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Engaging preservice primary and preprimary school teachers in digital storytelling for the teaching and learning of mathematics

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Abstract

A significant criticism made of preservice teacher education is that it fails to prepare teachers in such a way that they would feel confident in the use of information and communication technology (ICT) in teaching, despite the assumed digital literacy of student-teachers and the children they will eventually teach. New technologies have enabled multimodal design and digital storytelling in meaning-making and communication and are now often instrumental and influential in shaping students' social practices and identities. The purpose of this study was to explore an integrative approach in applying ICT in learning with specific reference to the formation of mathematics teaching capability in preservice teachers. It takes into consideration student-teachers' lived experiences when introducing ICT supported learning into their classrooms as well as their exposure to related university courses such as educational technology, special didactics of mathematics and mathematics. This paper describes the instructional design framework and assessment criteria for mathematical problem solving and digital storytelling introduced to an ICT course for student-teachers. Based on the analysis of pre- and posttesting of the subjects' capabilities and reports of their perceptions, it is suggested that preservice teachers can efficiently develop their content knowledge in mathematics problem solving and that an integrative approach such as that described here may facilitate both mathematical problem-solving competences and pedagogical competences for applying digital storytelling in solving mathematical problems. The cohort of preservice teachers had no prior experiences of digital storytelling or multimodal design and perceived them as new practices. Their conceptions changed during the course from the passive recipients to active producers of media content. They demonstrated reflection relative to learning-by-design and representation modelling. They perceived digital storytelling as a strategy and means for empowering the "student-voice" and the active construction of knowledge. The findings of the study contribute to preservice teacher education indicating that an integrated approach of instruction that deploys digital storytelling and multimodal design can help facilitate preservice teachers' pedagogical competencies and mathematical content knowledge.

Practitioner Notes

What is already known about this topic

- A significant criticism made of preservice teacher education is that it fails to prepare teachers in such a way that they would feel confident in the creative use of ICT in teaching, despite the assumed digital literacy of student-teachers and the children they will eventually teach. Preservice teacher education provides a critical opportunity for developing technical as well as pedagogic ICT competencies in teaching and learning.
- Opportunities are afforded through ICT and specifically multimodal design and digital storytelling for visualisation in support of different representations for learning.
- In preservice teacher education, storytelling is applied as a pedagogical strategy and as a research method facilitating preservice teacher engagement in transformative pedagogical work.

What this paper adds

- How the integration of ICT together with multimodal design in digital storytelling into the learning design of an intervention aimed at preservice teacher education may:
  - develop student-teachers' competences for multimodal design in digital storytelling and support the inclusion of multiple representations in the design of teaching and learning materials, and
  - identify the perceptions held by preservice teachers relative to ICT and specifically multimodal design in digital storytelling, especially as applied to mathematical problem solving.

Implications for practice and/or policy

- Curricula that include ICT components in preservice teacher education should include pedagogies involving context-based, authentic tasks in order to maximise their impact and effectiveness.
- Including digital storytelling in teaching and learning practices can afford opportunities for concept and digital literacy development of both preservice teachers and the children they teach.

Introduction

The paper discusses preservice teacher education and presents an integrated approach to preparing preservice teachers for lesson planning, design and delivery in mathematics teaching. The intervention involved a contextualised approach in which an educational technology course was associated with, and applied material from, courses in the special didactics of mathematics, mathematics, integrated through an in-school practicum for preservice teachers. The instructional design framework and evaluation criteria are presented, along with the empirical testing and results. In developing the learning activities, the authors chose to promote a digital storytelling approach in engaging preservice teachers with multimodal design and digital literacy.

The issues under consideration illustrate how information and communication technology (ICT) in learning activities may support pedagogical competency as an intended learning outcome for these students. A significant criticism to preservice education is that it fails to prepare teachers in such a way that they would feel confident in the use of ICT in their teaching (Hermans, Tondeur, van Braak & Valcke, 2008; Huang, Lubin & Ge, 2011; Sang, Valcke, van Braak & Tondeur, 2010) and that this phenomenon remains despite the presumed digital literacy and abilities of the "next-generation" of university students (Funkhouser & Mouza, 2013; Lei, 2009; Mouza, Karchmer-Klein, Nandakumar, Ozden & Hu, 2014). The approaches to integrating ICT in preservice teacher education needs to take into consideration the lived experiences and identities of these students and promote ICT in the creation of learning activities for them. In doing so, ICT-supported learning may facilitate learning that is situated in social practices through the sharing and co-construction in the process of meaning-making and through a range of modes (Kress, 2003; Kress & Jewitt, 2003; Kress & Selander, 2012). Thus, digital storytelling has been applied as a pedagogical strategy in engaging students in a transformative learning experience (Coulter, Michael & Poynor, 2007) and is thus applied in the study reported here.

The integration of ICT provides opportunities in teaching and learning that may impact positively on learning outcomes; ICT has often been described as enabling a paradigm shift in teaching and learning (Hammond, 2014) and has been associated with innovative pedagogical approaches facilitating student-centred approaches to education (Ranguelov, Horvath, Dalferth, Noorani, 2011). However, it is argued that a gap exists between the rhetoric and reality of technology as enabler of the transition to constructivist teaching (Hammond, 2014). A report on mathematical education in Europe argues that there is no conclusive evidence about the benefits of ICT in mathematics teaching and, moreover, only a minority of teaching has ICT embedded within it (Parveva, Noorani, Ranguelov, Motiejunaite, Kerpanova, 2011, p. 60).

Applying a constructivist paradigm to science and mathematics learning and teaching assumes that the transitions between enactive, iconic and symbolic representations (Bruner, 1966), supported by exploration, investigation, visualisation and modelling will lead to an enhanced conceptual understanding (Principles and Standards for School Mathematics, 2000). Computer-based learning application design affords the use of digital media formats such as text, graphics, audio and video so that the symbolic, static and dynamic representations of problems and other learning activities might presented in a variety of ways (Bodemer, Ploetzner, Feuerlein & Spada, 2004). The exploration of various combinations of different media for effective learning has been the focus of several studies (Mayer, 1997). The work by Kress and others (eg, Kress & Jewitt, 2003; O'Halloran & Lim, 2011) highlights how multimodal literacy has at least two dimensions—media and semiotics, each with multiple literacies—hence, the representation and communication of meanings is multimodal (Kress, 2003); computer-based digital technologies provide efficient and effective access to multiple modes of representation and as such influence thinking (Kress, 2003); and multimodal design that incorporates different representational resources for meaning-making (Kress & van Leeuven, 2001) has become integrated across curricula within various subjects (Kress & Jewitt, 2003; Miller & McVee, 2012). Integrating ICT into the preparation of preservice teachers across various courses therefore requires attention to multimodal design. Multimodal design as a situated social practice in learning and communication (Kress & Selander, 2012) may facilitate the transfer of ICT skills of students across the boundaries of in and out of school activities (Jewitt, 2008). Multimodal design in learning incorporates design as an interactive process that facilitates meaningful engagement between the learner and the teacher. In this situation, the teacher is considered a professional designer of learning activities with students as the end users (Kress & Selander, 2012). In summary, as an applied practise, multimodal design in teaching responds to new literacy requirements; provides space for mediation in learning and teaching; facilitates embodied teaching and learning; takes into consideration the identity and the real-life world of the student; and provides instruction through multimodal design that can support multiple representations in learning (Miller & McVee, 2012).

The implementation of ICT in education has tended to focus on technological advancement and capabilities rather than pedagogy (Rushby & Seabrook, 2008). Preservice teacher education for ICT integration has also been technology oriented (Tondeur, van Keer, van Braak & Valcke, 2008) rather than application focused. The literature suggests that preservice teachers are not sufficiently prepared for integrating ICT into their classrooms (Funkhouser & Mouza, 2013). Teacher ICT capability must include pedagogical and technical competencies (National ICT Competency Standard for Teachers, 2000). Although technical competency has been proven to be higher in recent generations of student-teachers entering university, there is little evidence of proficiency in the pedagogy of advanced technologies in these students (Lei, 2009; Ng, 2012). Developing pedagogical competency is critical during preservice education (Chai, Ling Koh, Tsai & Lee Wee Tan, 2011) and is intimately connected with preservice teachers' beliefs and conceptions about teaching and learning (Funkhouser & Mouza, 2013). It has been found that preservice teacher education courses can help student teachers move from often teacher-centric views, towards more constructivist and student-centred conceptions, and that such student-centred beliefs, ". . . were strongly correlated with educational technology integration" (ibid., p. 272).

Incorporating ICT capacity building into the curricula and pedagogies for preservice education is typically facilitated through stand-alone courses, integration in various courses or through practicing technology in the field (Kay, 2006). Effectiveness and impact of ICT education for preservice teachers is limited when technology skills are taught in isolation, at a distance from the broader curriculum, and decontextualised (Huang *et al*, 2011; Kay, 2006; Moursund & Bielefeldt, 1999; Pellegrino, Goldman, Bertenthal & Lawless, 2007; Pope, Hare & Howard, 2002). Teaching ICT in context has repeatedly been found to be most effective (Kay, 2006).

Digital storytelling as the instructional design framework

Storytelling can be a useful tool in making sense of the world and one's experiences of problem solving, individual perspectives and insights (Egan, 1988; Rambe & Mlambo, 2014; Wyatt-Smith & Kimber, 2009). Storytelling has been included in curricula associated with literacy (Campbell, 2012; Yang, 2012), mathematics (Albano & Pierri, 2014; Casey, Kersh & Young, 2004), history and earth science. In preservice teacher education, storytelling is applied as a pedagogical strategy and as a research method facilitating preservice teachers in engagement with transformative pedagogical work (Coulter *et al*, 2007). Storytelling is described in the literature on constructivist learning as facilitating student-centred learning through student engagement and reflection for deep learning (Barrett, 2006; Psomos & Kordaki, 2012).

In solving mathematical problems, situational storytelling provides a semantic structure for the principles that are to be practised in solving the problem (Jonassen, 2003). Problems are not limited to one discipline; as Gardner (2011) pointed out, nature does not stand sharp boundaries and division into subjects. Cross-curricular connections in problem solving provide contextualisation and facilitate integration of knowledge across subjects. Storytelling includes problems anchored or played out in sagas (Casey *et al*, 2004), world problems, authentic real-life situations and professional contexts (Jonassen, 2003). Storytelling has the potential to engage learners in critical thinking and problem solving (Gaeta *et al*, 2014), providing situational context and structural relationships (Jonassen, 2003), and structure and sequencing for narrative topics (Gaeta *et al*, 2014; Psomos & Kordaki, 2012). Mathematical problem-solving teaching strategies that include storytelling (Casey *et al*, 2004) and provide a meaningful context connecting mathematics and literature (Casey *et al*, 2004; Wilburne & Napoli, 2008) may support the conceptual understanding of mathematical problems, structures and problem-solving skills (Jonassen, 2003) and increase mathematical literacy for the interpretation of mathematics in various contexts (Albano & Pierri, 2014). Nevertheless, students sometimes have issues with text comprehension in mathematical story problems (Walkington, Sherman & Petrosino, 2012), or with comprehension at the level of abstraction required when undertaking routine mathematical operations (Cotic, 1999).

Multiple representations of mathematical problems in stories may support comprehension in mathematical problem solving, understanding of textual information and visualisation of data (Jonassen, 2003). Using technologies increasingly available to preservice teachers and school children that immerse learners in multimodal digital design to create personal representations of concepts can provide a powerful cognitive and social teaching space (Hoban, Loughran & Nielsen, 2011). Hence, digital storytelling has the potential to facilitate narrative through the creation of multiple modes of representation and the sharing and consumption of interactive content (Spaniol, Klamma, Sharda & Jarke, 2006). However, the application of digital storytelling and associated theoretical frameworks for teachers and students in mathematics is somewhat rare (Albano & Pierri, 2014; Robin, 2008), even though digital storytelling has been recognised in teaching mathematical literacy and in improving students' capabilities for active, context-based, mathematical problem solving (Albano & Pierri, 2014). Elsewhere, there is some evidence of digital storytelling being used for investigating mathematical manipulatives where preservice teachers explore teaching concepts by creating a digital story (Browning & Willis, 2012). Following these observations, the authors identified an opportunity to provide explicit instruction in multimodal digital storytelling for preservice teachers and to investigate the impact of such an intervention on the students' own mathematical capabilities and their ability to create similar learning activities for children.

Digital storytelling authoring tools incorporating a variety of narrative approaches have been variously applied in learning and teaching (Gaeta *et al*, 2014; Hoban *et al*, 2011). Social media, eg, supports storytelling experiences and facilitates peer-to-peer collaboration (Liu, Liu, Chen, Lin & Chen, 2011). Basic desktop office software has been applied for multimodal design in storytelling (Yang, 2012) showing how the integration of digital tools already familiar to teachers might be combined with familiar digital and non-digital tools to good effect and thus avoiding the problem of less familiar, perhaps more advanced tools being accepted and trialled by teachers (Nussbaum & Diaz, 2013). With this in mind, the study reported here integrated digital tools most widely preferred, used and adopted by students, namely, Microsoft PowerPoint and Movie Maker. These tools are relatively easy to use and master and help redress the lack of confidence in the use of technology expressed by preservice teachers (Kobayashi, 2012). Digital stories were produced using these tools, combined with conventional resources such as drawing or physical models. The mathematical arithmetic problem story types were defined based on the work of Valenti (1987), Tenuta (1992) and Cotic (1999).

The framework in Figure 1 represents the various components incorporated in the multimodal digital design associated with this study. The framework has at its core the types of problems focused on when developing preservice teachers' competencies in mathematical literacy and problem solving and for teaching mathematical problems. Mathematical problem solving is conceptualised here as incorporating critical thinking, creativity and active engagement when searching patterns for solutions, whereas the teaching of mathematical problem solving is seen as facilitating the capability development of students for analysing data, selecting a strategy and reflecting on the whole activity. This approach is deemed necessary given the diverse nature of problems and contexts and the need for preservice teachers to be prepared for teaching various types of mathematical problems and designing learning activities that promote active knowledge construction in which students take into account: the nature and mode of data within the given context; distinguishing significant data from non-significant data; the analysis of relations between data; and discerning if the information available is sufficient to solve the problem. When

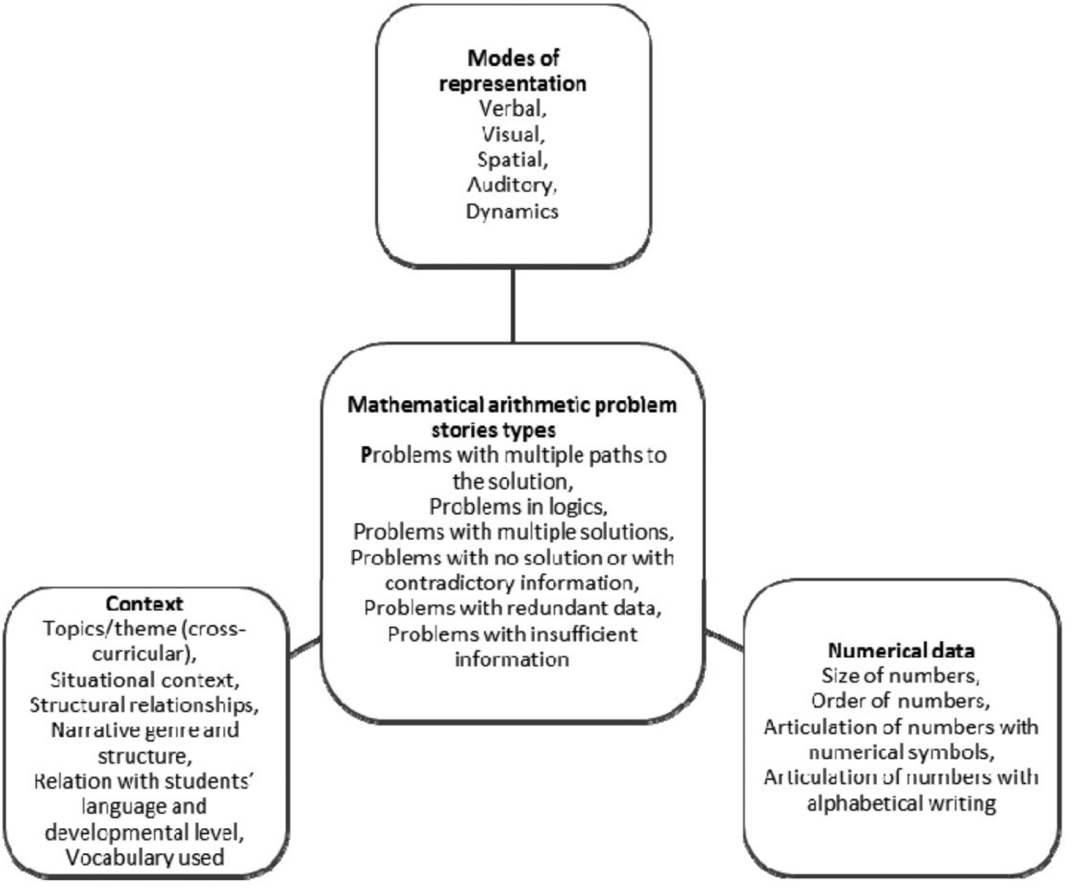

Figure 1: Design components

taught through digital storytelling, students apply the three processes of (1) the formulation of a scenario that incorporates a mathematical problem in a story; (2) application of mathematical concepts, procedures, reasoning; and (3) interpretation by applying the mathematical problem-solving strategies in a context of the story (Albano & Pierri, 2014).

Rotating around the core in Figure 1 are the semantic, contextual and modal components; we hope to engage learners with in solving these problems. This includes the contextualisation of a problem in situations and topics or themes that are meaningful for a student (OECD, 2003); connecting subjects through cross-curricular connections; and exploration and solving a problem by transitions between different representations (ibid.). In engaging students in this manner and with these problems we aimed to develop and evaluate a particular set of competences described in the next section.

Competencies and their evaluation criteria

To evaluate the competencies of students exposed to the intervention and the impact of the initiative, a set of intended learning outcomes was identified connecting mathematics, special didactics of mathematics and educational technology. In mathematics, eg, the intended outcome involves solving different types of mathematical arithmetic problems. In special didactics of mathematics, the intended learning outcomes include: a capability to facilitate students' strategies for problem solving appropriate to their developmental level; being able to provide problem content and contexts that are meaningful to students and foster meaningful learning and engaging and pleasant experiences that help build confidence; integration of computer supported learning through the application of digital storytelling in a way that combines various representational resources and that encourages active engagement, inquiry learning, imagination and creativity; and applying storytelling in which mathematical symbolism is contextualised and which facilitates the process of reasoning and searching for solutions to mathematical problems. The technological outcomes included: the production of online content (animations, images, moving images, photographs, video, sound and voice-over); editing and adding self-produced digital and non-digital material (drawings, other artefacts and concrete material, animations, images, moving images, photographs, video, sound and voice-over); managing basic editing and interactive tools; and using software and hardware to organise, manage and store computer files.

The specific criteria applied to the outcomes above are represented in Figure 2, which describes various modes of representation and criteria associated with them (The New London Group, 2000). Several design modes are defined as linguistic, visual, audio, spatial and multimodal. A sixth mode, gestural, was excluded as not relevant for this study and was substituted by "dynamics," which according to Bodemer *et al* (2004) is one of the key characteristics of multimedia. The modes of representation are based on two evaluation elements described by Wyatt-Smith and Kimber (2009) as *transmodal operations* and *cohesion*. Transmodal operations refer to meaning-making by shifting different modes and navigation between sequences in a way that facilitates meaning-making in learning. Students achieving high comprehension not only progress between concrete, visual and abstract levels of representation but also variously shift between them. Cohesion refers to combining modality elements to achieve unity and is, according to Kimber and Wyatt Smith (2010), defined as a technical proficiency for multimodal design facilitating meaning-making and the cohesion of ideas within the text. In the case of our study, this is demonstrated at three levels, the narrative type, conceptions of and ability to solve mathematical problems, and an ability to make cross-curricular connections between the learning objectives of multiple subjects. The perceptions of, and competencies in, ICT were manifest in multimodal design in digital storytelling. For the purposes of this study, each of the criteria described was assessed using a 4-point grading scale where 1 = low and 4 = high.

Having established a set of criteria for multimodal design and digital storytelling, a null hypothesis and two alternative hypotheses were developed:

Hypothesis 0: Engaging in multimodal design for digital storytelling in mathematics has no impact on the competencies of preservice teachers in multimodal literacy and composition, mathematical problem solving and their ability to teach mathematics.

Hypothesis 1: As a consequence of engaging in multimodal design in digital storytelling for solving mathematical problems, preservice teachers will show progress in their development of competences in solving mathematical problems.

Hypothesis 2: Preservice teachers who have higher grades in multimodal design for mathematical problems in digital storytelling will, compared with those that have lower grades, achieve higher marks in a mathematics test.

The above hypotheses were tested using quantitative data and augmented with qualitative data drawn from individual student reflections that focused on the perceptions held by the preservice teachers regarding multimodal design in digital storytelling and its contribution within their broader competency development.

Methods

Settings

The setting of the intervention was a course of educational technology in the academic year 2011–12 at the University of Primorska Faculty of Education. [Correction added on 09 April,

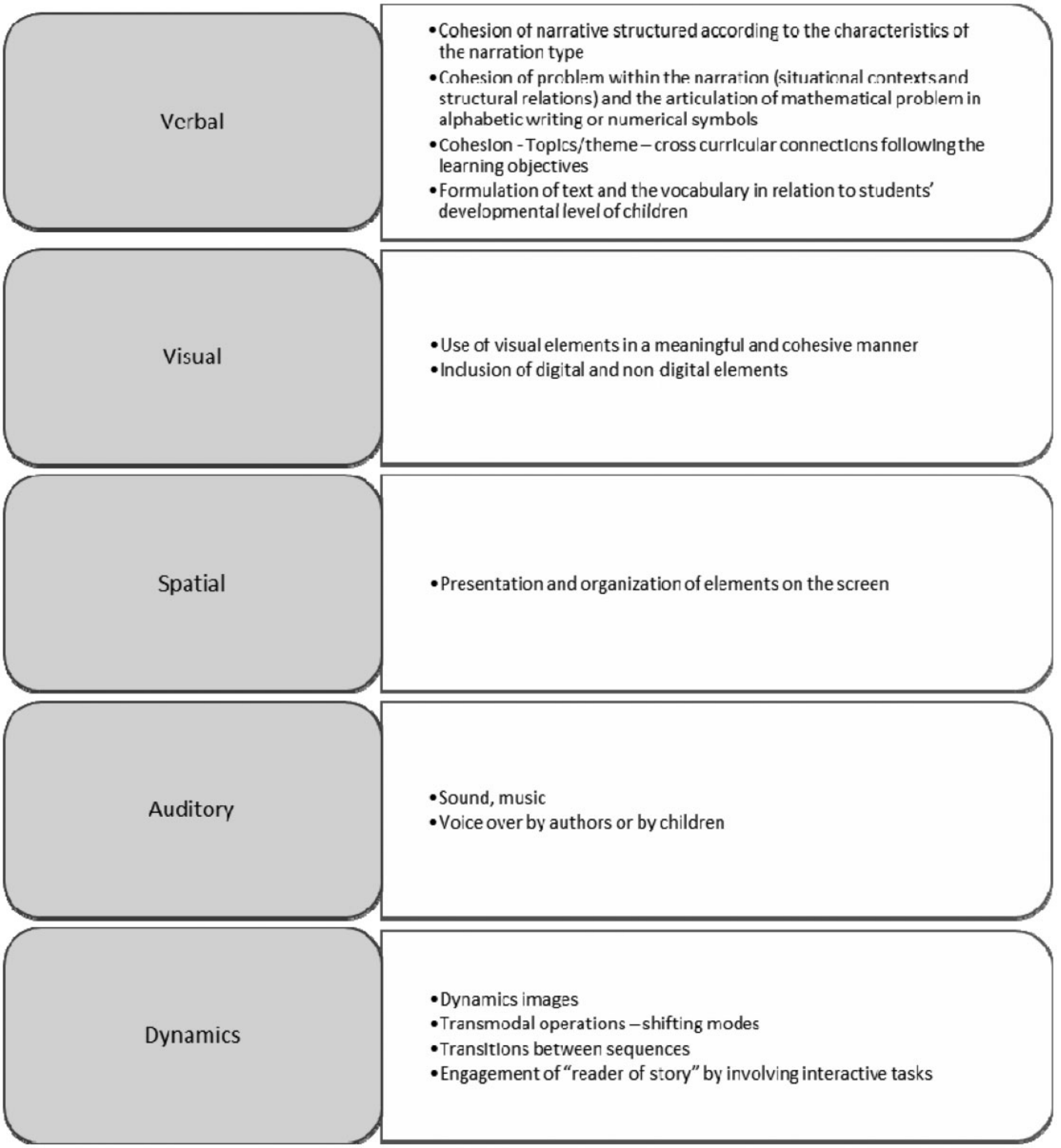

Figure 2: Assessment criteria for evaluating competencies in the multimodal design of a digital story

after first online publication: in the preceding sentence, the academic year was corrected to 2011–12]. This is one of three institutions in Slovenia offering two study programmes: pre-school teaching (hereafter PST) and primary classroom teaching (hereafter PCT). Instructional and learning activities were designed that required students to:

- reflect on their perceptions of ICT in pre-school and primary school as well as their own learning at the beginning of the course, during and after completion;
- design a lesson plan defining the age of children, the topic, subject areas and their cross-curricular connections, and learning objectives, together with the resources and material needed. The lesson plan required the creation of the digital story as the primary outcome;
- select a form of story (fairy-tale, fable, etc) and design a narrative relative the criteria above;

- apply digital and non-digital resources, such as drawings or other artefacts in the story. The non-digital artefacts were created by the preservice teachers or in collaboration with children;
- compose a story in digital format. This could include the production of animations, photography, video production, adding music and audio voice-over narration, etc; and
- make observations and written reflections regarding ICT integration in schools during the in-school practicum.

Software and hardware were made available for production and storing, with students selecting PowerPoint and Movie Maker. Mobile phones, digital cameras and scanners were also used.

Participants

One hundred and fifteen preservice teachers aged 19–20 years participated in the study, 50 students from the programme on PCT and 65 students from the PST programme as shown in Table 1. The teaching staff (also authors of this paper) included two course leaders of educational technology, mathematics and special didactics of mathematics, and a teaching assistant.

Study design and data collection methods

The study involved internal and cross-comparisons between two similar but non-equivalent groups, albeit both exposed to the intervention involving multimodal digital storytelling. Although this quasi-experimental approach enabled pre- and posttesting of students' knowledge, it should be noted that the lack of randomised sampling and control limits the conclusions that might be drawn from the analysis. However, the approach does enable the evaluation of the intervention even if more definitive cause-and-effect relationship are difficult to establish. Quasi-experimental designs are not unusual in education and the social sciences given the practical and ethical issues associated with applying scientific methods where an intervention is expected to be positive for all students. The design also followed a mixed methods approach involving the quantitative analysis of student performance along with qualitative analysis of written reflections provided by the same students.

Quantitative data included the *pre- and posttest* scores comparing the outcomes of a test to determine mathematic problem solving, whereas qualitative data were obtained from written reflections of the participants in the study. The pre- and posttests consisted of six tasks with a variety of mathematical problems, including problems with redundant data, problems with multiple solutions, problems with multiple paths to the solution, problems with no solution, mathematical problems in logic and problems with insufficient information. For example, a simple mathematical problem with insufficient data at a pre-school level might involve asking, "How many socks do you need for two people?" and might be solved aided by observation or the manipulation of objects rather than through the manipulation of numbers. It is important therefore, that teachers are able not only to recognise and solve these types of problems themselves, but to also imagine multiple ways of presenting these problems appropriate to the children they are teaching.

Table 1: Participants' structure by gender

Group	*n*	*Gender*	*Frequency*	*Percent*
Primary classroom teaching	50	M	3	6
		F	47	94
Pre-school teaching	65	M	4	6
		F	64	94

Students completed the pretest before the beginning of the study and the posttest a fortnight after the conclusion of the experiment. The duration of tests was 45 minutes. *Assessment of the digital stories* was based on the evaluation criteria described earlier and presented in Figure 2 using a 4-point grading scale. *Written reflections* were obtained by asking students to comment on their perceptions about the role of computers in the classroom, the process of multimodal design, the role of storytelling and their competencies relative to media content production.

Data analysis

SPSS 20 (Statistical Package for Social Science) (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.) was used to analyse the quantitative performance data using independent sample *t*-tests applied for the pre- and posttests. Following the quasi-experimental approach with no control group, *t*-tests enabled the comparative analysis of pre- and posttest results for the two different groups (independent samples) of students (PCT and PST). The two groups of students had different characteristics according to their mathematical prerequisite knowledge. Preservice teachers in the PCT programme had completed general secondary education (Gymnasium) and passed matriculation exams, whereas preservice teachers in PST education had completed technical secondary education and completed vocational examinations.

To evaluate the digital stories, two assessors independently applied the marking criteria and then moderated the scores. Pearson's coefficient was applied to determine the correlation between the scores for mathematical problem design in the digital story and a final test of the preservice teachers' arithmetic problem solving.

The qualitative data obtained from written reflections was coded and categorised. The categorising was undertaken in two steps. Firstly the analysis and grouping of similar statements, before these groups of statements were assigned codes. Two researchers independently coded and categorised the data. Cross-checks and peer debriefing during the processes of planning, data gathering and analyses helped to ensure validity and reliability.

Findings

The null hypothesis assumes that the intervention would have no impact on the development of the students' competencies. To support or reject this proposition, each of the alternative hypotheses is now examined followed by a discussion of the themes emerging from the qualitative study.

Hypothesis 1: As a consequence of engaging in multimodal design in digital storytelling for solving mathematical problems, preservice teachers will show progress in their development of competences in solving mathematical problems.

Table 2 presents the arithmetic means of scores, standard deviations and the percentages of students who solved a task entirely correctly for each of the six types of mathematical problems in the pretest and posttest.

The results of the *pretest* reveal that the students in both programmes performed best in solving mathematical problems with redundant data, which means they were quite well oriented in dealing with a multitude of data, managed to perceive the problem and then to correctly select the data that helped them on their path towards the solution. Seventy-four per cent of preservice teachers in the PCT group and 74% of preservice teachers in the PST group solved the task entirely correctly. The number of preservice teachers of both study programmes (21%) who solved the task entirely correctly was the smallest in task VI—the task with insufficient information. The differences in the performance of the students of both study programmes were the largest in solving task III, which included a mathematical problem with multiple possible solutions. Half of the PCT group and only 26% of preservice teachers in PST group solved the task entirely correctly. In general, in solving the tasks in the pretest, the PCT teachers performed better than PST teachers.

Table 2: The basic statistical parameters of the pre- and posttests by task focus

	Preservice teachers' achievement in individual tasks (pretest)					*Preservice teachers' achievement in individual tasks (posttest)*				
Task	*Group*	n	*Students who solved the task entirely correctly (%)*	*Arithmetic mean of the score*	*Standard deviation*	*Group*	n	*Students who solved the task entirely correctly (%)*	*Arithmetic mean of the score*	*Standard deviation*
I. Problems with multiple paths to the solution	PCT	42	48	5.83	2.52	PCT	50	48	6.65	2.70
	PST	58	34	4.64	3.23	PST	65	49	5.48	2.85
II. Problems in logics	PCT	42	50	0.51	0.50	PCT	50	46	0.46	0.50
	PST	58	31	0.31	0.47	PST	65	25	0.25	0.43
III. Problems with multiple solutions	PCT	42	50	1.88	1.25	PCT	50	56	2.43	0.78
	PST	58	26	1.15	1.19	PST	65	54	2.33	0.92
IV. Problems with no solution or with contradictory information	PCT	42	50	1.33	0.75	PCT	50	42	0.94	0.96
	PST	58	47	1.20	0.85	PST	65	35	0.86	0.93
V. Problems with redundant data	PCT	42	74	1.63	0.67	PCT	50	70	1.54	0.76
	PST	58	74	1.60	0.72	PST	65	57	1.32	0.87
VI. Problems with insufficient information	PCT	42	21	0.77	0.75	PCT	50	78	1.71	0.61
	PST	58	21	0.88	0.73	PST	65	64	1.58	0.63

The preservice teachers in both study programmes progressed considerably according to the *posttest* by solving the sixth task, ie, the problem with insufficient data. PCT students who correctly solved the task increased from 21% to 78%, and PST rose from 21% to 64%. During the course they learned that all the problems, including those we come across daily, do not always contain enough data to be solved and that to be able to solve the problem, there is a need to search for some information that is not immediately apparent. With task III (mathematical problems with multiple solutions), an additional 28% of the PST group solved the problem entirely correctly than in the pretest. It appears that during the course of the intervention they had learned that mathematical problems could have more than one solution and took this fact into account with solving task III. In solving task V, mathematical problems with redundant data, the performance of the PST group was worse than in the pretest—from 74% the percentage of students who solved the task entirely correctly dropped to 57%.

We compared the achievements PCT group with that of PST group in solving the pretest (Table 3). The results of the independent samples *t*-test (Table 4) shows that on average the PCT group scored better in assessing the initial knowledge ($M = 11.96$; standard error of the mean [SE] = 0.53) than PST group ($M = 9.77$; SE = 0.54). The difference is statistically significant $t(98) = -2.799$, $p < 0.05$. It was established in the final assessment of knowledge that on average PCT ($M = 12.73$, SE = 0.49) scored better than PST ($M = 11.87$, SE = 0.37): the difference between the groups is not statistically significant $t(113) = -1.421$, $p > 0.05$.

There are no statistically significant differences between the PCT and PST groups in the posttest results, possibly as both groups were received the same course lectures and tutorials. In solving mathematical problems, greater progress was noticed within the PST programme: in comparison with the pretest their average performance in the posttest improved for more than two points ($M = 2.10$), whereas on average the PCT group improved their scores for nearly one point ($M = 0.77$). From the data obtained, it was identified that the PST group made larger gains, although their total score in the final testing was lower than that of the PCT group.

Hypothesis 2: Preservice teachers who have higher grades in multimodal design for mathematical problems in digital storytelling will, compared with those that have lower grades, achieve higher marks in a mathematics test.

Table 3: Pre- and in the posttest averages and standard deviations for PCT and PST groups

	Preservice teachers' achievement pretest					*Preservice teachers' achievement posttest*				
Group	n	*Min. score*	*Max. score*	M	SD	n	*Min. score*	*Max. score*	M	SD
PCT	42	5.00	18.00	11.96	3.42	50	3.00	18.00	12.73	3.48
PST	58	1.00	17.00	9.77	4.15	65	2.00	17.50	11.87	3.01

Table 4: t-Test of preservice teachers' achievement in the pretest and in the posttest by study programme

						Levene's test		t-*test*		
	n	*Group*	n	M	SD	F	p	t	g	*2P*
Preservice teachers' pretest	100	PCT	42	11.96	0.53	2.745	0.101	–2.799	98	0.006*
		PST	58	9.76	0.54					
Preservice teachers' Posttest	115	PCT	50	12.73	0.50	1.739	0.190	–1.421	113	0.158
		PST	65	11.87	0.37					

*Indicates high significance ($p < 0.05$).

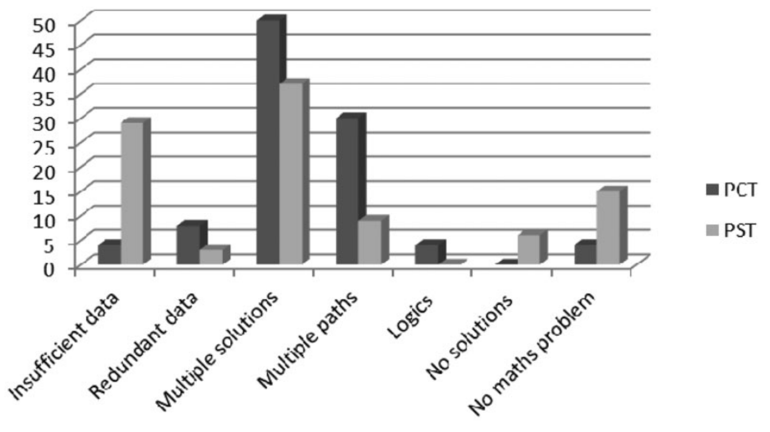

Figure 3: The types of mathematical problems used in the digital story in the study programme (%)

Based on H2, we explored whether high achievements in the multimodal design for mathematical problems in digital storytelling correlated with the achievements in the posttest. In assessment of the digital stories, we established which types of mathematical problems the students most frequently included into their digital stories produced for the children. Figure 3 shows both the PST (50%) and in PCT (37%) most frequently included mathematical problems with multiple solutions into their digital stories. From these data, it may be argued that through their digital stories, the students tended to demonstrate a belief that mathematical tasks do not always have just one correct solution and that digital stories can encourage the children to think about several possible solutions of a problem. Interestingly, these were also the tasks in which their own test performance was lower.

Mathematical problems with insufficient information were selected by 29% of PST students and only by 4% of the PCT students. In their digital stories, the PST group teaching put more emphasis on looking for missing data than the PCT group. As we can see from Figure 3, very few preservice teachers of both study programmes selected mathematical problems with redundant data (PCT 8% and PST 3%). It appears that they assumed that learners would be able to select the information necessary for the solution of the problem from the multitude of data available. In this instance, the students were most successful in solving this type of problems themselves.

In the stories, the set of mathematical problems with multiple paths to the solution was used by 30% of PCT group and by 9% of those in the PST group. The students very rarely chose to include logical tasks into their digital stories, as composing and solving these is the most complex of all the problems. No one in the PCT group chose a mathematical problem with no solution, whereas within the PST group, there were only 6% tasks of this type.

Some of the digital stories submitted contained no adequate mathematical problems or just a simple textual task instead of a mathematical problem. This phenomenon was larger within PST group (15%) than with the PCT group (4%). These students did not attain the learning objectives and were offered a second opportunity to complete the course. The digital stories produced by these repeat students were not included in the qualitative analysis.

Preservice teachers performed well, and assessment of their digital storytelling in a Table 5 shows the arithmetic means and standard deviations presented for PCT and PST. Large differences may be seen between the two groups in verbal cohesion of the problem. Both groups showed high achievement in narrative-type verbal mode cohesion, successfully implementing characteristics of the selected narrative. Less difference was found in managing cross-curricular learning

Table 5: Assessment results across modes by the study programme—arithmetic mean

Modality	*Assessment criteria*	*M PCT*	SD	*M PST*	SD
Verbal	Cohesion—narration type	3.74	0.44	3.70	0.45
	Cohesion of problem (situational contexts and structural relations) and the articulation of a mathematical problem in alphabetic writing or numerical symbols	3.46	0.99	2.38	1.38
	Cohesion—topics/theme—cross curricular connections and the cohesion of elements following the learning objectives	3.38	0.66	3.43	0.63
	Formulation of text and the vocabulary in relation to students' developmental level of children	3.66	0.47	3.63	0.51
Visual	Digital elements	2.74	0.63	2.69	0.72
	Non-digital elements	3.44	0.61	3.36	0.67
Spatial	Screen presentation and organisation	3.2	0.63	2.93	0.86
Auditory	Sound, music	3.72	0.45	3.66	0.50
	Voice-over	3.42	0.49	3.43	0.49
Dynamics	Dynamic images	2.56	0.76	2.43	0.82
	Transmodal elements	2.86	0.77	2.88	0.78
	Transitions between sequences	3.44	0.61	3.5	0.81
	Interactive tasks	3.34	0.65	3.36	0.67

Table 6: Pearson correlation coefficient between the number of points awarded for the mathematical problem within the digital story and the variables score in the final test of knowledge

		Score in the final testing of knowledge	*The points with the maths problem in the digital story*
Score in the final testing of knowledge	Pearson correlation	1	0.550**
	Sig. (two-tailed)		0.000
	n	115	115
The points with the mathematical problem in the digital story	Pearson correlation	0.550**	1
	Sig. (two-tailed)	0.000	
	n	115	115

**Correlation is significant at the 0.01 level (two-tailed).

objectives and themes and language use relative to the developmental level of children. Visual mode results were higher with addition of non-digital elements as compared with pure digital images only. Similarly, creating dynamic images and animations resulted in lower grades. Spatial mode results reflected the fact that this was the first media content the students had produced in a multimodal way. Adding sound and voice-over was not so problematic, as was creating transitions between sequences and adding interactive tasks.

To determine whether there was a connection between the achievements in setting of a mathematical problem in the multimodal digital story design and the achievements in the posttest, the Pearson correlation coefficient was calculated (Table 6). This showed that there was a significant correlation between performance in final testing and the marks awarded for the design of the mathematical problem in the digital story, $r = 0.550$, p (two-tailed) < 0.01.

The integrated approach of applying multimodal design in digital storytelling to mathematical problems had supported both PCT and PST learning of mathematical problems and their competency for multimodal design in digital storytelling for learning and teaching mathematical problems. Students who had higher achievements in mathematical problem multimodal design through storytelling also had higher achievements in mathematical problem-solving tests. Based on the results obtained and the analysis, we can conclude that the integrated approach appears to be beneficial. On the basis of the findings, Hypothesis 2 is confirmed: that preservice teachers who have higher grades in multimodal design for mathematical problems in digital storytelling will, compared with those that have lower grades, achieve higher marks in a mathematics test.

Findings of the qualitative analysis—preservice teachers' perceptions of digital multimodal design and storytelling

The focus of the qualitative analysis was to illuminate how preservice teachers perceive multimodal design and digital storytelling and its contribution to their competency. Analysis of the data established four identified themes: transitioning from passive recipients to active producers of media content; learning-by-design; representation modelling; and digital storytelling.

From passive recipients to active producers of media contents

Students felt that their experiences and perceptions of their ICT practices before the course were rather passive and consumerist. They extensively used media content such as music, movies, magazines, daily newspapers and a variety of websites. They engaged through social media where they communicate by text and they occasionally exchange ready-made media content (photos, audio and video). One student wrote, "*I have never engaged in designing media contents (like animations or other visuals) before; usually I use readymade content.*" They also distinguished their ICT practices between academic and free time activities as: "*In class I mostly use office software and in my free time I download stuff like music, movies.*" For their course work tasks they tended to use office software with pre-prepared templates. Their course work mostly included composing of text by computer. Only a few students reported the use of specialist editing software (eg, Photoshop). Very few students were using animation software in the primary elective computing course. The notion of multimodal design, digital tools and resources, tended to be associated with their free time activities, and related to video games, music and websites. They described themselves as modest users of ICT tools and resources in learning, and as not being encouraged to use them in the classroom, as this had not been required of them. For example, "*For the class I use PowerPoint with pre-prepared templates; I have never created my own animations.*" Exposure to multimodal design and digital storytelling through the intervention raised their awareness of and opportunities for ICT in the classroom and they felt that the course fulfilled their expectations. During the course they had gradually risen to the challenge of creativity and the production of media content. Although the task was challenging, they were motivated to engage with and benefit from it including reflections such as, "*Multimodal digital design opens possibilities for creativity in class and in free time.*" and, "*It was time consuming and took a while before I felt confident and skilled.*"

Learning-by-design

Students felt that they were developing technical ICT competency, ICT pedagogical competency and mathematical content knowledge through designing the digital stories. In the design process, they had to apply their technical, pedagogic and content knowledge. An example of student's reflections: "*The design process is very demanding as one have to think of pedagogical and technical side. It is easy to solve mathematical problems but more difficult to set a story context which will lead the child in search for path of solutions.*" They highly valued the ability to combine digital and non-digital self-produced artefacts. Being able to share and store digital and non-digital artefacts was perceived as a motivating factor in developing more positive perceptions of ICT integration in teaching and learning, eg, "*Digitalisation of artefacts is fun; one can publish and share.*" Preservice teachers in this study reported a perceived danger of becoming overwhelmed with the technical possibilities at the expense of meaning making process to support the learning of concepts developing of skills in mathematical problem solving; as one of the student noted, "*To insert technical visual effects is easy but to plan them in a meaningful pedagogical way is not as easy*".

Representation modelling

Students felt that multimodal design supported representation modelling at two levels, firstly through the structuring of the story appropriate to the learning objectives, and secondly combining various design modes for representations. Structuring the narrative to integrate the mathematical problem helped facilitate their understanding of problem structure and developed their problem-solving skills. The preservice teachers also described multimodal digital design with respect to the concrete and visual representations of a mathematical story, seeing this as offering advantages in comparison with analogue "paper and pen" designs. It was reported that in the paper-and-pen approach the primary and initial focus was on the verbalisation of the problem and expression using mathematical symbols. The opposite was evident under a digital approach where the visualisation of the story became the primary concern. One student reflected, "*With the paper and pen I concentrated on the problem structure and mathematical data and was not as focused on how to present and visualise data. The digital storytelling primary concern is in multimodal visualisation.*" Although another wrote, "*Digital storytelling allows working primarily with visualisation which supports children in their imagining of a problem situation that needs a solution.*"

Students felt challenged to design stories for problems they personally found demanding and in some cases in which they scored poorly in tests. Perhaps unsurprisingly they tended to focus on the types of problems they perceived would be most beneficial in their own development relative to the acquisition of knowledge or competencies. This aligns well with the work of Hoban *et al* (2011), who discuss the influence of ICT in preservice teachers' construction of understanding of science concepts and argue for a need to encourage the integrate ICT activities by preservice teachers into their designs for representations of science concepts.

Making transitions between different modes of design in order to facilitate representational modelling for problem solving was perceived as demanding. Quite often students reported using modes of design for decorative, rather than educative purposes. Students also found difficulty with articulation of a problem using different modes and structuring problem solving in order to support learning. They felt relative confident with the presentation of problems using linguistic resources and mathematical symbols. They often used a combination of linguistic resources supported by graphics and stated that it is unusual for them to use graphic design modes without allied linguistic resources.

Digital storytelling

The students' reflections provided insight into their attitude towards integration of computers for digital storytelling in the classroom. At the beginning of the course, students had concerns about computer-assisted teaching and learning. They agreed that at home the computer was used too extensively among children of pre-school and of early primary school age. They were in favour of traditional activities without a computer and only very small number of the preservice student teachers could think of significant ways for integrating computers into teaching and learning. A majority of the students were convinced that a computer would not support the child's learning style, exploration and experiences in acquiring skills by providing a stimulating learning environment. They expressed concerns that the computer would replace traditional activities, which provide space for exploration, and experimentation through experience of and contact with natural materials and objects. Prior to the course the students had no previous experiences or courses designed to introduce ICT into the classroom, nor had they observed ICT in pre-school or primary settings. Reflections expressed before the course were, "*Keep the computer out of the early classroom,*" "*Computers provide passive activities of watching, listening, playing games pressing the button, which destroys the child's creativity*" and "[the] *computer doesn't provide space for child's natural engagement in exploration and experimentation using whole body.*" During the course the students began to slowly explore teaching and learning through construction of multimodal design in digital storytelling where the achievement of learning objectives was conducted through a combination of non-digital traditional and computer-assisted activities. By the end of the course students felt equipped for computer integration and had changed their perceptions of ICT integration in the classroom. They agreed that digital storytelling could provide a strategy in mathematical problem solving for themselves and for the children they teach.

Many of students argued that digitalisation of artefacts created by children is very stimulating for parents, teachers and most of all for the children themselves. Firstly, because the stories are authentic expressions of the child's lived experience and builds on their imagination. Secondly, because creating a story with a narrative integrating various forms of creation and expression is a fun and intrinsically motivating learning activity, which increases the student's own voice, communication skills and acquisition of multimodal expression. As one suggested, "*Digital storytelling and multimodal design fosters imagination and also a pleasant atmosphere*." They argued that digital storytelling facilitated creativity and personal expression in the learning process and the connections with prior experiences and schema needed to actively construct knowledge. Thirdly, digital storytelling was perceived to provide opportunities for co-creation of artefacts and understanding between the student teachers and the children in their classrooms. Preservice teachers therefore overall perceived multimodal design and digital storytelling as a positive enabling strategy for integrating ICT in early learning with the caveat that a level of competency in multimodal design is needed if to be successfully integrated and sustained, leaving another student to reflect that, "*Starting with personal experiences and knowledge, it supports shared experiences and knowledge building*."

Discussion

This study examined the impacts of an integrated approach in ICT competency development of preservice teachers. The quantitative study analysed the impact on tested learning outcomes, whereas the qualitative study provided some insights into preservice student-teacher perceptions of multimodal design and digital storytelling. The cross-curricular connections of educational technology with special didactics of mathematics and mathematics combined with an in-school practicum for applying the digital stories provided a productive context for developing the competency of the preservice teachers. This is consistent with the findings of Mouza *et al* (2014), who identified an integrated approach combining educational technology courses with methodology courses and field placements as being most efficacious. The practicum placement in schools provided the authentic context for observation and reflection of ICT in use and the testing of the digital stories with pupils.

The use of ICT by preservice teachers is not as extensive or individually engaged with as the rhetoric associated with the net-generation and digital literacy sometimes assumes. Generic descriptions or generation-based arguments related to preservice teachers, technological change and ICT practices are problematic as individual ICT skills and practices are very diverse (So, Choi, Lim & Xiong, 2012). Far from being lead-users in ICT, most of the subjects in this study had experiences limited to the use of the office software. In line with other findings (Lei, 2009; Ng, 2012), they had little or no previous experiences with creative media content design as such as photo editing, movie making and web design. Although being active participants in social networks such as Facebook, they tended not to use other web tools such as Wikis and blogs. During the course they were ready and motivated to engage with tasks in order to design media content for digital storytelling. This was similar to outcomes reported by Ng (2012) in Australia where students reported most benefit when learning activities required the development of authentic learning activities and artefacts using web tools.

ICT in teaching and learning, together with the associated technical, pedagogical and content knowledge are interrelated. Personal beliefs and conceptions about teaching and learning influence the decisions made by practitioners about ICT integration. Preservice education, therefore, is a critical moment during which student-teachers might be thoughtfully and carefully exposed to transformational learning experiences related to ICT in the classroom. Some authors have indicated the importance of using digital tools that are already familiar to teachers in combination with non-digital tools and resources (Nussbaum & Diaz, 2013). The study reported here has adopted that approach to good effect. The teacher educators facilitated activities designed to prepare preservice teachers for integrating technology in lesson plans and activities through the design of authentic tasks developed during the educational technology course (Evans & Gunter, 2004).

The preservice teachers' lived experiences as ICT users are considered as situated social practice. Multimodal design practices were predominant, if at all, in free time activities only, whereas in the academic setting, the linguistic mode was predominant (Shin & Cimasko, 2008). Although digital media facilitates new possibilities for presenting curriculum content (Jewitt, 2008), multimodal design supports the representation of knowledge in multiple forms and provides opportunities for the active construction of knowledge. Preservice teachers in the study perceived multimodal design as digital practice new to them. Prior to the study, they were more consumers of multimodal design in their free time rather than producers. Similar to the findings by Yang (2012), the study reported here has revealed that preservice teachers perceived digital storytelling as a means by which they can interpret and express subject material in creative and more personally meaningful ways.

We applied digital storytelling in order to facilitate meaningful learning within the contexts of mathematical problem solving and ICT integration. It was observed that multimodal design enabled the use of graphic language and visual representations to support abstract and symbol manipulation in problem solving. Multimodal design and digital storytelling may be considered as effective when included in the design of ICT pedagogies (Vratulis, Clarke, Hoban & Erickson, 2011). Our findings indicate that the strategic use of digital storytelling in a course of educational technology, specifically applied to mathematics and special didactics of mathematics is effective in developing the pedagogical, technical and content knowledge of preservice teachers. Pre- and posttesting also identified a positive impact on the content knowledge and mathematical problem solving of our students, along with a correlation between multimodal design in mathematical problem storytelling and actual mathematical performance.

The difficulties arising in solving problems at all educational levels are consequences of: failing to comprehend the problem posed or to perceive the problem situation; the inability to translate the problem into mathematical form; and the inability to use adequate mathematical strategies (Yeo, 2009). An optimal learning environment is created when the learner uses the newly acquired knowledge in a novel problem situation, as this contextualises new knowledge in ways that are personally meaningful. As Jonassen (2003) argued, the modelling of mathematical problems is a key process by which a learner may develop new concepts and develop problem-solving skills. The learning activates and assessment criteria developed in this study successfully sought to integrate and promote the contextualisation of problems through narrative and storytelling; to involve wider topics and themes that enable cross curricular connections, situational context and structural relationships (Jonassen, 2003); to take appropriate account of the child's developmental level; and facilitate multimodal representations and transition between different representational modes.

The digital storytelling approach provided a context in which topic-based mathematical problem was explored through situation, narrative genre and structure. Mathematical symbolism may be expressed in a digital storytelling process through a variety of modes, combining concrete, visual and abstract representations. The production process helped to facilitate problem-solving capabilities as students created their own multimodal representations of concepts (Hoban *et al*, 2011). Often focusing on visual representations, this facilitated a transition from the enactive, through visual, to symbolic levels of understanding.

Fox (2013) argues that digital story composition is sometimes limited to stylised artefacts with no intellectual challenge (Fox, 2013). Preservice teachers in this study reported the danger of becoming overwhelmed with technical possibilities and not paying sufficient attention to meaning-making processes that support learning of concepts and develop skills in mathematical problem solving. It was observed that students found shifting different modes and enabling transitions between representations for meaning-making very demanding. Similar findings were reported in an Australian study, indicating that students are more familiar and comfortable with print-based practices (Reed, 2008).

The limitations of the study

The participants were all first-year preservice teachers from one of three faculties of education in Slovenia. More random sampling and cross-cultural studies would provide grounds for greater generalisation of the results. The impact on preservice teacher learning outcomes could be better established with greater reliability if a true experimental design provided randomised sampling and a control group with no intervention. The impact of teaching practice or other extraneous variables was not examined in this study. The transfer of ICT skills and integration in teaching from preservice education to classroom practice is reported to be weak (Vratulis *et al*, 2011) and a follow-up study would be needed to identify the impact of the digital multimodal storytelling approach on actual teaching practice after graduation.

Conclusions

The study reported in this paper highlights the importance of interrelating pedagogical, technical and content knowledge competencies within the education of preservice teachers. The evidence put forward is enough to reject the null hypothesis and to argue that the intervention has indeed impacted positively on the competencies of preservice teachers in multimodal literacy and composition, mathematical problem solving and their ability to teach mathematics. The research reported here extends the understanding related to student-teacher education in ICT by redressing the tendency to make ICT practice adjunct to, rather than integrated with, the pedagogic and subject education of preservice teachers. A teacher's capability to engage in creative work with ICT in teaching involves sound knowledge of the subjects being taught as well as pedagogic and technical competencies. The use of multimodal design in digital storytelling has the potential to impact not only on the perceptions preservice teachers may hold relative to ICT use in the classroom, but also on their understanding of subject specific concepts, such as mathematical problem solving. By taking a multimodal design approach, preservice teachers can be forced to develop, combine and present a variety of knowledge constructions and representations. The process encourages teachers to create opportunities for digital storytelling that can encompass active learning of objectives form a variety of subjects. In order to do so, it is important that ICT with multimodal design in digital storytelling is included in the intended learning objectives and assessment criteria (Shin & Cimasko, 2008; Wyatt-Smith & Kimber, 2009). Matching sound and efficacious learning principles and assessment to new digital-literacy practices that include multimodality will further help facilitate the learner-centred curriculum (Wyatt-Smith & Kimber, 2009).

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Ethics

The research reported in this paper was carried out in accordance with the guidelines published by American Psychology Association's following the general Ethical Principles of Psychologists and Code of Conduct principles (2002). The agreement from the management of the Faculty was obtained before the study. Students were provided with the details of the study and that participation was voluntary at their consent. They were informed that participating or not participating would not affect their grades.

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