ability to draw inferences across multiple text documents (cf. Bråten & Strømsø, 2009). The test consisted of 14 statements, eight of which could be inferred by integrating knowledge entities from at least two of the three texts (i.e., valid inferences). The other six statements did not ask for an integrated set of valid knowledge entities (i.e., invalid inferences). Participants were asked if the statements can reasonably be inferred by combining information from more than one of the teachers’ professional knowledge dimension. They were instructed to indicate whether a statement is a valid or invalid inference (they could also state “I don’t know” to reduce chance probability). Cronbach’s alpha for the InterVT was .76, suggesting good reliability of the test.

With regard to the importance of motivation for effective self-regulated learning in general (e.g., Boekaerts, 1999; Zimmerman, 2002) and knowledge integration based on multiple documents in particular (e.g., Maier & Richter, 2014) we also assessed participants’ motivation. German adaptations of three scales of the intrinsic motivation inventory (IMI; Deci & Ryan, n.d.) with a five point Likert-scale were used: interest/enjoyment (7 items), perceived competence (6 items), and effort/importance (5 items). Reliability coefficients for the three scales have been reported to be satisfying (Cronbach’s alphas between .77 and .92).

Procedure. Participants received a link to the pretest which was administered online and comprised a demographic data survey as well as the three domain-specific knowledge tests on ck, pk, and pck. The processing of the pretest took them in average 27.05 minutes (SD = 14.40).
Next, they signed up for the laboratory experiment, which was conducted about one week later, in an online calendar and received a confirmation email.

Within the laboratory, participants were randomly assigned to the four experimental conditions (UU, PU, UA, PA). Then they completed a short form of the demographic data survey, so online and laboratory data could be matched. Next, they received the unspecific or argumentation writing task, the integration prompts where applicable, and the three text documents described in table 1. Participants then learned in a self-regulated manner for as long as they considered as necessary to comprehend the documents’ content and acquire an overall understanding ($M = 75.87$ minutes, $SD = 15.22$). After that, participants had to hand in their written text and the learning material to the experimenter. Finally, they answered the posttest, which included the IMI, the ck-, pk-, and pck-test, and the InterVT ($M = 24.26$ minutes, $SD = 6.07$).

**Results**

Table 2 shows the descriptive results for the motivation according to the three dimensions interest/enjoyment, perceived competence, and effort/importance, the increases of ck, pk, and pck, and the degree of knowledge integration according to the InterVT.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Experimental condition¹</th>
<th>UU</th>
<th>PU</th>
<th>UA</th>
<th>PA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest/enjoyment</td>
<td>2.77 (1.23)</td>
<td>2.56 (0.70)</td>
<td>2.73 (0.62)</td>
<td>2.45 (0.70)</td>
<td></td>
</tr>
<tr>
<td>Perceived competence</td>
<td>2.74 (0.72)</td>
<td>2.49 (0.54)</td>
<td>2.76 (0.50)</td>
<td>2.47 (0.55)</td>
<td></td>
</tr>
<tr>
<td>Effort/importance</td>
<td>3.31 (0.51)</td>
<td>3.07 (0.46)</td>
<td>3.18 (0.65)</td>
<td>3.11 (0.53)</td>
<td></td>
</tr>
<tr>
<td>CK acquisition²</td>
<td>3.45 (1.87)</td>
<td>3.28 (1.65)</td>
<td>3.17 (2.33)</td>
<td>2.27 (2.76)</td>
<td></td>
</tr>
<tr>
<td>PK acquisition²</td>
<td>6.05 (2.40)</td>
<td>5.88 (1.62)</td>
<td>5.88 (2.46)</td>
<td>5.05 (2.72)</td>
<td></td>
</tr>
<tr>
<td>PCK acquisition²</td>
<td>3.00 (2.74)</td>
<td>2.56 (1.64)</td>
<td>2.21 (2.09)</td>
<td>2.00 (2.45)</td>
<td></td>
</tr>
<tr>
<td>Knowledge integration³</td>
<td>4.23 (1.69)</td>
<td>5.72 (2.15)</td>
<td>4.96 (1.52)</td>
<td>4.77 (1.97)</td>
<td></td>
</tr>
</tbody>
</table>

*Note:*

1 Abbreviations for experimental conditions: UU = unprompted with unspecific writing task condition, PU = prompted with unspecific writing task condition, UA = unprompted with argumentation task condition, PA = prompted with argumentation task condition.

2 Knowledge acquisition is based on the increase between participants’ pre- and post-test results in the according domain specific knowledge test.

3 Knowledge integration is based on test performance in the InterVT where participants could score a maximum of 14 points.

To test hypotheses 1a and 1b, we performed a 2x2 repeated-measures ANOVA for each knowledge domain. The results indicated that the participants in each experimental condition
gained a significant amount of knowledge in the ck dimension (Wilks’ $\lambda = .331$, $F(1,89) = 180.182$, $p < .001$, $\eta_p^2 = .669$), in the pk dimension (Wilks’ $\lambda = .136$, $F(1,89) = 564.092$, $p < .001$, $\eta_p^2 = .864$), and in the pck dimension (Wilks’ $\lambda = .448$, $F(1,89) = 109.814$, $p < .001$, $\eta_p^2 = .552$; see table 2 for descriptives). Results revealed no significant main effects of prompts and task condition on knowledge acquisition in neither of the three domains. Also, there were no statistically significant interaction effects between prompts and task found. Hence, hypotheses 1a and 1b were accepted.

Regarding hypotheses 2a and 2b, results of a factorial ANOVA failed statistical significance for the main effects of prompts, $F(1,89) = 2.882$, $p > .05$, $\eta_p^2 = .031$, and task, $F(1,89) = .079$, $p > .05$, $\eta_p^2 = .001$. However, there was a significant interaction effect between prompts and task, $F(1,89) = 4.752$, $p < .05$, $\eta_p^2 = .051$. Considering the importance of motivation for self-regulated learning and knowledge integration, we conducted an additional factorial ANCOVA that controlled for intrinsic motivation according to the three dimensions interest/enjoyment, perceived competence, and effort/importance. Contrary to the ANOVA, the results of the ANCOVA suggested a significant main effect of prompts after controlling for intrinsic motivation, $F(1,86) = 4.567$, $p < .05$, $\eta_p^2 = .050$, indicating that students’ knowledge integration was enhanced by receiving prompts ($M = 5.33$, $SE = .27$) compared to receiving no prompts ($M = 4.50$, $SE = .27$). Thus, hypothesis 2a was accepted in consideration of a compensatory effect of intrinsic motivation.

Moreover, there was no significant main effect of task, $F(1,86) = .102$, $p > .05$, $\eta_p^2 = .001$, indicating no significant difference of pre-service math teachers’ knowledge integration based on receiving either an unspecific writing task ($M = 4.98$, $SE = .27$) or an argumentation task ($M = 4.86$, $SE = .27$). Hence, we rejected hypothesis 2b.

In addition, results of the factorial ANCOVA that controlled for intrinsic motivation showed a significant interaction effect between prompts and task, $F(1,86) = 5.546$, $p < .05$, $\eta_p^2 = .061$. Follow-up analyses suggested that prompts were of particular effectiveness for knowledge integration when they were provided supplementary to the unspecific writing task ($M = 5.84$, $SE = .37$) compared to the unspecific writing task without prompts ($M = 4.12$, $SE = .39$). Prompts lost their positive effect on knowledge integration when they were combined with the argumentation task ($M = 4.83$, $SE = .39$) compared to the argumentation task which was not supplemented by prompts ($M = 4.89$, $SE = .37$). Accordingly, the enhancing effect of prompts on knowledge integration was task specific and we subsequently rejected hypothesis 3.
Discussion

In this study, we compared the effects of unspecific and argumentation writing tasks as well as of task-complementary integration prompts on pre-service teachers’ domain-specific knowledge acquisition and the integration of knowledge entities from three text documents. Each document addressed one of the dimensions of participants’ professional knowledge, that is, mathematical ck, general pk, and pck of mathematics.

As hypothesized, all participants gained a significant amount of ck, pk, and pck due to their self-regulated learning with the documents. The gain in each knowledge domain was not interfered by experimental conditions, that is, receiving integration prompts and/or an argumentation task prior to the actual reading and learning phase. Also, there was no interaction effect of prompts and task that influenced domain-specific knowledge acquisition.

With regard to our hypotheses on the enhancement of knowledge integration through prompts and/or an argumentation writing task, results are divergent. On the one hand, we found that providing cognitive integration prompts when inducing self-regulated learning with a writing task was an effective method to enhance pre-service teachers’ self-regulated integration of professional knowledge from multiple documents. Pre-service mathematics teachers achieved significantly better results in the InterVT, which served as a measure for the degree of successful knowledge integration, when they received task-complementary prompts. This indicates that prompts can be effective in triggering pre-service teachers to intentionally engage in and apply knowledge integration strategies to construct relations between texts in self-regulated learning environments with multiple documents on their professional knowledge domains.

Contrary to this finding and somewhat surprisingly, no positive effect of initiating pre-service teachers’ learning with an argumentation task on their performance in the InterVT was found. Also, complementing the argumentation task with additional integration prompts did not affect pre-service teachers’ performance in the knowledge integration measure. These findings were unexpected and may be due to the fact that the three texts on mathematics teachers’ professional knowledge domains did address different knowledge facets whereas prior multiple document research usually included texts that addressed the exact same topic (e.g., Bråten & Strømsø, 2009; Maier & Richter, 2014; Wiley & Voss, 1996, 1999). Future research on differences in pre-service teachers’ self-regulated knowledge integration when learning with multiple documents that either do or do not elaborate on identical aspects is therefore recommended. Again, since our experimental groups were either instructed to write down their thoughts or to write an argumentation for the interrelatedness of text information when trying
to develop an overall understanding, an analysis of participants’ texts may shed further light on pre-service teachers’ learning with multiple documents and their integration processes.

Furthermore, our results provided evidence for an interaction effect between receiving prompts and the type of writing task. Contrary to our third hypothesis, we found that prompts were of particular benefit in combination with an unspecific writing task but suffered the loss of their effect when used supplementary to an argumentation task. Hence, the effect of prompts (a) is task-specific, and (b) cannot be considered as additive to unspecific and argumentation writing tasks. This result may be explained by the freedom for a self-directed writing-to-learn process that is given by an unspecific writing task since this type of task leaves much room to engage deeply in the processes stimulated by the integration prompts. In contrast, an argumentation task, which asks students to prepare an argumentative continuous text, may make them feel trapped in this specific text type and format to be written, and thus, inhibit the positive effects of the task-complementary prompts for knowledge integration.

Together, the aforementioned findings on knowledge acquisition and the effectiveness of prompts for knowledge integration indicate that prompted knowledge integration might not necessarily implicate a shift of readers’ focus on knowledge-telling and the construction of isolated text models to knowledge-transforming and the construction of an interrelated mental model (Scardamalia & Bereiter, 1987; Wiley & Voss, 1999). Such a shift of focus or the according change of readers’ intention and goal orientation, respectively, would imply a different application of the cognitive resources available (Rouet & Britt, 2011) and consequently result in a stronger emphasis on either acquiring or integrating knowledge. However, the present study provides evidence that students of the prompted unspecific writing task condition gained a comparable amount of domain-specific knowledge and still developed a more integrated model of understanding across multiple documents. Hence, we conclude that gains within teachers’ professional knowledge domains are not necessarily interfered by prompting integration processes. This conclusion should apply at least for the context of a self-regulated learning setting where students have the freedom and time to decide how and how long they want to engage in their reading and writing process, as well as in knowledge acquisition, comprehension, and/or integration procedures. Still, we suggest to conduct further studies that investigate the question of how knowledge acquisition and knowledge integration interact and relate to each other. Also, the analysis of our participants’ written texts will presumably allow to draw more conclusions about the extent of students’ knowledge-telling and -transforming, and thus, about their integration efforts. Besides, the question arises in what way the task models and subsequent goal orientations differ from each other and influence
subsequent processes based on receiving either task-supplemental prompts or not. Also, more research is needed to identify tasks that are effective in enhancing pre-service teachers’ self-regulated learning and integration of knowledge based on multiple documents since the argumentation task did not significantly affect learning in the present context.

Also, this study supports the importance of motivation in self-regulated learning and knowledge integration settings. Thus, future work should further investigate how instructional support of motivation, for example, providing positive feedback (cf. Maier & Richter, 2014), can positively affect learners’ knowledge integration.

Finally, it should be acknowledged that the present experimental study comes with certain limitations. First, an important limitation lies in the fact that our findings are based on a sample of pre-service elementary mathematics teachers and that the majority of the sample was female. This restricts generalizability and asks for further studies that take, for example, pre-service secondary teachers and possible gender effects into account. Second, the findings presented in this paper are solely based on participants’ performance in an InterVT, a test which measures subjects’ ability to draw inferences across multiple text documents that is frequently used in multiple-documents research (e.g., Bråten & Strømsø, 2009; Wiley & Voss, 1999). An analysis of different knowledge integration measures, like participants’ written texts, should complement the present findings. Moreover, further studies need to be carried out in order to estimate the influence of more integrated models on pre-service teachers’ decision making and problem solving, for example, by implementing transfer tests that comprise the evaluation of existing learning material, the design of own learning tasks, and/or the development of a rational for the arrangement of learning and instruction elements in lesson planning.

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