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RESEARCH ARTICLE

Digital Storytelling in Science Teacher Education: Evaluation of Digital Stories

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ABSTRACT

The aim of the study was to evaluate digital stories prepared by preservice teachers in the frame of their planning, content, mechanics, story structure, and use of technology dimensions. In addition, the study aimed to reveal differences among the aforementioned dimensions' scores. To achieve this, the study's participants attended a course on theoretical and technological process and tools implemented in digital story creation. A total of 46 digital stories were scored through a rubric and then analyzed. From the analysis, only the content dimension received a high score, while all other dimensions were scored at the medium level. The results revealed a significant difference among the digital storytelling dimensions, with mechanics, story structure, and use of technology dimensions negatively differentiated from content and planning. These findings support the use of digital storytelling content that is primarily based on the use of technology and basic digital storytelling principles for science teacher education programs. From this point of view, it can be strongly said that both in field education courses and for instructional technology and vocational courses, the potential for preservice teachers to graduate with having acquired higher skill levels may be realized through digital storytelling. Hence, teacher education programs should be supported by digital storytelling activities and instructions.

KEY WORDS: Digital storytelling; science education; teacher education; technology in education

INTRODUCTION

The power of stories passed down through the generations by word of mouth has been known for centuries. Stories have been used by the older generations to convey their experience or knowledge to future generations (Duveskog et al., 2012). People have learned from the stories which are told to them and have identified with them in their own lives, or through the life of others. While a person cannot identify mere knowledge with themself, they can form an emotional bond with characters in stories and thereby identify with them. Thus, the aim of behavioral correction can be achieved through not repeating the same mistakes made by others before them or through being inspired by positive results having occurred as a result of events described in stories (Sukovic, 2014). With stories told and transferred from the past to the present, the behavior order of a society can be effectively and easily maintained across numerous dimensions.

Storytelling is one of the oldest and most preferred teaching methods used to describe events experienced in the past or yet to be experienced (Bratitsis and Ziannas, 2015). Storytelling has been accepted as a universal teaching method since it appeals not only to certain age groups, but to all ages and has a place in every culture. Although religion, language, and race are variables, the place of storytelling in education has remained constant, yet the way in which stories are told has changed over time (Condy et al., 2012). With the more recent proliferation seen in the use of digital tools, a new era has begun in which user-generated content is presented, providing storytelling using new types of multimedia programs amongst various other materials (Alexander, 2011). With the widespread use of digital cameras, photo-editing software, writing tools, and Web 2.0 technologies such as Flickr and Myspace, stories have become more and more integrated with technology, and digitized to serve a new pedagogical purpose (Alexander and Levine, 2008; Şentürk Leylek, 2018).

Digital storytelling has been defined numerous times in the literature, by different authors, and at different points in time (Chung, 2006; Robin, 2006). In its most general sense, digital storytelling is the delivery of personal short films created using multimedia programs that utilize materials containing digital text, images, video, and sound replayed through a television, computer monitor/screen, or projector, and conveyed to an audience to provide information on a specific subject. The origin of digital storytelling dates back to the 1980s (Hartley and McWilliam, 2009; Robin, 2008). It was put forward by members of a theater group and others there at the time who asked, "I also have a story to tell. How can I explain it?" (Şimşek et al., 2018). Digital storytelling is concerned not just with the transfer of knowledge, but also as a movement designed to raise the voice of a community (Burgess, 2006). A young person sharing their life through social media platforms, retelling the life of a former slave

or a Nazi Holocaust victim on Facebook are considered examples of such storytelling (Alexander, 2011). Today, most students share stories through social media platforms such as YouTube, Facebook, blogs, or through creating content with various so-called Web 2.0 tools. The use and adoption of digital storytelling by students in their daily life, and the fact that students have fun whilst creating their stories, have made it inevitable that digital storytelling has found a purpose in today's education.

Digital storytelling consists of seven basic elements: perspective, interesting questions, emotional content, good voice acting, power of music, economy, and speed (Robin, 2008). Someone who prepares a digital story should be able to convey their own point of view and a message created based on their own experiences. Stories should start with an engaging question to connect with the audience and maintain their attention through to the end of the story. An effective digital story should evoke positive feelings that emotionally impact on the viewer or student according to the tone and timbre of the storyteller's voice. Through its delivery, a story should convey the intended message by paying particular attention to both emphasis and intonation of the storyteller's voice. The power of music should also be used to enrich the central theme of a digital story, to add depth to the narrative, and to help convey the intended message and emotion to the audience. Digital storytellers should employ a plain and clear narrative style and ensure that they correctly set the pace and rhythm of the story being told (Bull and Kajder, 2004).

ASSESSMENT OF DIGITAL STORIES

Not all electronic material created using digital technologies can be considered a digital story; equally, the expected efficiency may not always be realized from every digital story told. There are, of course, numerous reasons for this, as with any learning situation in education. However, when considered in the context of digital storytelling, the reasons why a digital story may or may not be deemed successful have been determined in the literature, with certain features that every successful story should include, although various classifications of this have been put forward (Kearney, 2011; Morra, 2013).

Morra (2013) described the process of creating digital stories, starting with an idea, researching/exploring/learning, writing the story text, preparing a storyboard, researching multimedia tools (pictures, sound, and video), creating, and sharing the digital story, reflection, and feedback. The digital story starts with an idea and continues through a process of research to achieve a deep level of knowledge regarding the initial idea. Those who make the best preparations in these two process steps are then well positioned to write the text of the story, which is, after all, the most important step in digital storytelling.

The text of the story, which is shaped through significant effort in the preparatory stages, can then emerge. A good story is one that has been prepared in stages, having followed the most appropriate steps in its creation. An early significant step in the process is the preparation of the storyboard, which shows how all the various elements, such as text, images, and graphics will help narrate the story through digital means. At this stage, the storyteller or creator needs to research and determine the most appropriate multimedia tools to use. Next, the necessary preparations are undertaken to create a digital story using a dedicated program that includes all the required materials from the storyteller's own perspective. The created story is then shared with friends or through the Internet through a website, or on blogs or social media platforms. As a final step, storytellers seek feedback on their digital stories. One tool utilized in this feedback process, and which is used to determine whether or not a digital story is considered successful, is a rubric. Kearney (2011) stated that rubrics are the most appropriate form of evaluation used in the process of writing the text of a story and for digital story creation, since digital stories combine many different skill areas.

Rubrics are scoring tools that determine the expectations of certain tasks according between three and five levels of performance, based on the aim of increasing reliability, validity, and transparency, and in reducing subjectivity (Chowdhury, 2019; Silvestri and Oescher, 2006). In the literature, too, it is deemed necessary to determine the most successful instances of digital storytelling, to provide feedback to students about their stories, to separately determine the performances of each element of digital storytelling, and to identify deficiencies in fulfilling each element. Rubrics developed by experts in the field are utilized in performing these tasks.

The literature contains numerous external story rubrics that can be used as evaluative tools (Çıralı Sarıca and Koçak Usluel, 2016; Tse et al., 2021). The dimensions and criteria of rubrics found in the literature, from 2004 to the present day, are the same in some rubrics, with different dimensions with different names used in others. However, when these rubrics are examined in general, while different aspects are covered, the criteria most discussed are "purpose, storyboard, sound, visuals, content, economy, arrangement, language, grammar, speed/rhythm, [and] originality" (Çıralı Sarıca and Koçak Usluel, 2016). Each of these elements has been taken into account in the selection of the rubric applied in the current study.

RESEARCH AIM AND IMPORTANCE

Many reasons have been cited for integrating digital storytelling into education since the Digital Storytelling Center first began its work with students. Digital storytelling in the classroom can be used to attract the attention of students with different learning styles (Robin, 2008), to facilitate student-centered learning strategies such as student participation, deep learning, the integration of technology into teaching, and to interact with project-based learning (Barrett, 2006). This approach facilitates the liberation of students as learners (Merritt, 2006) can help

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to increase their academic success and clarity of subject knowledge, as well as helping to develop their high-level thinking, social, language, thinking, and artistic skills (Yuksel et al., 2011). In addition, digital storytelling can help improve students' cognitive, conceptual, academic, and linguistic skills that contribute to their overall social skills (Çetin, 2021; Wu and Chen, 2020), as well as supporting development of their 21st century skills (Dewi et al., 2019; Gürsoy, 2021), and aiding their motivation toward a course or program of learning (Bilen et al., 2019; Filiz et al., 2016). These fundamental benefits underline the need for integrating digital storytelling in today's teaching classroom.

In benefitting from the aforementioned advantages of digital storytelling, one area that should be considered is science. Science courses include abstract concepts and have gained significant importance in terms of 21st century skills, with new methods and techniques used in science curricula to increase learning effectiveness in this area. Science courses aim to raise science literate individuals, with skills in research and inquiry, problem solving, organization, and in the use of technology and effective communication in today's society. It may be said that one of the best methods for this is digital storytelling.

The processes involved in creating a digital story, through its design, writing, and presentation, helps to improve students' skills in areas such as research, writing, organization, technology use, presentation, interviewing, communication and cooperation, problem solving, and also evaluation, and thereby have made digital storytelling an inevitable and important component of teaching in today's classroom. Science teachers can, therefore, introduce digital storytelling into their classroom environment subject to acquiring proficiency of using this method. To gain sufficient competence, digital storytelling samples should be prepared through appropriate technologies integrated into courses taken during undergraduate teacher education programs, with detailed feedback given to students regarding their storytelling.

Ohler (2013) argued that following the creation of digital stories, it is crucial to perform assessments in order to create stronger reflection and rating systems. Tse et al. (2021) stated that the assessment of digital stories can help to provide teachers and students with a well-defined and systematic outline, and that this outline can then be used as a tool for students to offer further suggestions to improve their stories. However, Aagaard (2014) stated that the literature contains only limited information regarding the evaluation of digital stories.

The current study therefore aims to determine the stages of digital storytelling where problems are experienced the most, and the measures necessary to help eliminate such issues. To improve the digital storytelling skills of preservice science teachers, the current study consists of them preparing digital stories with the aim to evaluate and describe their artifacts in various contexts. Within the framework of this general aim, answers were sought to the following research questions:

RQ1. What is the level of digital stories prepared by preservice science teachers according to:
- Planning,
- Content,
- Mechanics,
- Story structure, and
- Use of technology dimensions?

RQ2. From the evaluation of the digital stories prepared by preservice science teachers according to the relevant dimensions, was a significant difference established between the scores?

METHODS

Research Design

The study was designed within the framework of a survey research, one of the quantitative methods of academic research, with the aim being to describe a current situation using quantitative data (Creswell, 2012). Within the framework of the study's research questions, the first question was attempted to be answered using the survey research design. In this model, a single variable is defined within the framework of criteria (Karasar, 2003), with the digital stories defined according to five different categories or dimensions. The second research question was attempted to be answered though causal-comparative research, with the subject of research described through comparison with other criteria (Sönmez and Alacapınar, 2013). In this case, the second research question was addressed by classifying the rubric scores, and then comparing those scores related to each dimension.

In summary, both the survey and causal-comparative research design methods were combined in the current study. The study aimed to examine the digital stories of preservice science teachers from various perspectives, to determine the level according to these aspects, and to reveal any differences between these levels. Since the research process was described in terms of quantity, the study's design was shaped on the basis of a survey research.

Participants and Products

The participants of the study were 50 preservice science teachers enrolled to an Instructional Technologies and Material Design course. Within the scope of the study, it was assumed that the participant preservice teachers should possess at least a basic level of technological and pedagogical skill, plus content knowledge at a moderate level to be able to create an appropriate and effective digital story. Since no course presents the content of digital storytelling holistically within the existing undergraduate science teaching programs, it was not possible to form a sample from the Turkish population. Instead, the Instructional Technologies and Material Design course was considered to be the most suitable course to reach preservice teachers with the necessary prerequisite skills, knowledge, and readiness. Furthermore, the course was able to be taught by the researchers of the current study.

The criteria for the study's participants were their having the required basic level of knowledge and skill, and that the opportunity exists for support and guidance to be provided to the participant preservice teachers during the research process. When a research process has certain requirements, to meet those requirements, the criterion sampling method may be applied (Creswell, 2007). Therefore, the current study used the criterion sampling method for the selection of the study's participants. This process is illustrated in Figure 1.

During the 1st week of the course, the preservice teachers were informed about the study. It was also explained to them that digital storytelling content would be presented and taught during the course, and that they would then be asked to prepare digital stories for use as an instructional material. Finally, the prospective participants were informed that their digital stories would be evaluated and then used for scientific purposes. The preservice teachers were free to choose whether or not they wished to participate in the study. In other words, if they did not elect to participate voluntarily, they were excluded from the process. In total, 50 preservice teachers volunteered to participate in the study, and accepted the responsibilities mentioned to them regarding the process of the study.

The participants already had a certain level of readiness with regards to the technology, pedagogy, and content, but this was deemed insufficient for the purposes of creating a digital story and that they did not fully understand what digital storytelling was. Course content regarding what digital storytelling is from a pedagogical perspective, what it is used for, and its benefits and limitations were presented to the preservice teachers. Following the content presentation, the scenario creation process was explained, along with visual editing and creation (ComicLife, Toondoo, Pixton), sound editing (AudioStudio, AudioTrimmer), and storyboard creation (Powtoon, Canva) that they would acquire the necessary technology use skills needed in the process of digital storytelling. Web 2.0 tools potentially needed for video creation (MovieMaker, Movavi) were introduced and sample applications conducted. The Web 2.0 tools that the participants were presented with were completely or partially open to free access and were considered appropriate to be used effectively by the preservice teachers in the digital storytelling process.

The participant preservice teachers were each tasked with creating a digital story within the framework of the "Human and Environment" unit of the course. For validity of the study, some general feedback was provided to the preservice teachers during the lessons, as some attempted to create the digital stories by themselves, while others asked too many detailed questions in seeking constant help. In terms of the study process, if the researchers had allowed special or one-to-one feedback within the class, there was a risk that the study's data could have been inadvertently manipulated or skewed. However, it was explained about the importance of emotional effect through the use of music, sounds, and rhythm, four of the stories created were unable to be evaluated because they contained no audio or video elements/features and were therefore eliminated from the study. As such, the evaluated dataset of the study consisted of 46 digital stories.

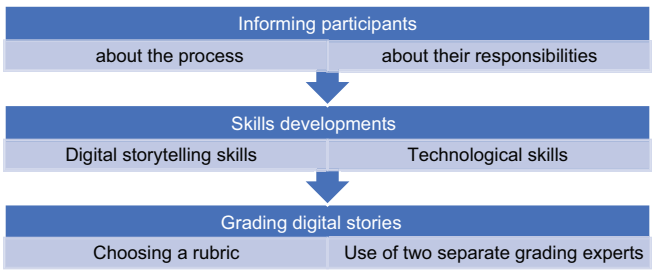

Figure 1: Implementation process scores, is illustrated graphically in Figure 2

Data Collection

Within the scope of the research, a dataset was created from the digital stories, as the products generated by the participant preservice teachers, were evaluated according to a rubric. In the selection of the rubric used within the scope of the study, the current literature was examined so as to understand what rubrics already existed and that were accessible for use in the study. Since it was agreed that the rubrics published in the literature could be applied in the current study's product evaluation, no new rubric development was deemed to be necessary. From among the rubrics evaluated by the researchers, it was decided to use the "Digital Story Evaluation Rubric" because it contains criteria suitable for the research process, it allows for detailed scoring, and its pedagogical criteria were considered to be more qualified than seen in other rubrics. Permission for usage of the rubric in the current study was obtained through e-mail using the contact information on the www.storycenter.org website.

The Digital Story Evaluation Rubric contains a total of 20 items within five dimensions (Appendix). The rubric's items are grouped as under the dimensions of Content (six items), Planning (three items), Mechanics (three items), Story Structure (four items), and Use of Technology (four items). Each item is graded according to its relevant dimensions (Appendix). Items in the Content dimension are graded using a scale of 0–10, whilst the other dimensions are graded according to a scale of 0–5. Therefore, the highest total score that can be obtained from the rubric is 130 points, while it is also possible to score zero from all 20 items.

In total, 46 products created by the preservice teachers were scored by two experts using the Digital Story Evaluation Rubric. The scores obtained were then averaged for each item. Scale dimensions were standardized in terms of dimensions as percentages of the total score of the relevant items, and the scores were made suitable for comparison in terms of dimensions.

Data Analysis

The scores for each item were summed under the associated dimension, and a total score obtained and percentage value calculated. In answering the first research question of the study, the mean scores for each dimension were visualized and

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examined. In each dimension, the highest possible percentage value is 100%, while the lowest is 0%. The 100-unit section between these highest and lowest scores was scaled as low, moderate, and high, with a low-level score in the range of $0 \leq \bar{X} \leq 33.3$, while a moderate-level score was in the range of $33.3 < \bar{X} \leq 66.6$, and a high-level score in the range of $66.6 < \bar{X} \leq 100$. At this point, classification was made according to the average scores and descriptive statistics were presented.

To answer the second research question, repeated measures one-way analysis of variance (ANOVA) test was used. This test reveals the statistical significance of comparisons using more than two measurements. The data compared while conducting ANOVA tests should be continuous and within the same minimum-maximum score range (Akbulut, 2010). For this step of the analysis, each scale dimension was compared and for dimensions with different score ranges due to the numbers of items in each dimension. For example, the "Planning" dimension has six items, so its maximum score is 30 and its minimum score is 6, whilst for the "Mechanics" dimension, it consists of three items, so its maximum score is 15 and the minimum is 3. Therefore, the scores between these two dimensions could not be compared in a valid and reliable context, so they were converted into an equivalent 100-point score to standardize the rubric's scoring results. Thus, the points range obtainable from each dimension was transformed to between 0 and 100.

Whilst there are no other prerequisites for performing measurements in the one-way ANOVA test, it can only produce a finding of whether or not a significant difference exists according to the model. Since the findings produced for the source of this difference were basically produced according to the logic of paired samples *t*-testing, Bonferroni adjustment was applied in the interpretation of these test results. In addition, it was questioned whether or not the parametric test prerequisites were met, and it was seen that the skewness-kurtosis values of the data ranged from −1 to +1, and that the sample size was over 30 (Pallant, 2011). In this way, it was determined that the prerequisites for the analysis were met, and the aforementioned tests were able to be conducted. The results obtained from the tests are presented in the findings section of the study.

FINDINGS

Within the scope of the current research, the participants' digital stories were evaluated with a rubric that examined them according to five dimensions. These are Planning, Content, Mechanics, Story Structure, and Use of Technology. In this part of the study, each dimension was examined in terms of standardized score and level. Descriptive statistics for each dimension are presented in Table 1.

As shown in Table 1, the highest score was realized for the content dimension (73.62). It was also the only dimension that was evaluated as being at the high level. In the most general sense, the source of this finding appears to be the preparation of digital stories towards a common and framed goal. When the items within the content dimension were examined, it was noted that the dimension covered not only the content creation purpose, but also pedagogical knowledge and other skills such as producing content suitable for the intended purpose, associating, and making it suitable for the target audience. From this perspective, it may be said that the source of the dimension in which the preservice teachers were found to be most successful in the process of producing their digital stories were their field competencies in the pedagogical sense. However, when the minimum and maximum scores of the content dimension were examined, it was seen that the lowest score (36.67) and the highest score (86.67) indicated that the preservice teachers' scores did not differ much from each other in terms of the content dimension in which they displayed their pedagogical content knowledge. To put it another way, the preservice teachers showed less difference between their worst and best scores in the content dimension than for the other four dimensions, which reveals that they are more homogeneous as a group in terms of these skills compared to other dimensions. From this perspective, it may be said that the preservice science teachers' deficiencies in their digital storytelling skills were mainly evident in dimensions other than the content dimension.

Table 1: Descriptive statistics of digital story scores

Dimension	*N*	Min.	Max.	Δ*X*	$\bar{X}$	*df*	Level
Content	46	36.67	86.67	50.00	73.62	15.35	High
Planning	46	20.00	100.00	80.00	64.35	29.49	Moderate
Mechanics	46	20.00	100.00	80.00	52.46	22.95	Moderate
Story Structure	46	20.00	100.00	80.00	50.00	22.80	Moderate
Use of Technology	46	15.00	90.00	75.00	52.07	19.51	Moderate

When the planning, mechanics, and story structure dimensions were examined, it was seen that the minimum (20.00) and maximum (100.00) points were found to be the same. In the context of average scores, the highest average among these three dimensions was for the Planning dimension (64.35). When the rubric criteria for this dimension were examined, it was seen that digital storytelling measures the standards during the planning phase. In terms of the story structure dimension, it was revealed to have the lowest average score (50.00) among the five dimensions. This dimension includes important criteria such as scenario, dramatic questions, and the economy of the story that together form the basis of a digital story. At this point, it can be predicted that the preservice teachers' lack of story structure skills significantly reduced the effectiveness of their digital stories. The mechanics dimension defines the digital story standards for its length, spelling, and ethical issues. Based on all these findings, it may be said that the preservice teachers' skills in this dimension did not differ in terms of range, but in their application points.

The lowest minimum score (15.00) among the five dimensions was for use of technology. The mean score for this dimension

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(52.07) was also among the lowest scores. The fact that the maximum score for the use of technology dimension was not 100.00 indicates that none of the preservice teachers achieved a full score in this dimension, which clearly indicates that the participant preservice teachers were unable to implement their technology usage competencies in their digital story creation process, or that they were in need of greater support in this regard. A comparison of the information presented in Table 1, in terms of the range and mean.

When evaluated from a holistic perspective, none of the preservice teachers' digital story scores were interpreted as being low, but that it was undesirable that only one dimension was found to be high, whilst the range of all dimensions was revealed to be quite high, as can be seen from the illustration presented as Figure 2. From this perspective, it may be said that the participant preservice science teachers need to be further supported during the digital storytelling process, and that their relevant knowledge and skills are in need of further development.

The average scores were compared to test whether or not the observed differences between these averages were statistically significant. Each measurement was revealed to be normally distributed, but the Sphericity condition was not found to have been met (Mauchly's $W = 0.948$; $p > 0.05$). For this reason, the Greenhouse-Geisser results of the test results were taken as the basis in the interpretation of the analysis. In Table 2, the metrics are named Ds_category.

In the model created as a result of the applied ANOVA test, it was observed that a significant difference was found to exist between the scores of the digital story dimensions ($F_{2.9,\ 45} = 21.65$; $\rho < 0.001$; $\eta p^2 = 0.325$). However, in comparison analyses, the difference or significance is not evidence of any great importance on its own, as the effect size of this significance level is also considered. The eta square value is therefore interpreted in order to make sense of the level of the effect size. In one-way ANOVA testing, the eta square value is considered equal to the partial eta square value (Levine and Hullett, 2002; Pierce et al., 2004). With the model having been found to be significant, the partial eta squared value was interpreted and found to have a high level of effect ($\eta p^2 > 0.14$) according to Cohen (1988).

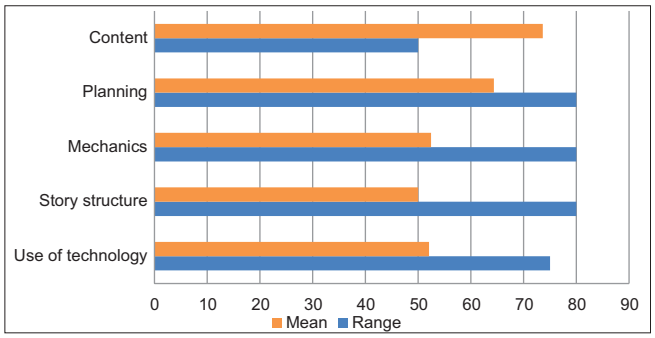

Figure 2: Range and mean scores of digital stories

This analysis confirms the hypothesis that the five measures form an inter-measure difference within the framework of the model. However, it is also possible to interpret between which averages this difference exists using pairwise comparison. ANOVA produces statistical findings of pairwise comparisons, and Bonferroni adjustment was applied in the interpretation of the pairwise mean comparisons. Based on this adjustment, to increase the margin of error when more than one test was performed, and to prevent a Type 1 error from occurring, the significance level was divided by the number of tests performed and the significance level of the test evaluated according to this new value (Akbulut, 2010). To make the findings interpretably correct, the measurements were conducted with 10 different paired samples *t*-tests, and each matching with the other. In the mean comparisons presented in Table 3, the dimensions that differed significantly according to the 0.005 value obtained by dividing the significance level of 0.05 by 10, and the statistical values for those dimensions are presented.

As shown in Table 3, the differences found to be significant in the ANOVA result were between the dimensions of content and mechanics, content and story structure, and content and use of technology in favor of the content dimension; while between the dimensions of planning and story structure, and planning and mechanics, the dimension of planning was favored. In light of these findings, the participant preservice teachers' digital stories were revealed to be statistically and significantly more successful in the content and planning dimensions than in the three other dimensions of Mechanics, story structure, and use of technology. This finding is shown in Figure 3, which was generated by the analysis program.

As shown in Figure 3, the scores for the content and planning dimensions were found to be significantly higher than for the three other dimensions of mechanics, story structure, and use of technology which each have close averages. From this perspective, it may be said that the preservice teachers should

Table 2: ANOVA statistics for digital story score categories

Source	*df*	*SS*	*MS*	*F*	*ρ*	η_p^2
Ds_category	2.9	18998.02	6546.30	21.65	0.000	0.325
Subjects	45	74463.06	1654.74			
Residual	130.60	39490.87	302.39			
Total	178.50					

Table 3: Pairwise comparison of digital story score categories

(I) Ds_categoryA	(J) Ds_category	Δ*X* (I-J)	*SE*	*ρ*
Content	Mechanics	21.16	2.92	0.000
	Story Structure	23.62	2.44	0.000
	Use of Technology	21.56	2.67	0.000
Planning	Mechanics	11.88	2.97	0.002
	Story Structure	14.35	3.79	0.0045

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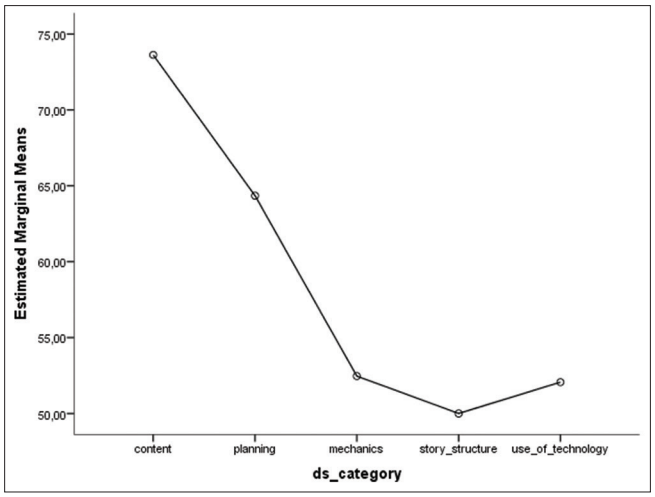

Figure 3: Estimated margins of digital story category scores

be primarily supported during the digital storytelling processes of mechanics, story structure, and use of technology.

DISCUSSION AND CONCLUSION

One of the aims of today's teacher training programs is to train preservice teachers to integrate technology into their classrooms and to utilize technology to facilitate their future students' learning. It is open to research as to what level the number, quality, and availability of such courses are that teach these skills to student teachers during their preservice education. In their study, Hare et al. (2002) argued that Information Technology courses in undergraduate programs are insufficient to provide preservice teachers with the required knowledge and skills in this area. Within the scope of the current study, preservice teachers created moderate-level digital stories according to the use of technology dimension, which may be considered as an indication that the need for targeted instruction in this area still exists today. Following attendance to Information Technology courses, preservice teachers should also be provided with opportunities that specifically allow for the integration of technology into all courses taken during the remainder of their undergraduate education, and that preservice teachers should be actively supported in this regard. It is essential, however, to accurately determine where preservice teachers experience or potentially face problems, especially in the integrating of technology into the classroom, to offer appropriate solutions to overcome such issues. One of the recommended methods is for preservice teachers to prepare digital stories within the framework of specifically assigned topics in order to gain the skills required to successfully integrate technology into their future classrooms. Considering this approach, Campbell (2012) stated that digital storytelling is an effective means of combining technological features.

In the current study, the participant preservice teachers were tasked with preparing a digital story within the framework of the environmental pollution unit of their science course. A rubric was then applied by the researchers to determine in detail with which steps the preservice teachers experienced the most problems. The participants' digital storytelling skills were evaluated according to a rubric that made an assessment based on five dimensions, planning, content, mechanics, story structure, and the use of technology. The study's findings revealed that none of the five dimensions were found to be at a low level for the digital stories the preservice teachers had created. However, with only the content dimension having scored at a high level, this finding suggests that while preservice teachers may have sufficient competency in terms of their content knowledge, they may need additional targeted support in the other four dimensions of planning, mechanics, story structure, and use of technology.

The revealed descriptive difference was also found to be statistically significant ($F_{2.9, 45} = 21.65$; $\rho < 0.001$; $\eta p^2 = 0.325$). The effect size value, which is the most important element of proof that the difference may also be observable in practice, was also interpreted as being at a high level. As a result of interpreting this difference, which is deemed significant in the context of the model, and with the Bonferroni adjustment to determine between which dimensions the scores showed a significant variation, it was established that the content dimension score differed significantly from all other dimensions except for the planning dimension, and that all of these differences were in favor of the content dimension score.

As previously mentioned, the preservice teachers reflected their pedagogical skills in the products they created in an observable way. When the items in the planning dimension were examined, it was noted that they were mostly based on pedagogical skills, and that there was no statistical difference found between the planning and content dimensions' scores. On the other hand, a significant difference was found to exist between the scores for the Planning dimension and those of the Mechanics and Story Structure dimensions (in favor of the Planning dimension). It is suggested that the reason for the separation of planning from the other dimensions is also related to the participants' pedagogical competence. As shown in Figure 3, scores for both the content and planning dimensions are clearly separated from those of the other dimensions.

When the content dimension of digital stories was evaluated, it was determined that the participant preservice teachers were quite competent in determining the main themes of the given topics, in choosing the event, the context related to the content, reflecting their feelings and thoughts with regards to the content, and looking at the situations from the perspective of an alternative time period. It is notable that the preservice teachers were instructed numerous times by the researchers that their knowledge of the subject matter was of considerable importance in terms of their achievement, and that they should carefully review all of the available resources in some detail. It can also be said that the preservice teachers exhibited the ability to organize the content required for their digital stories due to their efforts in seeking knowledge about

the content as a prerequisite to their storytelling. Through the task of digital storytelling, the preservice teachers were able to actively explore a given topic based on their perspective on the content of the text (Araya, 2020). In the determination of teacher training and teaching standards, a transition has largely taken place from the behavioral approach to the technological pedagogical content knowledge approach. This may be said to be one of the standards that teachers should possess in developing their subject content knowledge, which includes information regarding the concepts, content knowledge, and structure of their respective field. In the current study, during their preparation of digital storytelling is was clearly necessary for the preservice teachers to possess adequate content knowledge regarding the subject area and is widely considered to be the first step in demonstrating proficiency in terms of technological pedagogical content knowledge.

When evaluating the planning dimension of digital storytelling, the preservice teachers' ability to prepare a storyboard, resource list, brainstorming sheet, and finalized script as a work portfolio were determined to be moderately sufficient. In addition, their planning skills in terms of sketches used, sequencing, pacing, script, images, music and sound for their storyboard, and also reflecting their feelings and thoughts in terms of the stories they created as a reflective write-up were all determined to be moderately sufficient. Other studies in the literature have also revealed the difficulties experienced by preservice teachers during the preparation of digital stories (Anılan et al., 2018; Gürsoy, 2021; Sancar-Tokmak et al., 2014), which supports why these skills were also found to be at a moderate level in the current study. It has also been revealed in the previous studies that preservice teachers can experience difficulties in writing scenarios, as well as matching images to a scenario rather than adjusting the audio-image transition. One way to improve this situation would be to provide preservice teachers with significant experience preparing digital stories, especially in terms of sequencing, pacing, and scripting, plus the appropriate use of images, music, and sounds, and also to increase their storyboard preparation skills through research.

When the mechanics dimension of digital storytelling was evaluated in the current study, it was determined that the participant preservice teachers showed moderate proficiency in citing the pictures, cartoons, and music they found according to the citation of sources and permissions. Although many questions were asked repeatedly to the researchers, especially with regard to the citing of references, the preservice teachers experienced problems in displaying some of the sources at the end of the process. In terms of the length of the digital stories they created, it was seen that the preservice teachers had the ability to adjust the length from between 3 and 5 min, which is the generally accepted length for digital storytelling. With respect to the grammar and spelling used in their digital stories, the preservice teachers exhibited a moderate level of voice intonation and grammatical skills. In another study, Cheng and Chuang (2019) stated that their participant students experienced difficulties in searching for related images when there was a copyright issue in play for internet-sourced images.

When the story structure dimension of the created digital stories was evaluated in the current study, it was determined that the participant preservice teachers exhibited moderate proficiency in dramatic questioning, personal narrative, economy of story, and evolution of their dramatic questions. The fact that the scores received by the preservice teachers in this dimension were lower than in the others and that the range was higher shows that they experienced difficulties the most in this area. It may be said that although the preservice teachers demonstrated having a sufficient view and knowledge with regards to the content, they were unable to create remarkable dramatic questions in their stories, or prepared stories for which they were unable to adequately answer the question they were tasked to explain. Story structure itself should be evaluated as the most crucial element of any digital story. In their study, Cheng and Chuang (2019) aimed to reveal the learning processes of students participating in a marine science digital storytelling project. Their findings revealed that the participant students were unable to sufficiently describe the relationships between the key scientific concepts in their science-based digital storytelling. Similarly, in the current study, although the preservice teachers exhibited appropriate science "content" proficiency, their story structure lacked the desired level of proficiency. This reveals that the students' knowledge of science concepts was insufficient to construct a solid story based on the assigned subject area.

When the use of technology dimension was evaluated in terms of the preservice teachers' digital stories, they were shown to have exhibited a moderate level of proficiency. This was particularly evident in their use of images to complement and support the ideas in the script, the use of a soundtrack (optional) that contributed to the message of the story, a voiceover that supported the purpose and tone of the story, and an inability to effectively utilize video-editing software. The fact that the participant preservice teachers were unable to perform adequately in finding the necessary images or music to fit their story scenarios indicates that they lacked sufficient knowledge with regard to the available technologies and their application. If preservice teachers possess adequate technological knowledge, they will be able to enrich their storytelling using the most appropriate technological tools available. Göçen Kabaran and Aldan Karademir (2017) reached similar results in their research, stating that the participant preservice teachers in their study experienced the most difficulty in finding pictures appropriate to their storytelling, and that except for one student, they did not present any drawing skills to illustrate their own scenarios, and that their self-efficacy in using the internet for educational purposes was considered low. In a study by Gürsoy (2021), it was revealed that preservice teachers can experience problems adjusting the voice-photo transition from the recording completion stages in digital story preparation, and in adjusting their tone of voice in accordance with the character being narrated.

SUGGESTIONS

This study may be evaluated as a piece of research that revealed the importance of holistic adequacy when we consider the technological content knowledge of teachers. The moderate level of digital storytelling skills revealed in the study's participant preservice teachers is offered as proof that those who possess adequate subject knowledge but lack sufficient pedagogical and technological knowledge may experience problems integrating technology into the classroom. It is, therefore, not considered desirable that preservice teachers have moderate or lower levels of digital storytelling skills. In congruence with the existing published literature, the current study has helped to demonstrate that digital storytelling can improve many skills, and that there is a clear need for preservice teachers to acquire higher levels of digital storytelling skills to successfully graduate from teacher training institutions. As such, training in digital storytelling should form part of all teacher training undergraduate program courses, and those studies should be conducted to determine via rubrics at which stages preservice teachers experience the most difficulties, with time and effort invested in order to address these deficiencies. Through eliminating these deficiencies, both in field education courses and for instructional technology and vocational courses, the potential for preservice teachers to graduate with having acquired higher skill levels may be realized through digital storytelling.

One potential limitation of the current study was that it was conducted based on the evaluation of 46 digital stories prepared by preservice science teachers. However, the preparatory skills involved in the digital storytelling process may also be compared in future studies that compare preservice teachers from different branches.

Ethical and Consent Statement

The study's participants were informed about all the relevant processes of data collection and analysis. The privacy of the participants' personal data and the storage of the study's digital data were assured. Each participant signed an informed consent statement. There was no requirement to seek ethical approval to conduct this study. All research procedures were performed according to ethical standards and fully explained in advance to the study's participants.

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APPENDIX TABLE

Appendix: Digital story evaluation rubric

Categories	Excellent to Supreme 7–10	Good to Very Good 5–6	Satisfactory 4–4.5	Unacceptable 0–3
Content (Critical Incident)				
Rationale for choice of critical incident and context	Clear rationale for choice of particular critical incident, identifies what initial beliefs were about incident, interprets possible significance of incident in context of school and wider society.	Rationale for choice of particular critical incident apparent, identifies what initial beliefs were about incident, interprets possible significance of incident in context of school and wider society.	Rationale for choice of particular critical incident somewhat apparent, attempts to identify what initial beliefs were about incident and significance of incident in context of school and wider society.	No rationale evident for choice of particular critical incident, does not identify what initial beliefs were about incident nor possible significance of incident in context of school and wider society.
Outline of incident	Clearly describes key features of incident, chronology of events in the incident are clearly understandable.	Describes key features of incident, chronology of events in the incident are stated.	Somewhat describes key features of incident, chronology of events in the incident are unclear.	Does not describe key features of incident, chronology of events in the incident are not explained.
Demonstrates learning that involves the whole person	Critically reflects and shows evidence of learning that involves the whole person; clearly shows how the incident impacted on their emotions, thoughts, beliefs and actions.	Evidence of reflection and learning that shows how the incident impacted on their emotions, thoughts, beliefs and actions.	Little evidence of reflection that shows how the incident impacted on their emotions, thoughts, beliefs and actions.	No evidence of reflection, does not show how the incident impacted on their emotions, thoughts, beliefs and actions.
Draws on other perspectives and time frames	Critically reflects and draws on other perspectives about incident, including literature and colleagues. Considers incident in different ways and within different time frames.	Reflects and draws on other perspectives about incident. Considers incident in different ways and within different time frames.	Little evidence of reflection on other perspectives about incident, or consideration of incident in different ways or within different time frames.	No evidence of reflection on other perspectives about incident, or consideration of incident in different ways or within different time frames.
Demonstrates change in thoughts or actions	Clearly conveys how critical incident has changed their thoughts and/or actions.	Conveys how critical incident has changed their thoughts and/or actions.	Somewhat conveys how critical incident has changed their thoughts and/or actions.	Does not convey how critical incident has changed their thoughts and/or actions.
Evidence of integration of theory and practice	Incorporates at least three quotations from academic literature about teaching and learning that hold significant meaning for them in relation to critical incident.	Incorporates two quotations from academic literature about teaching and learning that hold significant meaning for them in relation to critical incident.	Incorporates one quotation from academic literature about teaching and learning that holds significant meaning for them in relation to critical incident.	Does not incorporate quotations from academic literature about teaching and learning in relation to critical incident.
Categories	**Excellent to Supreme 5**	**Good to Very Good 3**	**Satisfactory 1**	**Unacceptable 0**
Planning				
Working Portfolio	Working Portfolio includes complete and detailed planning materials: • Brainstorming sheet • Story drafts • Story map • Storyboard, • Final script • Lists of resources used • Reflective write-up	Working Portfolio includes most required planning materials.	Working Portfolio includes some required planning materials.	Working Portfolio does not include any of the required planning materials.
Storyboard	Complete and detailed evidence of planning throughout entire storyboard, including sketches, sequencing, pacing, script, images, music, and sound.	Evidence of planning through most of the storyboard, including sketches, sequencing, pacing, script, images, music and sound.	Evidence of planning through some of the storyboard, including sketches, sequencing, pacing, script, images, music and sound.	Little to no evidence of planning, including minimally completed sketches, sequencing, pacing, script, images, music and sound.

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Appendix: ***(Continued)***

Categories	Excellent to Supreme 7–10	Good to Very Good 5–6	Satisfactory 4–4.5	Unacceptable 0–3
Reflective write-up	Reflective write-up is within the 800–1000 word count. Write-up clearly conveys the author's feelings on the making of the digital story, explaining both the process of making the film and how they feel about the product.	Reflective write-up is 5% above or below the expected word count. Write-up conveys the author's feelings on the making of the digital story.	Reflection write-up is 10% above or below the expected word count. Write-up somewhat conveys the author's feelings on the making of the digital story	Reflection write-up is 20% above or below the expected word count, or, is not included in the working portfolio.
Mechanics				
Citation of Sources and Permission	All sources are cited completely and accurately in the credits. All copyrighted material, if used, is identified individually. (*Google images is NOT cited as the source*.)	Most sources are cited completely and accurately in the credits.	Some sources are cited completely and/or accurately in the credits.	No sources are cited in the credits. Or, Google images has been cited as the source.
Length	Length of digital story is between the required 3–5 min.	Length of digital story is 30 seconds shorter or longer than the required 3–5 min.	Length of digital story is one minute shorter or longer than the required 3–5 min.	Length of digital story is more than one minute shorter or longer than the required 3–5 min.
Grammar and spelling	Grammar and spelling are correct (for the dialect chosen) and contribute greatly to clarity, style and story development.	Grammar and spelling are mostly correct (for the dialect chosen) and contribute to clarity, style and story development.	Grammar and spelling are somewhat correct, but errors detract from the story.	Repeated errors in grammar and spelling detract greatly from the story.
Story Structure				
Dramatic question	Use of strong dramatic question; opening statements demonstrate thoughtfulness and creativity and engage audience in an interesting and subtle fashion.	Use of dramatic question; opening statements demonstrate thoughtfulness and creativity and engage audience.	Use of dramatic question; opening statement somewhat engages audience.	No dramatic question apparent; opening statement does not engage the audience or has no relationship to the rest of the story.
Personal narrative	Story is clearly told in the first person, conveys why events are important and how they affected the author, expresses feelings throughout, and includes many relevant sensory details.	Story is told in the first person, conveys why some events are important and how they affected the author, expresses the feelings, and includes some relevant sensory details.	Story is mostly told in the first person, reason behind importance of events and how they affected the thoughts and feelings are not well expressed, includes few relevant sensory details.	Story is not told in the first person, importance of events and how they affected the author is thoughts, feelings and/or relevant sensory details are not included.
Economy of story	The story is told with exactly the right amount of detail throughout. It does not seem too short nor does it seem too long. Only language necessary to further plot and complete story arc is used.	The story is mostly told with the right amount of detail throughout. However, it does need slightly more detail in some sections, or seems to drag somewhat in others. Very little unnecessary language is used.	The story seems to need more editing. It is noticeably too long or too short in more than one section. Some unnecessary language is used.	The story needs extensive editing. It is too long or too short in many sections. A great deal of unnecessary language is used.
Resolution of dramatic question	Dramatic question is clearly resolved. Story is concluded through the use of details that allow the audience to interpret the message of the story. The audience feels satisfied and is given the opportunity to think about the content.	The story concludes with enough information to provide a response to the dramatic question. The audience feels satisfied and the conclusion does not sound preachy.	The story concludes with the resolution to the dramatic question. The audience feels satisfied, although the conclusion may be moralizing or preachy.	The conclusion does not address the dramatic question, is not a logical conclusion given the content of the story, or the story trails off without a response to the dramatic question.

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Appendix: ***(Continued)***

Categories	Excellent to Supreme 7–10	Good to Very Good 5–6	Satisfactory 4–4.5	Unacceptable 0–3
Use of Technology				
Images complement and help convey the ideas in the script	Implicit imagery used to convey information that is not contained in the script but that adds to storyline and sense of satisfaction with the story. Tone of the visuals is aligned with tone of the story or is juxtaposed to the story with specific intent.	Some use of implicit imagery to convey information not contained in the script. Images experience of the story. Tone of most visuals is aligned with the tone of the story.	Limited use of implicit imagery to convey information not contained in the script. Most images reflect the voiceover exactly and do not provide additional information. Tone of some visuals is aligned with the tone of the story.	Many images undermine intent of story. Almost all images reflect the voiceover exactly and do not add any new information to the script. Tone of visuals is not aligned with the tone of the story.
Soundtrack (optional) contributes to the message of the story	Soundtrack choice enhances sense of satisfaction with the story and makes it more interesting. Soundtrack does not interfere with ability to hear voiceover and adds greatly to the emotional tone of the story.	Soundtrack enhances sense of satisfaction with story. Soundtrack does not interfere with ability to hear voiceover and adds to emotional tone of story.	Soundtrack somewhat enhances story. Level of soundtrack interferes with ability to hear voiceover.	Soundtrack interferes with ability to hear voiceover and/or undermines purpose of story or makes it impossible to understand story.
Voiceover supports purpose and tone of story	Voiceover is clearly audible, voice inflections and pacing draws audience in and creates intimacy with authentic emotion.	Voiceover is clearly audible. Voice inflections and pacing in most of the script makes it easy to listen to and engage with the story.	Voiceover is mostly audible. Some interest created with inflection and pacing.	Voiceover is difficult or impossible to hear or is missing. Interest is lost due to lack of inflection and pacing.
Student utilizes video editing software effectively	Exceptional use of movie editing software. Titles, transitions and effects used effectively and greatly enhance the experience of watching the digital story.	Effective use of movie editing software. Titles, transitions and effects used effectively and enhance the experience of watching the digital story.	Titles, transitions and effects under or over used, and can distract from story.	Titles, transitions and effects under or over used, or not used at all. No evidence of knowing how to apply movie editing effects.