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Engaging adolescent Kyrgyzstani EFL students in digital storytelling projects about astronomy

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This research is based on the *Journey through Space and Time* (JTST) educational astronomy project for primary and junior high school science curricula in Australia, which seeks to improve students' astronomy content knowledge through science inquiry. The focus of the current project is on the learning needs of students for whom the language of instruction is a foreign or second language (EFL/ESL). This article reports the results of a pilot case study conducted in Bishkek, Kyrgyzstan in December 2017. The research employed a Type II Case Study design. Data were collected through video and audio recordings of classroom interactions. The *Astronomy Diagnostic Test* measured changes in content knowledge and written feedback at the end of the course and helped to understand students' overall impression from the course. The study revealed that engaging Kyrgyzstani EFL students aged between 12 and 15 years in making videos about their learning of astronomy significantly facilitated their content knowledge acquisition. This research contributes to the existing knowledge about the use of technology in students' science education, and specifically as a tool to enhance EFL students' understanding of the integrated science, technology engineering and mathematics (STEM) curriculum. The results of the shared knowledge construction stimulated by the collaboration in video production create a case for further research in EFL students' disciplinary literacy development.

Introduction

The need for an integrated science, technology engineering and mathematics (STEM) curriculum has been recognised internationally, reported in the *Next Generation Science Standards* (NGSS Lead States, 2013) and presented by the Australia's Office of the Chief Scientist (2014). However, literature on its implementation in classrooms is scarce, and much of the focus is on improving students' learning outcomes in the individual subjects that comprise STEM rather than on their integration (Thibaut et al., 2018). Astronomy is one content area that integrates STEM learning through its strong links between mathematics and science learning, as well as positioning technology and engineering as essential to enhance our understanding of astronomical phenomena (Fitzgerald, McKinnon, Danaia, Cutts, Salimpour & Sacchi, 2018).

Despite the benefit of using astronomy as a vehicle for STEM integration, there is a body of Western research that reports on the poor quality of primary school astronomy classes (Buaraphan, 2012; Dunlop, 2000; Skamp & Preston, 2015) where teachers often select knowledge-transmission pedagogies and limit students' active inquiry (Hamm, 1992; Moyer, Hackett & Everett, 2007). Similar issues in astronomy implementation are found in Eastern countries; for example, in the Central Asian country, Kyrgyzstan, astronomy has been completely removed from the 2018-2019 curriculum (Usenaliev, 2018). In past curricula, Kyrgyzstani students were introduced to astronomy either in Year 10 or Year

11, but had only one academic hour per week of instruction which amounted to 34 academic hours of astronomy per year.

Starting from 2018-2019 the Ministry of Education in Kyrgyzstan decreed that astronomy lessons should be integrated into the physics course without allocating any extra hours. Thus, the decision of whether or not to teach astronomy within physics is solely at the discretion of the teacher (Usenaliev, 2018). Consequently, this decree has significant implications for the integration of astronomy in Kyrgyzstani students' learning. Therefore, this research piloted the use of an astronomy course as a vehicle for exploring the intersection between STEM learning, English as a foreign language (EFL) learners and technology, as it was unlikely that students had covered astronomy content in their regular schooling.

STEM learning, including astronomy (STEM-A), poses a number of challenges for EFL learners. Students are exposed to much specialised vocabulary and concepts that can be taught in isolation to context; this is a challenge for EFL/ESL learners as they may not be able to connect new vocabulary to their prior experiences and conceptual understandings (Arya, Hiebert & Pearson, 2011; Varelas, Pieper, Arsenault, Pappas & Keblawe-Shamah, 2014). If EFL/ESL students cannot attach meaning to the specialised concepts and vocabulary they may disengage from learning STEM disciplines (Arya et al., 2011; Braden, Wassell, Scantlebury & Grover, 2016; Meyer & Crawford, 2015; Varelas et al., 2014).

Internationally, standardised testing for science literacy shows EFL learners consistently perform worse than native English students (National Assessment Program, 2015; The Nation's Report Card, 2015). Consequently, there is a need for teachers to adjust their pedagogy with EFL/ESL students, identifying and developing best practice pedagogical approaches that support rich and authentic STEM learning to engage students. This is essential if EFL/ESL students wish to continue STEM studies post-schooling, as English is the dominant language in international STEM collaboration (Foyewa, 2015).

Technology is one tool that could enhance STEM learning for EFL/ESL students. Complex technology has penetrated everyday life (Holmes, Gore, Smith & Lloyd, 2018), and education is no exception (Prensky, 2008). Authentic technological processes allow students to apply learned concepts to the creation of a product (Hammerman, 2006) and thus foster an interaction between the learners' background knowledge and learning objectives, addressing some of the key issues for EFL/ESL learners when engaging in STEM and scientific learning.

The pilot study described in this paper is situated at the nexus of technology, STEM and EFL learning. It explored the role of technology, specifically digital storytelling (video making), as a pedagogical strategy for enhancing EFL learners' language and conceptual understandings of astronomy during an extracurricular course offered to adolescent Kyrgyzstani students (aged 12-15 years). The pilot study sought to answer two key research questions:

- How does video making in the course affect EFL students' astronomy content knowledge development?
- How do EFL students engage with learning science through the astronomy extracurricular course when it is enhanced with collaborative video making?

Collaborative inquiry learning

Astronomy is a subject that opens opportunities to comprehend other science content and mathematics through inquiry learning (Ampartzaki & Kalogiannakis, 2016; Hamm, 1992; Krogh & Slentz, 2001; McKinnon, 2013; MacLeod, Razul & Powell, 2015). The essence of inquiry is in engaging students in planning, organising, enacting, and reflecting on experiences that facilitate their understanding of a task, and which help them to relate learning activities to the key concepts and goals of a course (Hammerman, 2006). Inquiry as authentic science learning is often collaborative, which implies the integration of the learners' real-world experiences to develop deeper scientific understandings in conversation and active engagement with others (Pietarian, Vauras, Laakkonen, Kinnunen & Volet, 2018; Prairie & Buckleitner, 2005).

This pilot study adopted the constructionism epistemology (Crotty, 1998) and was underpinned by the Vygotskian concept of zone of proximal development (ZPD) (Vygotsky, 2011). As a result, collaborative inquiry work was used in response to students' learning needs and to enable scaffolding of students' learning in astronomy (Ashman & Elkins, 2009; Pietarian et al., 2018; Vygotsky, 2011) emerging as a result of shared knowledge construction (van Aalst, 2009). Shared knowledge construction is a collaborative creation of concepts based on the prior knowledge of the participants and through their interactions (van Aalst, 2009). Shared knowledge construction involves cognitive processes such as questioning, interpreting, evaluating, critiquing, testing and sharing information, that result in a prior-knowledge restructuring, leading to a deeper understanding of a concept (van Aalst, 2009).

Using technology to engage EFL students

Accepting that the 'laboratory' nature of science lessons can make students question the relevance of science learning (Aikenhead, 1998; Zellner, 2018), the pilot integrated technology to draw on students' creativity, experiences and worldviews to enhance the effectiveness of educational projects (Thompson & Hall, 2008; Zellner, 2018). The inclusion of technology into educational processes allows for the creation of authentic learning experiences and attainment of STEM learning objectives that were otherwise impossible (McKinnon & Geissinger, 2002; Nicholas & Ng, 2012; Zellner, 2018).

The success of any technology inclusion in learning is primarily attitude dependent. Students' attitudes toward technology depend on their valuing of it as a tool for learning, and require both scaffolding by the teacher and active engagement by the student (Ardies, De Maeyer, Gijbels & van Keulen, 2015; Rohaan, Taconis & Jochems, 2010). As a result, it is the task-design and pedagogical approaches that turn technology into a powerful educational tool (Bower, 2008; Ng, 2011) where teachers use technology to not only teach the content, but also to develop digital literacies and new skills in the process of learning.

One approach to integrating technology in the classroom is through digital storytelling. Digital storytelling is information communication technology (ICT) mediated storytelling; it entered the education domain in the early 1990s and since then has obtained many dedicated supporters (Papadopoulou & Vlachos, 2014). Digital storytelling is a pedagogical approach to video making that strongly emphasises student centred narratives, and it is an approach that has been piloted in international science education contexts, including at a specialised school for struggling First Nations students in Canada (Pirbhai-Illich, 2010; Pirbhai-Illich, Turner & Austin, 2009). However, in the area of astronomy, digital storytelling has only been introduced to American college students as an outside of class project (Zellner, 2018). As an outside of class project, Zellner's (2018) work did not involve in-class collaboration and teacher scaffolding of the video making process, that would presumably enhance students' learning when applied within the EFL context.

While the implementation of video making requires explicit teaching early on in the course it has resulted in positive outcomes for students (Morgan, 2015), including EFL students. When creating videos, EFL students are encouraged to undergo 'self-auditing' and develop as reflective and autonomous learners, raising their awareness of areas for improvement in their language, content knowledge and learning skills (Chubko, 2017; Laycock & Stephenson, 1993; Papadopoulou & Vlachos, 2014; Sprague & Pixley, 2008). Importantly for EFL students, video making gives the students control over the task as they can exercise creativity in relating task content to their interests and past experiences to enhance their confidence (Ashman & Elkins, 2009; Jang, 2008; Tarnopolsky, 2004). This is important for EFL learners, for whom the language of instruction is not only new, but it is also a new form of discourse (Menken, 2003; Schleppegrell, 2007).

Project background

This pilot is an extension of the *Journey Through Space and Time (JTST)* educational project, which aims to improve students' astronomy content knowledge through science inquiry (McKinnon, 2013). As a social constructivist designed program that has been taught in Australia with primary and junior high school students, *JTST* was used as the core resource for the development of this pilot interdisciplinary STEM course, entitled *The Secrets of the Stars*. The original *JTST* course used astronomy to facilitate deep integration of STEM areas into an engaging course for students from diverse socio-cultural backgrounds (McKinnon & Geissinger, 2002), which made it appropriate to adapt specifically for EFL learners. The original *JTST* learning package also provides support that relates to participating teachers' content knowledge and enables them to create the context for scientific inquiry that engages students in active learning (McKinnon, 2013), which aligned with the constructivist epistemology used in the design of the pilot course.

However, the original *JTST* educational package (McKinnon, 2013) did not have a specific focus on technology. Based on the extant literature on the role of video making as a pedagogical tool for enhancing EFL/ESL student learning (Papadopoulou & Vlachos, 2014; Pirbhai-Illich, 2010; Pirbhai-Illich, Turner & Austin, 2009) this pilot included digital storytelling as a core activity for EFL students to demonstrate their understanding of astronomy content knowledge during the course.

Course design

The *Secrets of the Stars* course consisted of nine 150-minute lessons. The course was conducted in English and contained three stages: raising awareness of the importance of collaboration; introducing the video making and the video editing software, and making videos about the astronomy concepts. The first stage set the context for making videos about the astronomy concepts. This stage introduced the research participants to the idea that each person's view of the world is unique and provides them with a certain view of a situation. This part of the course included team building, and attempted to facilitate students' understanding that different points of view are valuable for gaining a better understanding of a situation. The second stage introduced students to the work with a camera (*iPad mini*) and simple video editing software (*iMovie*) to create a sample introductory video, in order to scaffold technology skill development. During the final stage of the course students were involved in astronomy inquiry and created videos about their emerging understanding of the astronomy phenomena in small groups. Throughout the video making components of the course, students also had access to a shared *iCloud* location and to *DropBox* but they could not access social media. Data were securely stored on the *iPads*, which remained with the instructor. The mobile version of *Stellarium*, a planetarium software package, was also installed on the students' *iPads* to enable them to investigate celestial objects and their movement while students were within the classroom setting.

Method

Study design

The pilot astronomy course *The Secrets of the Stars* was conducted in Bishkek in December 2017 and facilitated by the first author. This pilot study employed mixed methods within a quasi-experimental longitudinal design (Shadish, Cook & Campbell, 2002), Type II Case Study (Yin, 2014) to measure the effect of the course on students' content knowledge and learning. Quantitative data collected through *The Astronomy Diagnostic Test* (McKinnon, 2013) were complemented by qualitative data collected through participant observation (Patton, 2002), which included both video recordings of the lessons as well as audio recording of collaborative work during each lesson as the students made their videos in small groups. Each component allowed for the triangulation of results, and were used to enhance research validity and to gain a better understanding of the concepts under investigation.

Instructor

The course instructor has an expertise in teaching English to the speakers of other languages (TESOL), but it was the first time she had applied English to teaching astronomy using digital storytelling. Thus, prior to commencing this study, she participated in professional learning for delivering the *JTST* educational package (McKinnon, 2013), and sought advice and coaching on how to make videos from specialists in this area and from her past students, to whom she had assigned making videos about grammar as a home task in her past courses (Chubko, 2017). To better understand the process of video making, the instructor prepared an introductory video about herself and her pathway towards becoming a teacher of astronomy. This allowed her to identify the stages of the video making task and the approximate amount of scaffolding required for each of the stages.

Participants

Participation in this pilot astronomy course was offered as an incentive for students already attending English language courses and was advertised as an opportunity to practice English and test their ability to apply the acquired English language skills in a real life context. To be enrolled in this astronomy course, students had to be aged between 10 and 16 years, be non-native speakers of English and possess an intermediate level of proficiency in English (level B1-B2) that classifies the student as an 'Independent user' (Council of Europe, 2018). At this level, students are expected to understand the key points of various types of verbal and written input, and make meaningful contributions to classroom interactions (Council of Europe, 2018).

Nine graduates from the intermediate level English language extracurricular university-based courses for teenagers were recruited for the research. The real names of the participants are substituted with pseudonyms to protect their anonymity. Overall, there were five male participants: Chyngyz, Manas, Sanjar and Stas (all aged 12 years), as well as Talant (aged 15 years). There were four female participants: Kamilla (12 years), Diana (14 years), as well as Elena and Sayora (both 15 years). All of the participants spoke Russian as their first language (L1). Five of the participants had Kyrgyz ethnicity (Chyngyz, Manas, Talant, Sanjar & Kamilla); therefore, they were native speakers of Kyrgyz language, while other students were learning Kyrgyz at school as a second language. English was a foreign language for all the participants. Additionally, some of the research participants were learning at least one other foreign language, for example French, at school. Thus, to a greater or lesser extent, all of the research participants were multilingual EFL students.

Ethics committee approval

This research project was granted approval from the University's Human Research Ethics Committee (HREC), Project ID: 15076, approval date 8 March 2017.

Data collection tools

The *Astronomy Diagnostic Test* (Northern Hemisphere Edition) is included in the *JTST* resource pack (McKinnon, 2013). The test was administered in English and there were no translations to other languages. The ADT contains 15 items targeted at the elementary-school curriculum. The first four questions were aimed at students' understanding of the key astronomy concepts such as day and night, the movements of the Sun, the Earth and the Moon, phases of the Moon, and the seasons. To answer these questions, students were asked to draw a diagram and provide a written explanation for their drawing. The remaining 11 questions were multiple choice questions, which also required students to provide the reasoning for their choice as a written response.

Other data collection tools were video recordings of the lessons and audio recordings of students' group interactions in the process of video making. At the end of the course students were asked to provide anonymous written feedback about their course experience.

Data analysis

The students' gain in astronomy content knowledge acquired during the course was measured by comparing the matched pre- and post- ADT outcomes in *SPSS*. For the first four questions of the ADT (McKinnon, 2013) students were given one point for the correct drawing and one point for the correct explanation or half a point for a close to correct explanation. For the multiple choice questions, students could score one point if they had both the correct answer and the correct explanation. If only the answer or only the explanation was correct students were given a half point. Additionally, ADT test results were interpreted in the context of students' attendance and the number of accomplished video projects.

The video and audio recordings from the nine lessons were transcribed by the first author. Table 1 shows symbols used during the transcription.

Table 1: Transcription symbols

Symbol	Meaning
[Translation]	Translation of students' utterances from Russian to English
(action)	Students' actions during the utterance
XXX	Unclear utterance

Discourse analysis (Schiffrin, 1994) of the transcripts of students' classroom interactions during the course was used to explore how EFL students engaged with learning science through the astronomy extracurricular course enhanced with collaborative video making.

Results and discussion

Astronomy content knowledge

Only six out of nine research participants managed to complete both the pre- and post-ADT. The results of these six students are summarised in Table 2.

The ADT gain score was calculated by subtracting the pre-test score from the post-test score. Thus, gain score of the six research participants showed that all of the students, except Sayora whose results remained the same, improved their astronomy content knowledge (Table 2). However, Sayora had missed two lessons (Table 3) and participated in the production of only one astronomy content knowledge related video (Table 4). The highest progress in ADT performance was achieved by Manas and Elena. Manas had a 100% attendance (Table 3) and participated in the highest number of video making projects (Table 4).

Table 2: Astronomy Diagnostic Test outcomes

Student	Pre-test	Post-test	Change
Diana	5.5	8.5	+3
Elena	2.5	9.0	+6.5
Manas	2.5	9.5	+6.5
Sayora	5.0	5.0	0
Stas	5.5	6.5	+1
Talant	3.5	5.5	+2

Notably, only the last four video projects presented in Table 4 were linked to astronomy inquiry based on the *JTST* resources (McKinnon, 2013). The first two videos, *Team introduction* and *Beliefs and assumptions about astronomy*, were aimed at setting up the context of the course and encouraging students' to share their background knowledge. Additionally, the role of the first video was to allow students to explore the process of video making so that later on in the course they could focus on the content rather than on the technical aspects of digital storytelling.

Table 3: Astronomy course attendance

Student	L1	L2	L3	L4	L5	L6	L7	L8	L9	Total days
Diana	1	0	0	1	1	1	1	0	1	6
Elena	1	1	0	0.5	0	0	1	1	1	5.5
Manas	1	1	1	1	1	1	1	1	1	9
Sayora	1	1	1	1	0	0	1	1	1	7
Stas	1	1	0	1	1	1	1	1	1	8
Talant	1	1	1	1	0	1	1	1	1	8

It is interesting that even though Elena missed three and a half lessons (Table 3) and participated in only one astronomy content knowledge related video, she demonstrated the same high ADT gain score as Manas (Table 2).

The Cohen's d effect size for this sample was calculated from the difference between pre- and post-ADT scores, where $d = 1.9$. This means that there was a significant change in students' astronomy content knowledge gained as a result of being engaged in the astronomy course enhanced with video-making. However, the non-randomised, small sample size restricts these findings exclusively to this population within this particular case.

Table 4: Participation in video making projects

	Lead-in videos		Astronomy inquiry-based videos				
	Team intro-duction	Beliefs and assumptions about astronomy	Our Solar System (scale model)	A planet of your choice	Moon phases	Seasons	Total
Student	V1	V2	V3	V4	V5	V6	
Diana	1	1	1	0	0	0	3
Elena	1	1	0	0	0	1	3
Manas	1	1	1	1	0	1	5
Sayora	1	1	0	0	0	1	3
Stas	1	1	1	0	1	0	4
Talant	1	1	0	0	1	0	3

Additionally, even though overall there is a positive correlation between the course attendance, video making and the ADT results, it was unexpected that the student with the highest attendance rate and the greatest number of produced videos, Manas (Tables 3 and 4) showed the same ADT gain score as a student with the lowest attendance rate, Elena (Table 3), and lowest participation rate in video making projects (Table 4). Hence, more research is needed that will control for other factors, including a student's ability and interest in astronomy.

Knowledge construction through collaborative video-making

The discourse analysis of the course revealed 43 types of classroom interactions the research participants were engaged in during the *Secrets of the stars* course (Appendix A). During the course students were observed to work most frequently in groups of three, however, sometimes they chose to work individually, in pairs, or in a group of four. To explore how EFL students approached the knowledge construction while being engaged in the integrated astronomy course enhanced with the video making process, the following section further presents the discourse analysis of four students' (Diana, Chyngyz, Manas and Stas) classroom interactions during lesson five of the pilot course. The lesson-by-lesson outline of the course and types of student interactions involved is presented in Appendix B.

The duration of lesson five was 150 minutes. This lesson was purposely selected to be included in this paper as it captures most of the stages of EFL students' engagement in the video making process (Appendix B).

During the first seven minutes on the lesson, there was no connection to the Internet. While the teacher attempted to connect the iPads to the Internet, Diana, Chyngyz and Manas were talking in Russian (their L1) about their eyesight issues and computer games. This off-task talk was triggered by Chyngyz, who asked if he could try Diana's glasses.

From the beginning, Stas sat apart from the other students to work on his video project about the Sun that he started on the previous lesson. After seven minutes and 45 seconds of the lesson Stas finished his task. At about the same time Manas and Chyngyz decided to work as a team to complete the video project about Saturn that Manas started on the previous lesson. Manas took their team's *iPad* and briefed Chyngyz on the progress of the work done and what else needed to be done to complete their video. Excerpt 1 illustrates how these students were involved in a construction of shared knowledge to work out how to make a voice recording in the *iMovie* program.

Excerpt 1

0082	Chyngyz	А как здесь записать голос? [How can I record the voice in here?]	
0083	Manas	Голос [Voice]	(Manas looks at the *iPad*, then takes *iPad* from Chyngyz)
0102	Manas	Нашел где наш голос записывается [I found how to record our voice]	
0103	Manas	Да, ты говоришь [Yes, your turn to talk]	
0104	Chyngyz	А как его поворачивать? [How to turn it?]	(Chyngyz takes *iPad*)
0105	Manas	Просто ты говори громко XXX [Just speak loudly]	
0106	Manas	Просто нажимаешь, голос записывается, XXX громкий не громкий [You just press the button and the voice is recorded, XXX loud not loud]	
0107	Manas	Нажимаешь вот эту кнопку [You press this button]	
0108			(Chyngyz takes *iPad* and talks to the bottom of it)
0109	Chyngyz	XXX где будет? [Where will XXX be]	
0110	Manas	Вот здесь [Here]	
0111	Chyngyz	Video	(Manas laughs)
0112	Manas	Просто прямо в него говори [Simply talk right to it]	
0113	Chyngyz	Где тут? [To where?]	

The teacher gives instructions and advises students on the class agenda only on the ninth minute of the lesson. For the next 40 minutes of the lesson, Manas and Chyngyz were completing their video about Saturn, while Diana and Stas were exploring the concept of scaling and making scale models of the planets. Since Diana and Stas missed the previous lesson about the scale models, the teacher (T) joined them to scaffold their understanding of a scale and to guide them in calculating the scale for their model planets (Excerpt 2).

Excerpt 2

0228	T	XXX we need to scale it.
0229	Stas	Model?
0230	T	XXX, so how big could be the Sun so that we can place it to this room, and all our planets XXX
0231	Diana	about XXX

0232	T	Ok, but if you make it XXX
0233	Diana	It's too small.
0234	T	Why?
0235	Diana	Because Sun is the largest model of our Solar System for now. So, if we do models, our planets will much smaller than sun. So, we can't do such planets, if we, our Sun, our Sun's diameter was about 10 centimetres.
0236	T	Yes, what we did, we assumed that Sun is XXX. Just 1 metre.
0237	Diana	It's one metre, right?
0238	T	And then we calculated that XXX. So, how can we calculate this XXX? How we calculate the scale? We need to have an equation, right? So, you take the diameter of the Sun and you assume that it is 1500 millimetres. Yeh?
0239	Diana	Yeh.

As a part of the group work process that empowers students with control over their work (Papadopoulou & Vlachos, 2014), boys were often observed to be involved in role allocation exemplified in Excerpt 3.

Excerpt 3

0488	Chyngyz	You should turn on
0489	Manas	You should XXX
0490	Manas	I was writing, you should

Eventually Manas and Chyngyz decided to use notes about Saturn made by Manas on a previous lesson as a basis for their video. Manas believed that he had almost completed the video and they just needed to record the voice (Excerpt 4).

Excerpt 4

0142	Chyngyz	XXX	(Wants to search information from the Internet)
0143	Manas	Да не надо, там все есть. Вот это прочитаем. [You don’t need it, we have everything there. We’ll read this]	(Manas shows Chyngyz his notes from the previous lesson)
0144	Chyngyz	А точно. [Ah, right]	

In practice; however, recording a voice appeared to be quite time consuming. Manas had seven and Chyngyz had nine attempts at the voice recording before they were more or less satisfied with the result, and they made numerous revisions to their initial script they had written on the whiteboard (Excerpt 5) that illustrate how video making creates a platform for self- and peer-editing (Chubko, 2017; Laycock & Stephenson, 1993; Sprague & Pixley, 2008).

As is illustrated through students’ actions in Excerpt 5, engagement of EFL students with writing in English was achieved by turning the video projects into an expected ‘product’ rather than by assigning students to complete a writing task. Thus, writing in a foreign language became an authentic process-driven activity that encouraged students to produce multiple forms of writing involving both self and peer editing (Chubko, 2017; Laycock & Stephenson, 1993; Sprague & Pixley, 2008). That way, students also escaped the pressure of accomplishing a big piece of writing on their own, although eventually they collaboratively produced a big piece of refined, peer-edited, explorative writing in English. Thus, students gained control over their learning and responsibility for their knowledge that they shared with others (Ng, 2011; Peters, 2000).

Excerpt 5

0459			(Manas stops recording and laughs. Chyngyz points at the text on the board with his hand with a questioning expression.)
0460	Diana	Uranus isn't blue, Neptune is blue	
0461			(Chyngyz rapidly corrects the text on the board. Manas starts recording.)
0462	Diana	Красный не вкусно пахнет [Red has unpleasant smell]	
0463			(Manas stops recording due to another mistake in the text on the board. Chyngyz corrects the text. Manas laughs.)

At the next stage of the lesson the teacher suggested that all four students combine their knowledge and focus on making a collaborative video about the scale model of the Solar System, in order to consolidate their understanding about making scale models and about the structure of the Solar System.

Brainstorming was attempted in a few stages. After the first round of the brainstorming time allocated by the teacher, the students attempted to start storyboarding. Shortly, they came to the realisation that during the brainstorming they did not generate any information about their topic and only agreed upon a sequence of how they would present the information, and therefore they decided to return to the brainstorming stage. However, they were confused about what information to present. Observing this, the teacher decided to intervene and asked students to think of how they would present this concept of the scale model of the Solar System to a younger brother or sister. It appeared that all of the students had younger siblings and could relate to this task. As a result, the students became authentically engaged (McKinnon & Geissinger, 2002; Nicholas & Ng, 2012; Zellner, 2018) in making the assigned video (Excerpt 6). By the end of the lesson, the students had a completed script and footage for their video imported into *iMovie*. They completed their work by allocating turns and rehearsing the reading of their parts of the text.

Excerpt 6 is consistent with the shared knowledge construction observed throughout the course and suggests that a safe and supportive environment is required for the acquisition of the content knowledge, as this environment supported students to share and clarify their understanding of the scientific phenomena, as well as to expose gaps in their knowledge.

Excerpt 6

0772	T	Ok, let's listen to everybody's story. How will you explain to your brother?	
0773	Diana	Я думаю он бы понял, если бы я начала говорить про отношения [I think he would understand if I started talking about relations.]	
0774			(Students laugh)
0775	T	Relations?	
0776	Diana	Нет, отношение в смысле [No, relations in the meaning of.]	
0777	T	You talk about size?	
0778	Diana	Yeh!	
0779	T	Ah! You will talk about ratio	
0783	T	Cool! How will you explain to your little brother or sister? I'll just say: proportion, what divide for what, what multiply for what, Manas?	
0784	Diana	You don't need all of these calculations?	

This learning experience was richer in comparison to the acquisition of terminology that happens when reading course material or listening to a lecture (Aikenhead & Huntley, 1999; Rezai, Derakhshan & Bagherkazemi, 2011). This research suggests that participation in authentic inquiry tasks (Prairie & Buckleitner, 2005) is even further enhanced by participation in shared-knowledge construction in order to advance conceptual understandings. Additionally, the exploration of lesson five confirms that technology does not need to be the primary focus of the lesson in order to be effective; rather it can create the context for students' collaboration and knowledge construction (Bower, 2008; Ng, 2011; Pirbhai-Illich, 2010; Pirbhai-Illich, Turner & Austin, 2009; Zellner, 2018) if students have a positive attitude towards its integration in the learning experience (Ardies et al., 2015).

Students' course feedback

At the end of the course, students completed a course feedback questionnaire anonymously They were asked to answer five questions, summarised in Table 5. Students' answers are presented verbatim.

Table 5: Participants' feedback about astronomy course

Prompt question	Student feedback
1. What was the best part of the course for you?	Making videos, I escaped of my shyness. When together with Stas and Talant do phases of moon. It was when we were making the models of planets. When we was doing little planet. Making videos, and after projects in the team. When we were modelling planets of the Solar System.

2. What was your favourite lesson? Why?	When we made photos colourful. It was funny. When we together working. I liked every lesson. Because it's very interesting for other and also for me. When we argued that the earth casts a shadow on the moon. About faces of the moon. Lesson about planets of the Solar System, because it was interesting.
3. What would you like to change?	More speaking. I became speak English. Nothing. Make lessons a shorter. Make lessons a little shorter. I would like to learn more about astronomy, and less editing video.
4. What else would you like to learn?	About other thing in astronomy. About space it's very interesting. All about Astronomy. More about stars. Something about other systems. Everything about astronomy.
5. Will you recommend this course to your friends? Why?	Yea. Because it's interesting and informative. My friends in course Astronomy very fun. Yes. Because it's interesting lesson. Yes. Because we must know more about space. Yes. I will. And I already recommended it on my Instagram account. Yes, of course. These courses were interesting. In my opinion, think that I know more now about Solar System than in the past.

Students' feedback reflects the overall course satisfaction as all of them were eager to recommend this course to their friends, and some of them reported already doing so. Moreover, two of the students stated that making videos was the best part of the course, while the remaining students liked the activities that were related to making videos, such as making scale models of the planets that indirectly supported their interest in the video making. However, one of the responses indicated that the student did not see a benefit of digital storytelling for learning astronomy. One of the key course drawbacks reported by the students was timing of the course. Students asked for shorter lessons, and were also interested in having more opportunities to speak during the course. Importantly, all of the students expressed an interest in further learning of astronomy.

Limitations

This pilot astronomy course was introduced during the last three weeks of December 2017, immediately before the winter holidays. It did not appear to be the best timing for introducing the extracurricular activities, because students were preoccupied with their end of term exams and preparations for the New Year celebration. This is one reason for the small number of students who enrolled in this course. Moreover, the winter season in Kyrgyzstan is usually accompanied by colds and influenza, resulting in most students missing one or more classes. Only Manas managed to attend all of the lessons. These gaps in attendance influenced the number of videos in which each of the participants managed to take part and impacted on the completion of the *Astronomy Diagnostic Test*.

Additionally, there was only one video camera for capturing the classroom interactions, which resulted in some gaps in the recording. An additional issue was multiple simultaneous speakers and high amount of noise in the audio recordings during group interactions, which resulted in some gaps in the final transcription of the students' interactions.

Conclusion

The results of this small-scale pilot case study revealed a positive trend in the Kyrgyzstani EFL students' astronomy content knowledge development in English, as a result of being engaged in a nine-day extracurricular STEM integrated astronomy course in English enhanced with the video making teaching approach. Particularly, the results show that the students participating in the course significantly improved their ADT score. Results also showed that students with more completed video projects tended to have a better post-ADT score compared to the students with lower numbers of completed video projects. However, there is an inconsistency in this trend within the pilot sample. In this pilot, Elena, who completed the least videos, attained the equal highest score in the post-ADT as Manas, who had the greatest number of completed videos. This suggests that there are other factors at play beyond the role of video making, and further research of the video making process including measuring other variables that may affect EFL students' astronomy content knowledge acquisition is required.

Since the video making technique was contextualised in this pilot study, it could not be isolated as a stand-alone factor that affected students' astronomy content knowledge acquisition. However, the discourse analysis of the lessons revealed that the inclusion of video making as a core integrated astronomy course component encouraged EFL students' engagement with writing in English, and revising their understanding of past or newly acquired scientific concepts. Therefore, it could be concluded that the primary feature of engaging EFL students in the video making process is the creation of an authentic and safe context for shared knowledge construction that serves to scaffold concept acquisition. Therefore, the focus of future research will be on the impact of digital storytelling on EFL students' subject disciplinary literacy development in English.

Overall, this pilot study showcases digital storytelling as a favourable context for integrating STEM with the learning needs of EFL students, with all parts of the lessons from narrative development to video making and editing supporting student learning. More research to further explore this trend is recommended. Further research will target a larger sample of students to generate sufficient quantitative data to analyse these trends using more rigorous inferential statistical techniques. Moreover, close attention will be devoted to examining the language related outcomes of engaging EFL students in digital storytelling projects incorporated in a STEM-A course.

Implications

Even though technology is becoming enmeshed in education, especially in STEM areas, many teachers may still feel cautious about teaching with unfamiliar technology. This case study is an example of a technology enhanced course where technology is used as a vehicle for content acquisition and does not require high technical proficiency or significant effort in its integration on behalf of a teacher. Students demonstrated peer teaching in the use of the technology throughout the course and it became a tool through which deep learning occurred, evidenced in the discourse analysis and the change in ADT scores. Being engaged in shared knowledge construction, students' themselves problem-solved any issues with the technology through trials and error. By creating an authentic context for digital storytelling and equipping EFL students with technology there was positive shared knowledge construction that enhanced EFL students' learning in the course, giving initial evidence of how technology can be used as a teaching strategy to engage EFL students in STEM learning. Even though this research uses astronomy as a context for integrating STEM areas, other disciplines such as geology or biology enhanced with digital storytelling could also serve as a vehicle for integrating STEM areas and engaging students from diverse socio-cultural backgrounds in authentic learning experiences and shared knowledge construction targeted at a deeper conceptual understanding.

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Appendix A: Engagement rating of the activities in the *Secrets of the Stars* course

Type of classroom interaction			
1	Answering questions	23	Revising
2	Calculating	24	Sharing hypotheses
3	Comparing	25	Shooting
4	Drawing from nature	26	Video making
5	Filling a questionnaire	27	Voice recording
6	Filling the table	28	Discussing
7	Finding the moon and constellations with *Stellarium* software	29	Editing
8	Interviewing	30	Arguing against students' models
9	Rehearsing	31	Making conclusions
10	Guided Internet search	32	Storyboarding
11	Making table/ diagram	33	Following the manual
12	Creating a story	34	Checking answers
13	Making inferences	35	Choosing the scale
14	Reading instructions	36	Completing the puzzle
15	Role allocation	37	Exploring
16	Modelling	38	Listening
17	Presenting	39	Scriptwriting
18	Writing a hypothesis	40	Viewing
19	Brainstorming	41	Report writing
20	Arranging scale models	42	Writing the test
21	Commenting	43	Learn to use *iMovie*
22	Preparing for shooting		

Appendix B: Lesson-by-lesson outline of students' interactions during the eight lessons of the astronomy course *Secrets of the Stars*

L#	Task	Time	Interaction type
L1	Astronomy Diagnostic Test (ADT)	50 min	Reading instructions Writing the test
	Elephant puzzle	12 min	Explore Write the observation report Presentation Listening to presentations Comments Completing the puzzle Making conclusions
	Introductory video	3 min	Viewing
		2 min	Discussion
	PPT about the video making stages	5 min	Making inferences Viewing and listening
	Video about storyboarding	5 min	Viewing Discussion Revision

	Video-making	65 min	Brainstorming Scriptwriting Storyboarding Role allocation Shooting
L2	Listening to the Western Australian Noongar peoples' creation story (Nannup, 2015)	46 min	Listening Discussion Listening Discussion Listening Discussion
	Interview	13 min	Role allocation Interview
	Visual representation of the answers	25 min	Brainstorming Discussion Making table/ diagram
	Video making	60 min	Learn to use *iMovie* Brainstorming Storyboarding Shooting Editing
L3	Video about Solar System	13 min	Viewing Discussion
	Guided Internet search	47 min	Searching information from Internet to fill the table
	Pulling data together	23 min	Filling the table Viewing the table Discussion
	Making scale models	67 min	Choose the scale Calculation Making models
L4	Completing projects from other lessons	70 min	Video making Scale models Brainstorming Storyboarding
	Making colour images	60 min	Follow the manual to process images
	Completing projects from the previous lesson	50 min	Video making Scale models
L5	Video making	106 min	Storyboarding Brainstorming Preparing for shooting Brainstorming Arranging the scale model Brainstorming Scriptwriting/ storyboarding Role allocation Rehearsing Shooting Editing Voice recording

L6	Completing projects from the previous lesson	30-35 min	Video making Scale models
	Learning about constellations	21 min	Creating a Story of a constellation Presenting a story Listening to the story Comparing with the existing constellation
	Video about the Emu Constellation	5 min	Viewing Discussion
	Moon phases inquiry	71 min	Finding the moon and constellations with *Stellarium* software Writing a Hypothesis Sharing hypotheses Modelling Moon phases Filling a questionnaire about Moon phases Checking answers
	Video about astronomy colour photography	10 min	Viewing Discussion
L7	Revision of Scale Models	37 min	Revision of the concept Drawing a bottle from nature Scale model of the distance between the Earth and the Moon
	Day and night inquiry	72 min	Moon phases revision Making inferences Modelling Presentation Comparing models Modelling Filling a questionnaire Making inferences Modelling Presenting Arguing against students' models Modelling
	Video making	21 min	Brainstorming Answering questions
L8	Sample Video	10 min	Viewing
	Developing video evaluation rubric	37 min	Brainstorming Discussion
	Video-making	103 min	Brainstorming Scriptwriting Shooting Editing
L9	Astronomy Diagnostic Test Watching videos		

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