Original research

# Digital explanations and nursing students' perception of learning science

Shahla Meedya*, Tracey Moroney, Wendy Nielsen, Ida Najafi Bokat

*School of Nursing, Wollongong University, Australia*

| ARTICLE INFO | ABSTRACT |
|---|---|
| | A thorough understanding of human physiology and anatomy are pivotal in the preparation of competent nursing students for clinical practice. However, anatomy and physiology are among the most conceptually perplexing subjects that nursing students will encounter throughout the duration of their course. Research in other science-based contexts has demonstrated a positive relationship between student-generated digital media and learning scientific concepts. Therefore, the aim of this study was to explore nursing students' experience in learning science concepts through a formative assessment task which was based on making a 'digital explanation'. Our work was guided by semiotic theory and the study design was a mixed method study where 428 first-year nursing students across five campuses volunteered to complete self-reported surveys during the first and last week of the academic session. Students who consented for an interview were invited to attend one of five focus groups. More than half of the participating cohort had prior experience with science (66%), but only 24% had previous experience with making digital media. After completion of the assessment task, two-thirds of the students strongly agreed or agreed that they learned more about science and fewer students agreed that searching for scientific knowledge could be boring. The qualitative findings confirmed the presence of learning about science and four themes were identified: 'learning about science', 'linking knowledge to practice', 'using technology', and 'making it real'. A key point was that the students began to see connections between science knowledge and nursing practice. But many students were challenged by the technology and the fact that the task was ungraded. Although the digital explanation was an overall positive experience for the nursing students, there is a need for a flexible and graded assessment task to achieve its potential benefits as a teaching and learning task in nursing. We conclude that additional intervention studies are warranted. |

## 1. Statement of significance

| Problem | Understanding the human body and its functions are pivotal for preparing competent nursing students for clinical practice. However, anatomy and physiology are among the most conceptually perplexing subjects for nursing students. |
|---|---|
| What is already known | Using student-generated digital explanations has been successful in learning science among students from different disciplines such as teaching, nutrition, pharmacology and engineering. |
| What this paper adds | This study demonstrates that student-generated digital explanations can assist the nursing students to perceive better learning in science and connect the science content knowledge into nursing practice. |

### 1.1. Background

Contemporary undergraduate nursing curricula has moved away from an old-fashioned medically oriented model to holistic and patient centred care since late 1980 (Salvage-Jones et al., 2016). This shift in the nursing education paradigm required integration of anatomy and physiology in the nursing curricula to prepare students with sufficient scientific background to be competent in their clinical practice (Birks et al., 2015; Craft et al., 2013; Gordon et al., 2017; Jensen et al., 2018; Johnston et al., 2015; Taylor et al., 2015). However, anatomy and physiology have been identified as the most conceptually challenging subjects that nursing students will encounter throughout their course (Birks et al., 2013). Similarly, a cohort study of 273 first year undergraduate nursing students demonstrated a high level of anxiety about learning science. Although the students appreciated the relevance of science in the workplace, they found anatomy and physiology to be among the most challenging subjects in the course (Craft et al., 2013).

There are a few factors that contribute to the existing challenges nursing students face in learning science. One of these is a disconnection between the teaching methods and learning styles of nursing students (Salvage-Jones et al., 2016). For instance, the lack of interactive learning methods and relying on watching and listening to science

* Corresponding author. School of Nursing, The University of Wollongong, Australia.
  *E-mail address:* smeedya@uow.edu.au (S. Meedya).

lectures or completing science modules have been identified as problematic for nursing students who are learning science (Jensen et al., 2018; Johnston et al., 2015). Some authors report that not all nursing academics feel confident to teach science, which can exacerbate the level of anxiety among the students who find learning science challenging (Davis, 2010). However, it is important to consider other confounding factors such as students' own academic performance history, values, beliefs and learning styles that can compound their fear towards learning science (Birks et al., 2015).

In a literature review of 23 papers, Jensen et al. (2018) showed that nursing students value pedagogic styles of technology-based learning. The students demonstrated a high level of satisfaction with digital learning tools such as podcasts, the use of digitally aided equipment, e-atlas and e-simulation practices. However, there are limited interventional studies that examined the students' learning experience and its connection with their clinical practices (Jensen et al., 2018). Learning science through creating digital artefacts, such as student-generated digital explanations, has shown positive learning outcomes for students because they choose or create representations of their understandings and learning that can then be incorporated in their professional practice (Hoban et al., 2016a,b). In student-generated digital explanation, students add their audio narration to the different forms of digital media such as still images, slowmation, videos, text-on-screen, and a blended media (combining a variety of modes) to create three to 5 min digital product (Hoban and Nielsen, 2011).

Semiotic theory is the main theoretical framework for using student-generated digital explanation in learning science (Nielsen et al., 2017). Semiotic theory is about using signs (representations) to generate an individual and unique meaning (personal interpretation) of concepts (referent) that is typically presented by experts, for example, in textbooks (Peirce, 1931/1955). Although Peirce's theory was instigated a century ago, the contemporary methods of learning science still rely on the dynamic interplay between referent, representation and personal interpretation, where students construct ever-changing individual meanings for a science concept and use different ways to express those meanings. Empirical research in science education demonstrates that making a blended media is a creative way for students to represent complex scientific concepts. Using various modes of representations in producing a blended media can help the students to enhance their awareness of different ways to communicate their understandings and improve their interpersonal skills towards deep learning (Nielsen et al., 2017) which are very important in the nursing discipline.

While the construction process is framed by semiotic theory, we are also interested in how construction supports student learning. Kidman (2016), among others, have preservice teachers produce a 'slowmation' (Hoban, 2005, 2009) and studying the pedagogy of slowmation has led to claims that learning science through creating slowmation is transformative. Kidman has focused on preservice teachers developing meta-awareness of their learning processes and draws from cognitive science literature on transformational learning.

Theorists in transformational learning (Mezirow, 2000; Morrell and O'Connor, 2002; Sterling, 2010) describe three orders when discussing learning and change: first-order learning is relatively shallow or 'surface' which involves 'cognitive learning' by simply accessing text-based materials, listening to lectures or other passive engagement typical in transmissive style pedagogies. Second-order learning, according to Kidman (2016), is distinct from first-order learning because the learner begins to critically examine the self in relation to the content. In other words, the learner engages with materials and ideas so as to challenge his/her prior understandings and question assumptions. This type of meta-awareness is key to 'transformative learning' referred as 'meta-learning'. This is also where original work is generated because it is a product of deeper learning strategies to rework or revise (e.g. transform) content. The deepest learning is third-order, where the learner can now step beyond the individual worldview to both see it in a wider context but also draw on other worldviews and possibilities. This

'epistemic' level of learning results in a shift in consciousness, but it is, however, rare (Kidman, 2015, 2016; Sterling, 2010).

Kidman (2015) argued that the students who simply produced the slowmation artefact were engaged in first-order learning. However, some students questioned the accuracy of the models and/or made extra modifications to them for use in the slowmation product, which Kidman identified as second-order learning. This could also be seen as working or thinking creatively and thus indicating that the slowmation construction was genuine learning activity. Kidman did not identify and third-order learning in that study. In the current study, nursing students had the opportunity to engage in deep learning by representing their knowledge and connecting it to nursing practice through using contemporary digital technologies in a teaching and learning activity.

Living in the current digital world, virtually every university student has a smartphone, tablet and/or laptop (Moll and Nielsen, 2017). Therefore, students have many opportunities to be multimodal designers and utilise a wide range of digital media including podcasts, digital stories or blended media (Nielsen et al., 2017). According to Prain (2006) 'manipulation of computer-generated texts, where students integrate imagery, sound, mathematical symbols, diagrams, and writing, alters the role of written language as the major or dominant medium of learning'. Student generated digital media has been introduced into some Australian tertiary institutions (Hoban et al., 2016a,b), but to date, there has been no large-scale study to explore nursing students' experience in representing their learning through creating a digital explanation. The current study reports the experiences of a large cohort of first-year nursing students across five campuses who were asked to create a digital media product as a learning activity in a science subject called 'The Art and Science of Nursing'. We address the research question: What are nursing students' perspectives on their experience of creating a digital explanation?

## 2. Method

The study was a sequential explanatory mixed-method study with 428 participants studying first-year nursing students across five campuses of the University of Wollongong, including Wollongong, Southern Sydney, Shoalhaven, Bega and Batemans Bay. The aim was to explore students' experience of creating a digital explanation and how this supported their perceptions of learning anatomy and physiology. We took a pragmatic approach to this mixed-method study and employed both qualitative and quantitative methodologies to gain a better understanding of the research problem and answer the research question (Creswell and Plano Clark, 2011; Onwuegbuzie and Johnson, 2004).The study was approved by the Human Research Ethics Committee of the University of (2017–415).

In January 2018, prior to commencement of the academic session, the subject workbooks, workshops and e-learning resources were amended in consultation with the subject co-ordinator to provide students with adequate resources for a new formative assessment task on making a digital explanation about a science concept. The digital formative assessment task was introduced into the subject as part of an evidence-based activity to support learning science in the subject. In late February 2018, all tutors received support for their new responsibilities with the digital explanation in the form of a 1-h video conference workshop. Any tutors lacking confidence in making digital products spent some time with the first author to make a short digital story. In week three (late March 2018), all students attended a 1-h workshop on digital media-making techniques and selected a topic of interest from a supplied list of 30 items. The list included the following topics: cellular processes (mitosis, active transport, gas exchange); cellular components (mitochondria, ribosomes, membranes); feedback mechanisms; introduction to body systems and functions; organs; cardiovascular system; and respiratory system. Irrespective of the topic, the digital explanation was to include three elements that were extracted from the semiotic theoretical framework: a) define the science

topic for the audience (referent), b) describe the way the concept will be represented (representation), and c) link this knowledge to nursing practice (personal interpretation). Students had three weeks to complete the task and submit it online. They also had a choice to use their preferred format for digital media such as podcast, slowmation, video, digital story or blended media. The authors did not have any teaching role with the science subject.

### 2.1. Data collection

Quantitative data were collected twice through a self-reported survey in the first and last weeks of the academic session from students who volunteered to participate in the study (Supplementary document). The first survey included questions about the students' demographic information, past experience in learning science and using digital media, and their attitudes towards learning science. The second survey included more questions about the students' experience in making the digital explanation such as the average time spent finding information, average time spent making the digital media, type of digital modes that they used, if they believed that they learnt more about the science topic during the activity and if they preferred digital media over their text books or lectures. The second survey also included one free-text question that sought participants' feedback on the learning experience. Additional qualitative data were collected through interviews with the students who had agreed to participate in an interview, either in a focus group or individual format. The research team (SM, HP, KR) conducted five focus group interviews (one on each campus) in a structured interview format lasting for about 30 min. Two students, who could not attend the focus groups, were interviewed individually. The interview protocol was mainly focused on the students' thoughts regarding the digital explanation task; if they found it a useful way to learn science, providing reasoning; how they could use their science knowledge in nursing practice; and positive and negative aspects of the activity.

### 2.2. Data analysis

Quantitative data were analysed using the Statistical Package for the Social Sciences (SPSS) Version 21.0 (IBM Corp., 2013). Qualitative data were analysed in the following steps: the hard-copy questionnaire responses and interview transcriptions were entered into a spreadsheet in NVivo; the transcripts were de-identified and compared with the original audio records by the first author to check for accuracy; thematic analysis was conducted based on the six phases described by Clarke and Braun (2013). After becoming familiar with the data, initial codes were generated to identify broad categories. Subsequently each of the categories was reviewed to identify common thoughts and patterns about the digital explanation as a formative assessment task, which became themes for further data analyses. Trustworthiness was checked by two authors (MS and TM) who worked together through this process to review the codes and themes to ensure consistency of interpretation. As questions arose, the two authors compared and discussed their interpretations and resolved definitions in this way. There was no need to set any extra interviews as we reached data saturation with five focus groups and two individual interviews.

## 3. Results

Results are presented in two sections. The first section summarises participants' demographic information and their perceptions about learning science. The second section presents these students' learning experience of the digital explanation activity and their perceived learning.

### 3.1. Demographic information

The entire cohort of 517 first-year nursing students was invited to participate in the research in March 2018. Of these, 428 (83%) completed the initial background survey. Demographic data are summarised

**Table 1**
General information about the participants.

| Characteristics | n = 428[a]<br>n (%) |
|---|---|
| Campus | n = 428 |
| • Wollongon (W) | 297 (69.4) |
| • Southern Sydney (SS) | 58 (13.6) |
| • Shoalhaven (SH) | 46 (10.7) |
| • Bega (B) | 15 (3.5) |
| • Batemans Bay (BB) | 12(2.8) |
| Age group | n = 415 |
| • < 20 | 198 (46.3) |
| • 20-25 | 133 (31.1) |
| • 26-30 | 32 (7.5) |
| • 31-35 | 17 (4.0) |
| • > 36 | 35(8.2) |
| Study status | n = 424 |
| • Domestic | 341 (79.7) |
| • International | 83 (19.4) |
| Gender | n = 426 |
| • Female | 370 (86.4) |
| • Male | 56 (13.1) |
| Ethnicity | n = 428 |
| • Caucasian | 261 (61.0) |
| • Asian | 97 (22.7) |
| • Aboriginal and Torres islanders | 10 (2.3) |
| • other | 60 (14) |
| Previous science study | n = 421 |
| • Yes | 281 (65.7) |
| • No | 140 (32.7) |
| Previous Experience with Digital media | n = 422 |
| • Yes | 103 (24.1) |
| • No | 319 (74.5) |

[a] Not all students answered every question and thus values do not always total to 428.

in Table 1. Reflecting the general pattern of undergraduate nursing students, the majority of participants were female (n = 370, 86%) and less than 26 years of age (n = 331, 77%). While more than half of the students had previous science studies in high school or university (n = 281, 64%), only about a quarter (n = 103, 24%) had previous experience with making digital media (Table 1).

The students were asked to report their agreement or disagreement if they believed that nursing was a hands-on profession and did not need science. The majority of the students before and after the activity strongly disagreed or disagreed that the nursing profession was only a hands-on job (n = 344, 80%).

### 3.2. Students' learning experience

After completing the formative digital explanation task, the students completed the second survey. A total of 388 students returned the follow-up surveys, which represents a 9.1% attrition rate. Of these respondents, 98% (n = 372) completed the digital task in a form of videos (n = 214, 58.5%) or digital stories (n = 86, 23.5%). A majority of students (n = 284, 77.4%) reported that they spent between one and 10 h in searching for science related information. Notably, about half of these students spent only one to 3 h to develop their digital explanation. Only a small percentage of the students spent two days or more on making the digital artefact (n = 48, 13%). Two-thirds of the students (70%) strongly agreed or agreed that they learnt more about science and found more science information during the search for the information and resources in developing the digital explanation. However, while this strong majority felt they learned more science, 53% of the participants disagreed or strongly disagreed that the digital media activity was a better learning method compared to lectures and text books.

In the sections that follow, we present our analyses of students' interview and free text feedback to elaborate the experience with generating the digital explanation. Interview comments are referenced with

a code for their location (W, SS, SH, B or BB) and a participant number. We identified four main themes: learning about the science, linking the knowledge into practice, using technology, and making it real.

### 3.2.1. Learning about the science

Students found the digital task a different learning experience and for some, this was advantageous to their learning. It is notable that a majority of students indicated that they learned more about the science in developing the digital explanation. Students commented on how the task supported learning. For example, *"I guess you had to research that topic and then, [be]cause you're putting a project together, you're thinking about it a lot more and how to present it and what's actually going on within that topic"* (W.4). This is consistent with the quantitative result where students spent time trying to learn the science concepts so that they can be represented in the digital explanation. Others enjoyed the learning: *"Making videos was fun"* (SS.4), *"I did think it (digital activity) was helping me to learn about the subject, a bit of research and putting it all together"* (B.3), *"exploring our ideas in short videos helps to learn more"* (W.280). Another participant stated, *"it was good to do something different other than just reading a textbook and reading, watching a lecture"* (W.4). This acknowledges the differing methods by which students learn and by extension, the benefit of offering different types of learning activities and methods to help students to develop their science knowledge.

The significance of doing your own research is an important part of the learning benefit, as noted by this student: *"I think actually making a video helped because then we had to do our own research and we had to actually go through the information, so that was kind of like, we were able to like, process it ourselves instead of just being information chucked at us"* (SS.2).

### 3.2.2. Linking knowledge to practice

Despite the issues that students raised in completing the digital explanation as part of the science subject, students began to link the science knowledge with nursing practice. Completing the activity assisted students to see the importance of science to practice, as illustrated by one participant who suggested, *"I think homeostasis itself is really important to understand in nursing"* (SS.4) and another who stated *"if your temperature's high, you know, your heart rate's going to be high and it just, you can relate it back to there" (W.1)*. At a basic level, these students seem to have realized one of our key aims in this first-year subject—that nursing students should understand the importance for their future work of science concepts in anatomy and physiology.

We also saw students begin to apply their science knowledge during workplace experiences and in the simulation labs. The simulations also supported these nursing students to link science with nursing care decisions. This connection was illustrated by one participant, who stated *"it gives you knowledge and self-awareness … when you are a nurse, you can detect things"* (SS.4).

Realising that science knowledge, such as how biological processes actually work in different contexts, can help ground patient care decisions is an important outcome for this subject. Some students in this study started to feel confident using the language of science when they were caring for patients during their work experience placement: *"I knew what I was talking about on placement"* (B.2). Recognising the science knowledge inherent in nursing care situations is a key demonstration of these nursing students' deep learning.

### 3.2.3. Using technology

Some students found technology distracting in terms of their overall learning and this was often attributed to the software. Other students commented on their poor technology skills, with one noting, *"I spent so much energy on the actual digital media part … rather than the science I was supposed to be learning"* (SH.2). When asked if they thought the digital explanation activity was a useful way to learn science, some revealed a particular view of what counts as science knowledge: *"I would say no, personally for me, because I felt like so much time was wasted on the actual digital media rather than the content of what we were supposed to be*

*learning"* (SH.1). For others, the time involved was the problem: *"I learnt more about my topic but it took longer to actually make it"* (SS.3).

### 3.2.4. Making it real

In the current study, the digital activity was not graded nor was feedback given. For some students, this was a disincentive to undertake the task or give it much effort. For example, *"The time I spend on making a movie could have been spent learning something else or doing work that was actually going to be marked"* (W.45). For others, an ungraded activity signaled that there was no purpose to the activity and participants gave the task a low priority: *"well it wasn't marked, it was kind of like just get it done, get it out of the way"* (BB.1). Students who 'perform' degree requirements because of marks awarded may be missing the point of learning more generally, relying on surface learning strategies, even in their professional development. However, this is the reality for many students in the nursing cohort, and it seemed to have a negative effect on their learning. Others questioned the value of technology skills for their future as nurses: *"Experience in making digital media and using iMovie would have made this activity easier. I don't feel we need to know how to make a movie in nursing"* (W.68). Some students recommended adding more e-resources into the program and changing the individual task into group work and providing more options to represent the science concepts.

### 3.2.5. Critical analysis of the students' perception on learning science

Critical analysis of the data from the identified themes revealed that the students' perceptions of their learning refkected different levels as shown in the nursing model in Fig. 1. For instance, a majority of the students perceived that they learnt more about the science by finding information from websites or text books. They were satisfied that they could put the information together and developed their own digital media successfully as part of their formative assessment task. This perception of learning is consistent with what Kidman (2016) reported as shallow learning by the preservice teachers in her study: through finding more information on the topic and putting the representations together to produce the digital explanation, the nursing students demonstrated first-order learning where pre-existing content is used to produce the task, in this case to make a digital explanation.

There were, however, many students in the current study who exhibited a level of self-awareness of their learning activity, indicative of second-order learning. We also read student questioning of the task as indicative of second-order learning, because they seem to have challenged themselves to understand the value and purpose of making the digital explanation. Through rearranging different types of
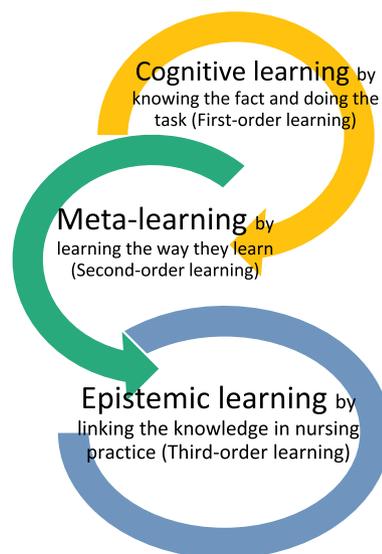


**Fig. 1.** A model of transformative learning for nursing education.

representations when constructing the digital explanation and making videos, digital stories, and slow-mations, the nursing students demonstratd a level ofmeta-learning or deep learning.

Further illustrations of these nursing students' deep learning are clear when they could connect their knowledge into nursing practice during their simulation labs and workplace experiences. We identify this as epistemic learning in the context of nursing care: using the science knowledge to ground decision making in a real world situation of patient care means that these nurses have linked the knowledge to practical situations, which will make a difference in clinical situations.

## 4. Discussion

This study reports the first introduction of student-generated digital explanation as a formative assessment task for nursing students who were enrolled in a first year science subject in an Australian tertiary institute. The aim of the study was to explore the students' learning experience with the task and their perceptions of learning science. The main findings of the study identify the different experiences of nursing students when generating their own digital explanation as a learning activity intended to expand their science knowledge. We have received positive feedback from the students, who reported that the experience allowed them to learn more about the science topics, have fun and explore a useful and interactive way of learning which took only a few hours. The findings of this study concur with other studies where student-generated digital explanation supported students' perceptions of learning science in different disciplines such as teacher education (Hoban and Nielsen, 2011; Kidman, 2015, 2016), pharmacology (Nielsen et al., 2017, 2018), biochemistry (Vanderlelie, 2016), nutrition/dietetics (Walton et al., 2018) and engineering (Belski and Belski, 2016).

Three orders of transformative learning were identified from the students' feedback. A majority of the students reported finding more information and learning about the contact (first-order learning). Some identified self-awareness in the way they learn (second-order learning). But one of the important aspects of the digital explanation activity was seeing some students linking the science content into nursing practice (third-order learning). The students reported that they could connect their science knowledge in the simulation labs and clinical practice. The importance of connecting science concepts to patient care in nursing curricula (Johnston et al., 2015) and text books (Beedholm and Frederiksen, 2015) has been highlighted by different authors. According to Smeby and Heggen (2015), the professional knowledge is mixed and should be embedded in the practical aspect of practice (Kidman, 2016) including nursing. The task of generating the digital explanation in the current study seems to have gone some way toward bridging the science learning and practical application of knowledge.

Despite the positive feedback, the students' learning experience is tempered by challenges with the technology and possibly, poor motivation to do 'extra work' that was not graded. Some authors report that nursing students may demonstrate a lack of interest in technology-based learning activities because they do not feel confident to use online tools or have limited digital literacy skills (Johnston et al., 2015). This frustration can be related to being comfortable in engaging with familiar or traditional methods of learning such as lectures and textbook, and or could be due to learning itself. Sterling (2010) refers to this type of discomfort as a shift from first-order to second-order learning, which some learners perceive as painful. The students also reported their need to give greater priority to marked assessment tasks and were therefore unwilling to spend time on an activity that was not graded. The irony of course, is that they felt they learned the science through the task, but then may have missed the point of studying in the first place—rather than doing assignments only because they earn marks. Even if they did not view the digital task positively, they may have developed an improved understanding of content and grades. This is consistent with a study that explored third-year pharmacology students' learning experiences (Nielsen et al., 2017). These students felt that their efforts were not

adequately rewarded when only a small percentage of the subject mark was allocated for the students' digital explanation.

One of the strengths of our study is that it was conducted with a large cohort of students across five campuses and had a very small attrition rate. We can thus view the range of students' perspectives as valuable feedback for subject design. Many of the students recommended having access to current e-resources and better-trained facilitators to help them generate the digital explanation. Others suggested they would like the opportunity to represent their learning in other creative ways, possibly as a group product. In a study by (Johnston et al., 2015), nursing students appreciated a combination of auditory, visual and hands-on learning activities in learning science. These authors also recommended flexible blended digital learning activities to translate hands-on activities into online or Web 2.0 learning resources.

The current study has a number of limitations. The primary limitation is the lack of direct evaluation on the students' digital work and their relationship with the final learning outcome such as exam results. Another limitation to the study was the lack of opportunity to verify the conclusion of the interviews with the participants.

## 5. Conclusion

Introducing the student-generated digital explanation as a formative assessment task to learn science can develop positive learning experiences among first-year nursing students and improve their learning perceptions of science concepts. Student-generated digital explanation can open a new dimension towards using science in nursing practice and influence the policies and the way we teach science in clinical settings for nursing, midwifery and allied health care students. However, due to challenges around learning and using the technology, there is a need for further interventional studies that can assess the effect of this intervention on the students' learning outcomes with a formal assessment task that includes an allocated mark. Moreover, there is a need to conduct further studies to compare the student-generated digital explanation with other creative artefacts where the nursing students have the freedom to choose their own imaginative ways to represent their learning about the science concepts.

## Declaration of competing interest

None.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.nepr.2019.102636.

## References

Beedholm, K., Frederiksen, K., 2015. The process of Danish nurses' professionalization and patterns of thought in the 20th century. Nurs. Inq. 22 (2), 178–187.

Belski, I., Belski, R., 2016. Student-generated dynamic worked examples as videos to enhance learning in STEM. In: Hoban, G., Nielsen, W., Shepherd, A. (Eds.), Student-generated Digital Media in Science Education: Engaging Students in Learning, Explaining and Communicating Content. Routledge, London, pp. 122–135.

Birks, M., Chapman, Y., Ralph, N., McPherson, C., Eliot, M., 2013. Undergraduate nursing

studies: the first-year experience. J. Inst. South East Asia Res. 18 (1), 26–35.

Birks, M., Ralph, N., Cant, R., Hillman, E., Chun Tie, Y., 2015. Teaching science content in nursing programs in Australia: a cross-sectional survey of academics. BMC Nurs. 14 (24).

Clarke, V., Braun, V., 2013. Teaching thematic analysis: overcoming challenges and developing strategies for effective learning. The Psychologist 26 (2), 120–123.

Craft, J., Hudson, P., Plenderleith, M., Wirihana, L., Gordon, C., 2013. Commencing nursing students' perceptions and anxiety of bioscience. Nurse Educ. Today 33 (11), 1399–1405.

Creswell, J., Plano Clark, V., 2011. Designing and Conducting Mixed Methods Research. Sage Pubns, Los Angles.

Davis, G.M., 2010. What is provided and what the registered nurse needs bioscience learning through the pre-registration curriculum. Nurse Educ. Today 30 (8), 707e712.

Gordon, C.J., Hudson, P.B., Plenderleith, M.B., Fisher, M., Craft, J.A., 2017. Final Year Australian nursing students' experiences with bioscience: a cross-sectional survey. Nurs. Health Sci. 19 (1), 22–28.

Hoban, G., 2009. Facilitating learner-generated animations with slowmation. In: Lockyer, L., Bennett, S., Agostinho, S., Harper, B. (Eds.), Handbook of Research on Learning Design and Learning Objects: Issues, Applications and Technologies. IGI Global, Hershey, PA.

Hoban, G., 2005. From claymation to slowmation: a teaching procedure to develop students' science understandings. Teach. Sci.: Aust. Sci. Teach. J. 51 (2), 26–30.

Hoban, G., Nielsen, W., 2011. Using 'slowmation' to enable preservice primary teachers to create multimodal representations of science concepts. Res. Sci. Educ. 35 (1), 1101–1119.

Hoban, G., Nielsen, W., Hyland, C., 2016a. Blended media: student-generated mash-ups to promote engagement with science content. Int. J. Mob. Blended Learn. (IJMBL) 8 (3), 35–48.

Hoban, G., Nielsen, W., Shepherd, A., 2016b. Student-Generated Digital Media in Science Education: Engaging Students in Learning, Explaining and Communicating Content. Routledge, London.

Jensen, K., Knutstad, K., Fawcett, T.N., 2018. The challenge of the biosciences in nurse education: a literature review. J. Clin. Nurs. 27 (9–10), 1793–1802.

Johnston, A., Hamill, J., Barton, M.J., Baldwin, S., Percival, J., Williams-Pritchard, G., Todorovic, M., 2015. Student learning styles in anatomy and physiology courses: meeting the needs of nursing students. Nurse Educ. Pract. 15 (6), 415–420.

Kidman, G.C., 2015. Facilitating meta-learning in pre-service teachers: using integration and slowmation animation. Procedia: Soc. Behav. Sci. 167, 117–123.

Kidman, G.C., 2016. Pre-service teachers' use of Slowmation: developing transformative learning. In: Hoban, G., Nielsen, W., Shepherd, A. (Eds.), Student-generated Digital Media in Science Education: Learning, Explaining and Communicating Content Routledge, pp. 166–175 Abingdon Oxon UK.

Mezirow, J., 2000. Learning as Transformation: Critical Perspectives on a Theory in Progress. Jossey-Bass, San Francisco, CA.

Moll, R.F., Nielsen, W., 2017. Development and validation of a social media and science learning survey. Int. J. Sci. Educ. 7 (1), 14–30.

Morrell, A., O'Connor, M., 2002. The project and vision of transformative learning. In: Sullivan, E.O., Morrell, A., O'Connor, M. (Eds.), Expanding the Boundaries of Transformative Learning: Essays on Theory and Praxis. Palgrave Macmillan, New York, pp. xv–xx.

Nielsen, W., Georgiou, H., Jones, J., Turney, A., 2018. Digital explanation as assessment in university science. Res. Sci. Educ. 43 (4).

Nielsen, W., Hoban, G., Hyland, 2017. Pharmacology students' perceptions of creating multimodal digital explanations. Chem. Educ. Res. Pract. 18, 329–339.

Onwuegbuzie, A., Johnson, R., 2004. Mixed methods research: a research paradigm whose time aas come. Educ. Res. 33 (7), 14–26.

Peirce, C., 1931/1955. Logic as semiotic: the theory of signs. In: J, B. (Ed.), Philosophical Writings of Peirce Dover, pp. 98–119 New York.

Prain, V., 2006. Learning from writing in secondary science: some theoretical and practical implications. Int. J. Sci. Educ. 28 (2–3), 179–201.

Salvage-Jones, J., Hamill, J., Todorovic, M., Barton, M.J., Johnston, A., 2016. Developing and evaluating effective bioscience learning activities for nursing students. Nurse Educ. Pract. 19, 63–69 2016.

Smeby, J.-C., Heggen, K., 2015. Coherence and the development of professional knowledge and skills. J. Educ. Work 27 (1), 71–91.

Sterling, S., 2010. Transformative learning and sustainability: sketching the conceptual ground. Learn. Teach. High. Educ. 5 (17–33).

Taylor, V., Ashelford, S., Fell, P., Goach, P.J., 2015. Biosciences in nurse education: is the curriculum fit for practice? Lecturers' views and recommendations from across the UK. J. Clin. Nurs. 24 (19–20) 2797e2806.

Vanderlelie, J., 2016. Musical explanations: using blended media for learning biochemistry. In: Hoban, G., Nielsen, W., Shepherd, A. (Eds.), Student-generated Digital Media in Science Education: Engaging Students in Learning, Explaining and Communicating Content Routledge, pp. 225–238 London.

Walton, K., Nielsen, W., Georgiou, H., 2018. Supporting development of cultural competence in nutrition/dietetics. In: Presentation at the Annual Meetings of the Australasian Science Education Research Association. Gold Coast, Queensland.