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Digital storytelling as an astronomy disciplinary literacy enhancement approach for adolescent Kyrgyzstani EFL students

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ABSTRACT

This research explored the impact of a digital storytelling (DST) video-making intervention in an astronomy course (STEM-A) on EFL students' STEM-A disciplinary literacy acquisition in English. The research was motivated by the increased significance of English as an international language of STEM instruction and addressed the transition between discourses encountered by students learning STEM in a foreign language.

The study was designed and implemented as a mixed methods four-cycle action research with multiple Case Study, multiple-probe quasi-experimental design. In the first cycle, the researcher transitioned from a teacher of English to speakers of other languages (TESOL) to a teacher of astronomy in English in a non-English speaking country and developed the STEM-A course. In cycle two, the STEM-A course was piloted and refined based on the learning outcomes of non-native English speakers (EFL) and an analysis of the interactive patterns amongst students who completed the course. In cycle three, the course sequence was further refined to support development of disciplinary literacy for EFL students. In the fourth and final cycle, the most profound course sequence was implemented in a different school context to explore transferability and the potential for the course to support learning in a community of practice.

Cycle one was documented after the researcher reflected on her observations of the participants, based on analysis of the video recordings of lessons and the course programs designed for the study. In cycles two, three and four, data were collected from written responses to pre- and post-Astronomy Diagnostic Tests (ADT), coded against SOLO taxonomy (Biggs & Collis, 1982), and analysed using repeated measures ANOVA. Discourse analysis was used to identify communicative functions used by students in the course to qualitatively analyse their growth in disciplinary literacy.

Overall, this research contributed to the body of knowledge on integrating technology in STEM education by exemplifying the process of STEM-A course design and refinement. The results indicated a positive effect of the DST intervention on EFL students' STEM-A disciplinary literacy acquisition in English. Additionally, the study revealed classroom interaction patterns that enhanced EFL students' disciplinary literacy development, as the DST teaching approach established a collaborative learning environment that led to shared knowledge construction and students' engagement in authentic learning inquiry. This approach allowed to bridge the gap between EFL and non-EFL students' disciplinary literacy in STEM subjects.

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

(i) Incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education;

(ii) Contain any material previously published or written by another person except where due reference is made in the text; or

(iii) Contain any defamatory material.

I also grant permission for the library at Edith Cowan University to make duplicate copies of my thesis as required.

Signed..................... [redacted] ....Date...25.02.2020.....................

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Thank you!

PUBLICATIONS, SUBMISSIONS AND PRESENTATIONS ARISING FROM THIS DOCTORAL RESEARCH

Table 1 *Peer Reviewed Journal Articles in this Doctoral Research*

Article No	Title	Date	Journal
1	Engaging adolescent Kyrgyzstani EFL students in digital storytelling projects about astronomy.	9.10.2019	Issues in Educational Research
2	SOLO taxonomy as EFL students' disciplinary literacy evaluation tool in technology-enhanced integrated astronomy course.	12.12.2019	Language Testing in Asia
3	Digital storytelling as a disciplinary literacy enhancement tool for EFL students.	In review	Education Technology Research and Development
4	Digital storytelling as a trigger for EFL students' disciplinary literacy development: Establishing communities of practice in an astronomy context.	Draft	

Table 2 *Research Conference and Presentations Originating from this Doctoral Research*

Year	Forum	Theme
2019	5th International Conference on Second Language Studies, Turkey, Istanbul.	SOLO taxonomy as EFL students' disciplinary literacy enhancement tool in technology-enhanced astronomy.
2019	3MT Presentation, Edith Cowan University, Perth.	EFL students' astronomy disciplinary literacy development through digital storytelling.
2019	Fogarty Foundation Postgraduate Research Forum, University of Western Australia, Perth.	EFL students' astronomy disciplinary literacy development through digital storytelling.

CONTRIBUTION STATEMENT

This thesis contains four co-authored papers that were published and/or submitted to peer-reviewed journals. I was the first author on all these papers and my contribution to each is specified below.

Paper One

As co-authors of the paper titled: "Learning Astronomy Through Video-Making: Engaging Adolescent Kyrgyzstani EFL Students in Digital Storytelling Projects about Astronomy" we confirm that Nadezhda Chubko made the following contribution:

1. Conceptualisation of the paper
2. Literature revision and interpretation
3. Extraction and analysis of data for review
4. Intervention design, implementation and management
5. Data collection and analysis
6. Manuscript writing and editing

Furthermore, we agree to inclusion of the paper in this doctoral research.

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Dr Julia Morris

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Associate Professor Geoffrey Lummis

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Professor David McKinnon

Paper Two

As co-authors of the paper titled: “SOLO Taxonomy as EFL Students’ Disciplinary Literacy Evaluation Tool in Technology-Enhanced Integrated Astronomy Course” we confirm that Nadezhda Chubko made the following contribution:

1. Conceptualisation of the paper
2. Literature revision and interpretation
3. Extraction and analysis of data for review
4. Data collection and analysis
5. Manuscript writing and editing

Furthermore, we agree to inclusion of the paper in this doctoral research.

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Professor David McKinnon

Paper Three

As co-authors of the paper titled: “Digital Storytelling as a Disciplinary Literacy Enhancement Tool for EFL Students” we confirm that Nadezhda Chubko made the following contribution:

1. Conceptualisation of the paper
2. Literature revision and interpretation
3. Extraction and analysis of data for review
4. Intervention design, implementation, and management
5. Data collection and analysis
6. Manuscript writing and editing

Furthermore, we agree to the inclusion of the paper in this doctoral research.

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Professor David McKinnon

Paper Four

As co-authors of the paper entitled: "Digital Storytelling as a Trigger for EFL Students' Disciplinary Literacy Development: Establishing Communities of Practice in Astronomy Context" we confirm that Nadezhda Chubko made the following contribution:

1. Conceptualisation of the paper
2. Literature revision and interpretation
3. Extraction and analysis of data for review
4. Intervention design, implementation, and management
5. Data collection, interpretation, and analysis
6. Manuscript writing and editing

Furthermore, we agree to the inclusion of the paper in this doctoral research.

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Dr Eileen Slater

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Dr Julia Morris

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LIST OF ABBREVIATIONS

ADT	Astronomy Diagnostic Test
CoP	Community of Practice
CSS	Cultural Sky Stories
DST	Digital Storytelling
EFL	English as a Foreign Language
ESL	English as a Second Language
ISS	Indigenous Sky Stories
JTST	Journey through Space and Time
L1	First Language (mother tongue)
L2	Second Language (additional spoken language)
SOLO	Structure of Observed Learning Outcome
STEM	Science, Technology, Engineering and Mathematics
STEM-A	Astronomy course that integrates science, technology, engineering and mathematics content
TESOL	Teaching English to Speakers of Other Languages

GLOSSARY

Astronomy Diagnostic Test (ADT)	The ADT is included in the Journey through Space and Time (JTST) resource package. It evaluates students' understanding of astronomy phenomena and aims to reveal students' alternative theories. There are both Southern and Northern Hemisphere editions, and 15- and 11-question versions. In all versions, the first four questions ask students to draw a picture to explain a particular astronomy phenomenon and the reasoning for their answer. The remaining questions ask students to select their answer from multiple choice options and write the reasoning for their answers (McKinnon, 2013).
Community of Practice (CoP)	A CoP is a group of people engaged in a shared activity or practice, resulting in the construction of shared knowledge to resolve issues arising within the community (Wenger, McDermott, & Snyder, 2002).
Digital storytelling/video-making (DST)	DST is a multi-literacy practice of storytelling mediated by digital tools (Angay-Crowder, Choi, & Yi, 2013; Castaneda, Shen, Claros Berlioz, 2018; Ohler, 2013; Rubino, Barberies, & Malnati, 2018; Teehan, 2006; Zellner, 2018). In this doctoral thesis, DST refers to students' engagement in the video- making process that contains a combination of brainstorming, scriptwriting, storyboarding, (video) shooting, and editing.
Disciplinary literacy	The ability to engage in discursive practice as an expert in a discipline or an apprentice, for example an engineer, a dancer, or a basketball player (Collin, 2014).
English as a Foreign Language (EFL) learners	This defines non-native speakers of English who learn English in the context of a non-English speaking country (Allen, 2017).
English as a Second Language (ESL) learners	An umbrella term used to define non-native speakers of English (Allen, 2017).
Indigenous Sky Stories/ Cultural Sky Stories (ISS/CSS)	ISS or CSS is an Australia-wide educational project that uses astronomy as a context for learning STEM areas. This project acknowledges students' diversity and creates an opportunity to explore local Indigenous and western scientific perspectives (Ruddell, Danaia, & McKinnon, 2016). The JTST resource package (McKinnon, 2013) is a key component of this project.

Inquiry learning	An authentic learning process during which students are engaged in planning, organising, enacting and reflecting on experiences that facilitate their understanding of a concept (Hammerman, 2006; Pietarian, Vauras, Laakkonen, Kinnunen, & Volet, 2018; Prairie & Buckleitner, 2005).
Journey Through Space and Time (JTST)	A resource package for primary and junior high school teachers aimed at improving students' astronomy content knowledge through science inquiry (McKinnon, 2013). It is implemented in both ISS and CSS.
Science disciplinary literacy	A student's ability "to communicate their learning, to synthesize ideas across texts and across groups of people, to express new ideas, and to question and challenge ideas held dear in the discipline and in broader spheres" (Moje, 2008, p. 99).
Secrets of the Stars	An extracurricular STEM-A course designed as a part of this doctoral thesis. It is based on a digital storytelling teaching approach (Chubko, Morris, McKinnon, Slater, & Lummis, 2019) and uses the JTST (McKinnon, 2013) as a key resource package.
SOLO taxonomy	An instrument for measuring development of students' reasoning. The SOLO taxonomy assesses the structural patterns students use to organise their ideas – it does not measure the factual correctness of their answers (Biggs & Collis, 1982).
Shooting (a video)	Using a camera for making video footage, such as photos and videos.
STEM	Integrated knowledge from four disciplines: science, technology, engineering and mathematics (Frey, 2018).
STEM-A	An acronym to describe the STEM course designed for this research, specifically contextualised to astronomy content.

NOTES ON STYLE

Throughout the thesis I have followed APA 6th edition referencing conventions and employed Australian English, consistent with Edith Cowan University policy guidelines at the time of writing. The four publications, listed as “published” or “in review”, reflect the referencing styles of the specific journals and their English language preferences. The conventions used are explained in the connecting statements between chapters. The format of all four publications have been adjusted to meet Edith Cowan University requirements; however, all components of the papers are also presented in their original publication format, which means that all the references and appendices included in the original papers follow each paper in the thesis. Due to this, some references are repeated throughout the thesis.

References for the glossary have been incorporated into the reference list following chapter one. The appendices at the end of the thesis contain supplementary material not included in the papers. The first three chapters of the thesis use first person narration as they describe the researcher’s journey and the background to the study.

In this thesis, the terms *digital storytelling* and *video-making* are used interchangeably and have the same meaning. The language and people living in Kyrgyzstan are referred to as *Kyrgyz*; in all other cases, the adjective *Kyrgyzstani* is used to refer to Kyrgyzstan.

PREFACE

The following preface was written as a 400-word story for "Performing the Word Writing Retreat" conducted in Queenscliff, Victoria, in November 2018. For one week, 20 PhD students from several Australian universities lived together in a historical guest house, where we were encouraged to collaboratively explore the art of writing. The workshop required the participants to select an idea critical to their research project and transform it into a short story. We were challenged to "use the directness of a novelist, the choosiness of a poet, the rhythm of a musician, and the colour of an artist", and to be mysterious, experiential, compassionate, entertaining, and above all, transforming. The resulting 425-word story below captures the central theme of my thesis in a somewhat creative way.

Have you ever noticed that in different countries the sky looks different? I will never forget the bulky grey sky with its solid dark blue clouds hanging over my motherland, the Ukraine. It is so different from the light bluish-white, almost cloudless sky of my home country, Kyrgyzstan. The sky in Kazakhstan, where I did my Masters, always seemed happier to me, brighter, even though Kazakhstan is only a four-hour drive from Kyrgyzstan. After visiting other countries on conferences, I can say that the sky in the Philippines is very different from the sky in Poland. Eventually, I discovered the sky of Western Australia. It is so deep blue that if you keep staring at it for a while, you get to notice how it is drowning in the Indian Ocean. It was Perth's night sky that triggered my curiosity for teaching astronomy.

But are we really seeing a different sky when we look at it in different countries? In reality, it is our perspective that makes us assume we are seeing different things and creates the divide in our knowledge that makes us believe our perceptions are right and others' are not. We always look at things through the prism of our

subjective experiences. Importantly, every new experience affects our perspective. When someone disagrees about the colour of the sky, it does not mean that one of you is wrong. Up until this moment, your perspectives were simply based on different life experiences.

This is an essential idea for science teachers. I encourage teachers to understand that science education should not enforce certain types of knowledge and experiences, but rather create opportunities to explore as many points of view as possible. That is why I believe that the ultimate goal in teaching science is for students to acquire scientific literacy, scaffolded through teaching tools that allow them to share experiences and see scientific problems from different perspectives. This is particularly relevant for teaching multicultural students with diverse language backgrounds. Hence, my thesis extends the Australian astronomy educational project, Journey through Space and Time (McKinnon, 2013), to encourage Kyrgyzstani students to learn astronomy and develop their English skills through making videos.

This is the story of an English language teacher from Kyrgyzstan who tried to make sense of the language of science upon coming to Western Australia and meeting a supervisor who was passionate about astronomy and pedagogy. My curiosity combined with my supervisor's passions ultimately emerged as an integrated extracurricular course in astronomy with a specific focus on English language learners' scientific literacy development.

CHAPTER ONE: INTRODUCTION

This chapter provides an overview of the study. It commences with the author's personal context and inspiration for the research, followed by the rationale for the study and identification of the research problem. The following sections explain the scope, purpose and significance of the research before concluding with a brief overview of the thesis structure.

Personal Context

My motivation to pursue action research was born out of a desire for justice in education and making education accessible around the globe, so that all children have an opportunity to develop their talents and reach their highest possible potential, regardless of cultural and language backgrounds. Therefore, my project was about breaking down the invisible walls of formality and ambiguity in education to allow all students to engage in a meaningful learning process. My aim was to create an educational environment that engages students in scientific inquiry, while at the same time, providing ongoing development of their disciplinary literacy. I attempted to bridge the gap between classroom discourse and students' home languages to enable effective communication about subject content, since literacy development has been shown to facilitate other learning capabilities and improve students' overall performance in subjects like science.

My personal experience of attending school as a Russian-Ukrainian bilingual in a post-Soviet Union country prompted this research. Prior to obtaining independence, my home country Kyrgyzstan, my motherland Ukraine and 13 other countries were under Russian rule. Before joining the Soviet Union, each of these countries had a rich cultural heritage. Despite the Soviet Union expecting us to believe that we were comrades and communists, in reality we were colonised countries, deprived of our unique cultures and ability to practice our religions. We were treated like a working class without identity,

and as part of Soviet policy, were strongly encouraged to abandon our native languages (Kononenko & Holowinsky, 2001).

Even though Kyrgyz people had their own language (Kyrgyz), it was not recognised by the Soviet Union as an official language of school instruction. Moreover, Kyrgyz was only taught as a second, and even as a foreign language, because it was hardly used outside the classroom. At the same time, the Russian language became the language of school instruction and remains so today, 28 years after Kyrgyzstan proclaimed its independence.

Russian was not my first language; at home we spoke Ukrainian. My parents strived to preserve our native language within the family, and as a result, the language transition from home to school was rather challenging for me. My family expected that the school would teach me Russian and chose not to interfere. It is worth noting here that Russian and Ukrainian people are similar in appearance and therefore it is difficult to differentiate them physically. Given that my Ukrainian identity was not obvious, the school expected my parents to help me with learning and did not devote any special attention to my Russian literacy development.

Despite my growing fluency in spoken Russian, I was conscious of an increasing language gap. The discrepancy between my home and school languages was magnified by my exposure to academic language. The outcome was predictable, as fluency in academic language is not innate, even when it is a mother tongue (L1), and requires active and targeted cultivation (Grandinetti, Langellotti, & Ting, 2013; Hinde, Popp, Jimenez-Silva, & Dorn, 2011). Upon entering secondary school, the linguistic challenges became overwhelming when the complicated linguistic patterns of a foreign language were accompanied by difficult terminology. This made abstract science instruction meaningless and completely detached from my life experiences.

Sadly, my learning experiences as a “non-identified” bilingual child struggling to decipher the language of school instruction is not unique and echo the learning experiences of many immigrant children worldwide. Upon entering mainstream education, these students have to make a significant transition from their “comfort zone” to the standardised academic environment (Menken, 2013). In addition, they face the challenge of adapting to a new system of values that sometimes contradicts their cultural heritage.

When I qualified as a teacher of English to speakers of other languages (TESOL), I noticed that this job title was regularly included in the Australian skilled immigration occupation list (Department of Home Affairs, 2019), a list issued by the Australian government to attract a workforce from other countries to compensate for a shortage of qualified professionals in Australia. After some research, I was fascinated by the cultural and linguistic diversity of learners in Australia (Australian Institute for Teaching and School Leadership, 2014). However, the most striking revelation was the alignment of my learning experiences in post-Soviet Kyrgyzstan with those of Aboriginal and Torres Strait Islander children in the Australian education system.

I assumed that marginalisation of these students stemmed partially from the lack of acknowledgement that Aboriginal English is not the same as Standard Australian English (Beresford & Partington, 2003; Peltier, 2010; Price, 2012). Even though children may sound fluent in their spoken English, they still need support with their learning. This revelation inspired me to pursue my PhD journey in Australia, where I transitioned from teaching English to speakers of other languages to teaching astronomy to English language learners.

However, once the PhD proposal was accepted and ethics approval was received from the university, it took almost nine months for the Department of

Education to review my application to work with Aboriginal students. Coupled with a restricted timeframe within which the proposal, ethics clearance, investigation, publication and thesis production had to occur (maximum four years of full-time study), my supervisors and I decided to move the location of the study to Kyrgyzstan, where native Kyrgyz students experienced similar language problems as their Aboriginal Australian counterparts. The decision to move the study was made almost one year before final approval was granted by education officials in the Australian school system.

Rationale

Over the past century there has been a dramatic increase in demand for science, technology, engineering and mathematics (STEM) professionals. However, the dominant role of English as the language of STEM subjects (Foyewa, 2015) has become an additional limiting factor for culturally and linguistically diverse student populations who are already historically marginalised from learning STEM disciplines (Mark, 2016). This marginalisation is evident in the reported divide in science disciplinary literacy between native and non-native (EFL/ESL) speakers of English in Australia (Department of the Prime Minister and Cabinet, 2018; Fleckenstein, Leucht, Pant, & Köller, 2016; The Nation’s Report Card, 2015).

The literacy divide has been exacerbated by the increased diversity in student populations internationally. Within the last decade, English-speaking countries experienced a noticeable increase in international students (Taylor, 2014; Williams, 2011). For example, in Australia, the number of international students increased 11% from 2018 to 2019 (Department of Education, 2019). In the USA, the number of students enrolled in public schools and classified as English language learners grew by 7%, from

4.3 million students in 2005 to 4.6 million students in 2015 (National Center for Educational Statistics, 2019).

Additionally, in non-English speaking countries such as China, the number of foreign students increased by 86%, from 238,184 students in 2009 to 442,773 students in 2016 (Statista, 2018). In post-Soviet central Asian countries, such as Kazakhstan and Kyrgyzstan, multilingualism is a common phenomenon due to the diversity of ethnic groups populating these countries (Ahn, 2016; Kuzembayeva, Karimsakova, & Kupenova, 2018).

Furthermore, there is a gap between the needs of the job market and students' desire to learn STEM subjects at school (Christodoulou, 2017; Holmes, Gore, Smith, & Lloyd, 2018), largely attributable to curriculum design and delivery that do not provide engaging authentic learning (Christodoulou, 2017; Goldspink & Foster, 2013; Holmes, Gore, Smith, & Lloyd, 2018; Silova, 2009). Thus, growing internationalisation has seen the role of English in STEM careers and STEM education deteriorate, creating a need for research in this area.

Statement of the Problem

Some of the main complications of learning STEM disciplines are the complexity of the language of instruction and a lack of authentic learning experiences (González-Howard & McNeill, 2016; González-Howard, McNeill, Marco-Bujosa, & Proctor, 2017; Grandinetti, Langellotti, & Ting, 2013; Stevenson, 2015; Zhang, 2016). Upon entering the science classroom, learners encounter a new form of discourse that is often dissimilar from their lived experiences, and thus they find it difficult to follow or understand the language of instruction.

STEM disciplines are already perceived by students as challenging (Arya, Hiebert, & Pearson, 2011; Braden, Wassell, Scantlebury & Grover, 2016; Meyer &

Crawford, 2015; Varelas, Pieper, Arsenault, Pappas, & Keblawe-Shamah, 2014), and the growing significance of English as the international language of instruction (Foyewa, 2015) has compelled more countries to teach STEM in English. For example, in response to global economic challenges (Nazarbayev, 2016), Kazakhstan was the first central Asian country to acknowledge the importance of teaching STEM disciplines in English in its 2016-2019 strategic plan (OECD, 2018). However, a new form of discourse in a foreign language makes the transition particularly difficult for STEM students (Menken, 2013).

Unlike Kazakhstan, the Kyrgyzstani system of education retained Russian as a language of school instruction. In 2018, the number of teaching hours allocated to STEM disciplines was reduced by the Ministry of Education. Among the most notable consequences of this reduction was the removal of astronomy as a standalone discipline from the school curriculum (Usenaliev, 2018). Accordingly, this study was aimed at supporting EFL learners in their STEM education to counteract the issues outlined above.

Scope and Significance of the Research

In light of the recent changes in the Kygyzstani curriculum (Usenaliev, 2018); the increasing role of English as a global language of science communication (Foyewa, 2015); and the cultural and linguistic diversity of Kyrgyzstani students (Ahn, 2016); the scope of the research reported here was narrowed to literacy development of STEM disciplines. In particular, the focus was on Kyrgyzstani EFL students learning astronomy in English. This research explored the capacity of digital storytelling (DST) as a teaching strategy to bridge the disciplinary literacy gap between native and non-native speakers of English (EFL) learning astronomy (STEM-A) in English.

The current study is significant because it contributes to the understanding of Kyrgyzstani EFL students’ STEM-A disciplinary literacy development. It offers

instructional strategies for teachers faced with increasing cultural and linguistic diversity among their student cohorts. In addition, it addresses the growing demand for English-speaking STEM professionals by supporting EFL students' disciplinary literacy in English. Finally, this research provides a practical guide for teachers who wish to integrate DST with an active inquiry teaching approach or engage students from diverse cultural and language backgrounds in learning astronomy in English. Importantly, this pedagogical approach can also be adapted to scaffold the learning of bilingual and multilingual students in other subject areas.

Overview of Thesis Structure

This dissertation has been formatted as a thesis with publication and includes four articles in various stages of publication. Each article is a separate case study focused on answering specific research questions. Collectively, these articles reflect the action-research process as the overarching methodological approach adopted for this doctoral research.

Chapter 1 described the researcher's reasons for undertaking the research, outlined the rationale and research problem, and explained the scope and significance of the research.

Chapter 2 provides methodological information about this mixed methods action research. It establishes a theoretical framework, explains the overarching action research approach used, and outlines the conceptual model for the study before concluding with the research questions.

Chapter 3 describes the first cycle of the action research and the researcher's shift from a TESOL teacher to an astronomy teacher. It also discusses the design of the astronomy course for the research.

Chapter 4 presents the second cycle of the action research project and contains two journal articles. The first article was the pilot study, focused on the overall course evaluation and identification of key trends to inform the subsequent research. The second article presents the data obtained from the pilot study, with a particular focus on establishing the construct of disciplinary literacy within astronomy (STEM-A) and validating the use of the Structure of Observed Learning Outcome (SOLO) as an instrument for measuring STEM-A literacy development.

Chapter 5 contains the third article, which represents the third cycle of the action research and trials the different course sequences in order to identify the teaching approach that most contributes to EFL students' STEM-A disciplinary literacy development. In this study, an Australian sample provided the baseline data for monitoring the STEM-A literacy gap between EFL and non-EFL students.

Chapter 6 contains the fourth article and describes the final cycle of this action study. This article is a discourse analysis of the classroom interactions amongst the EFL group of students that demonstrated the largest gain in their literacy development as a result of their participation in the astronomy DST intervention.

Chapter 7, the final chapter, discusses the limitations of the research and provides recommendations and suggestions for future research. The chapter also presents the overall conclusions from the research. This is followed by references and appendices, the latter containing sample information letters and informed consent forms (Appendices A-I), the Astronomy Diagnostic Test in English and in Russian (Appendices J and K), astronomy course programs (Appendices L-Q), links to original publications, proof of submissions (R-T) and other supplementary materials.

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CHAPTER TWO: METHODOLOGY

Chapter 2 establishes the theoretical framework for this mixed methods study by extending the Australia-wide *Indigenous Sky Stories* (ISS) educational project for primary and secondary school contexts (Ruddell, McKinnon & Danaia, 2017). The ISS is based on a social constructivist approach, designed to not only improve the science learning outcomes of Australians who speak English as their first language, but also ESL students, including Aboriginal and Torres Strait Islander students. The fact that the ISS project acknowledges student diversity encouraged me to apply its educational resources to my own research with culturally and linguistically diverse Kyrgyzstani students learning English as a foreign language. To enhance these EFL students' disciplinary literacy in English, I linked their STEM-A learning experiences to making videos about their inquiries into astronomical phenomena.

In this chapter, I contextualise the chosen overarching methodology to explain the connection between the four individual papers presented in the thesis. The chapter commences with an outline of the theoretical considerations underpinning the research, followed by the research context. It then presents a description of the methodology and conceptual model for the study, followed by a table summarising the research questions, data collection and data analysis strategies, risks to validity and ethical considerations. In addition, I use authentic examples from my research to illustrate conceptual links with the overarching methodology.

Theoretical Considerations

This section presents the theoretical considerations that served as the context for this research. The study is positioned within a constructivist epistemology (Coghlan & Brydon-Miller, 2014; Crotty, 1998; Frey, 2018; Given, 2008) and underpinned by the Vygotskian concept of the Zone of Proximal Development (ZPD) (Kozulin, 2011; Vygotsky, 1935,

1962), underscoring the importance of aligning both teaching methods and resources with students' learning needs and styles (Ashman & Elkins, 2009; Kozulin, 2011; Vygotsky, 1935, 1962). The theoretical framework is supported by recent research that highlighted misleading interpretations of the performance gap between EFL/ESL and non-EFL/ESL students (Dąbrowska, 2019; Hulstijn, 2019). The following sections elaborate the listed below nine key factors that position the theoretical backdrop of the study:

1. The transition from a constructivist to a social constructivist epistemology;
2. Cultural and language diversity among the students;
3. Learning dichotomy between EFL and non-EFL students;
4. Instructional design;
5. Information overload and problem solving;
6. Cooperative learning and Communities of Practice;
7. Discourse as a form of social practice;
8. Empowerment through digital technology; and
9. Digital storytelling as a mechanism for shared knowledge construction.

The Transition from Constructivist to Social Constructivist Epistemology

To situate STEM-A education within the research context (Fitzgerald, McKinnon, Danaia, Cutts, Salimpour, & Sacchi, 2018) this section outlines the evolution of epistemological ideas, from constructivism, prompted by Piaget's research on children's development, to social constructivist theories introduced by Vygotsky (Coghlan & Brydon-Miller, 2014). As a theory of learning, constructivism reflects a belief that knowledge is actively constructed by humans and is context specific (Burkhalter, 2016; Coghlan & Brydon-Miller, 2014).

Twenty-first century researchers, educators and policy makers recognised the need for a greater focus on the social nature of knowledge construction, sparking the evolution of

constructivism to social constructivism (Given, 2008). Adopted by educators in the late 20th and early 21st centuries (Charles, 2018; Given, 2008; Kozulin, 2011; Vygotsky, 1935, 1962), Vygotsky's Zone of Proximal Development is the essence of social constructivism, as it explains the development of a child's knowledge as the outcome of interactions with more knowledgeable peers (Burkhalter, 2016; Charles, 2018; Given, 2008; Kozulin, 2011; Vygotsky, 1935, 1962). Importantly, interactions with more knowledgeable peers and adults facilitate language acquisition within culturally-specific knowledge construction. Through these interactions, a child learns language and constructs knowledge specific to his or her culture (Charles, 2018; Given, 2008).

Therefore, the major argument for adopting a social-constructivist framework for this research is its recognition of individuals' prior knowledge. This is in contrast to other learning theories, such as objectivism, that position the learner as a passive recipient of knowledge (Coghlan & Brydon-Miller, 2014; Dennick, 2016; Frey, 2018). Given that new knowledge is always filtered through our prior knowledge, our own worldview or model of reality represents a reflection of our life experiences (Dennick, 2016). Exposure to different life experiences and interactions with others allow us to enhance and sometimes even alter our worldviews. According to social constructivist epistemology, since our cultural and language backgrounds are acquired from our past life experiences and interactions with other people, they have a vital impact on newly acquired knowledge (Coghlan & Brydon-Miller, 2014; Dennick, 2016; Frey, 2018).

Moreover, social constructivism underscores the importance of active learning and engaging students in a problem-solving approach, representative of the scientific method (Dennick, 2016; Frey, 2018). Constructivism-based teaching approaches became highly recognised in science education, whereby students engage in a process of authentic problem solving that usually involves group interaction and encourages

critical thinking (Burkhalter, 2016; Frey, 2018). To promote critical evaluation of information and facilitate a deeper conceptual understanding, rather than mere rote memorisation, students need to develop an interest in certain knowledge prior to accessing already discovered and established facts (Frey, 2018).

Cultural and Language Diversity among Students

Globalisation has transformed most areas of our lives, including education (Kapur & Ghose, 2018). Besides the undeniable advantages, for example, the acceleration of information exchange that has facilitated greater general prosperity, increased literacy and enhanced women's conditions, globalisation has also brought some challenges (Kapur & Ghose, 2018). One of these is the challenge of adjusting to the rapidly changing demands of the global market. As a consequence of ongoing change, a key outcome is the need for education to facilitate students' critical thinking to cope with new, unimagined changes (Burkhalter, 2016; Kapur & Ghose, 2018).

The Learning Dichotomy between EFL and Non-EFL Students

A further challenge brought about by globalisation is the greater cultural and language diversity of students within any learning environment (Kapur & Ghose, 2018; Taylor, 2014; Williams, 2011). One of the reported effects of increased diversity among students is the learning dichotomy between non-native (EFL/ESL) and native speakers of English (non- EFL/ESL). However, this dichotomy is misleading, as globalisation also coined the notion of World Englishes to eliminate a single norm for Standard English (Higgins, 2003) and allow for significant variation in the English language proficiency of native speakers of English, as well as variation in the language proficiency of non-native speakers of English (Dąbrowska, 2019; Higgins, 2003; Hulstijn, 2019).

A social constructivist epistemology suggests that language is socially constructed and therefore EFL/ESL and non-EFL/ESL students have equal opportunities to attain English

proficiency if they are exposed to appropriate learning experiences (Charles, 2018; Coghlan & Brydon-Miller, 2014; Gee, 1992; Given, 2008; Higgins, 2003). For example, differences have been observed in individual adult native English speakers' abilities to acquire various morphological, syntactical, and even simple grammatical structures, such as passive voice (Dąbrowska, 2019).

The difference between highly educated individuals outperforming less educated individuals was usually correlated with level of education when other factors, such as misinterpretation of a task or uncooperativeness, were controlled (Dąbrowska, 2019). In a study comparing ESL and non-ESL adult learners' task performances (Dąbrowska, 2019), native speakers of English as a group gained better scores for grammar comprehension, vocabulary and collocations. However, in contrast to previous research, there was significant variability in individual performance in both groups that caused considerable overlap between ESL and non-ESL participants (Dąbrowska, 2019). These results support the hypothesis that EFL/ESL learners can attain English language proficiency to match native English speakers and suggest that the choice of instructional design is important as it establishes a context for this learning to occur.

Instructional Design

Given that level of education is a predictor of ESL and non-ESL students' task performance (Dąbrowska, 2019; Sherer & Shea, 2011), underperformance of both EFL/ESL and native speakers of English can, by extension, be linked to unsatisfactory instructional design. In acknowledging the constructivist nature of learning, it is important for tasks to allow for connections between students' school lives and their practical everyday experiences (González-Howard & McNeill, 2016; González-Howard, McNeill, Marco-Bujosa, & Proctor, 2017; Grandinetti, Langellotti, & Ting, 2013; Jang, 2008; Regmi, 2017; Stevenson, 2015; Zhang, 2016). Research suggests that students' engagement with meaningful authentic tasks

that establish links between their school and broader everyday experiences facilitates deeper conceptual understanding (Hammerman, 2006; Pietarian, Vauras, Laakkonen, Kinnunen, & Volet, 2018; Prairie & Buckleitner, 2005).

Information Overload and Problem Solving

Another challenge is information overload (Kapur & Ghose, 2018). The problems we face today are complex and often require collaborative solutions (Sun, Liu, Luo, Wu, & Shi, 2017; Wenger, McDermott, & Snyder, 2002). Consequently, it is not feasible for students to have access to diverse instrumental knowledge or specific skills for every potential situation they will encounter (Nygrén, 2019). In this context, knowledge is often perceived as being contextually disruptive, transient and continuously evolving (McDougall, Readman & Wilkinson, 2018; Nygrén, 2019; Wenger, McDermott, & Snyder, 2002).

In such scenarios, educational models built on knowledge transmission become redundant, and greater value is placed on collective or collaborative learning that encourages multiple perspectives and flexibility through shared problem-based learning experiences (Charles, 2018; Given, 2008; Lin & Chan 2018; Vuopala, Näykki, Isohätälä, & Järvelä, 2019). In this way, language establishes connections between participants within particular sociocultural settings (Charles, 2018; Given, 2008), with shared language mediating students' perceptions of social interactions linked to practical contexts. During the process of engagement, shared discussions generate cognitive transformations through authentic problem-solving activities (Allison, 2011; Lin & Chan, 2018). Therefore, language and literacy function as a form of generative social practice with the potential for multiple cognitive manifestations (Chomsky, 2006), testable as STEM-A discourse (Spires, Kerkhoff, Graham, Thompson, & Lee, 2018). However, this learning and engagement is dependent on participants' language-related

capacity and the actions that emerge as a result of engagement in certain sociocultural STEM learning contexts (Gee, 1992; Lin & Chan, 2018).

Communities of Practice and Cooperative Learning

Communities of Practice (CoPs) are proven social formations that facilitate cooperative learning and promote knowledge stewardship (Wenger, McDermott, & Snyder, 2002). Despite variability in CoPs, they all embed three core elements: a domain of knowledge; an organisational structure made up of a group of people engaged with the domain; and shared practice that establishes a connection between the group of people and their domain of knowledge (Kaethler, 2019; Lin & Chan, 2018; Pyrko, Dörfler, Eden, 2016; Wenger, McDermott, & Snyder, 2002). In many long-standing CoPs, interactions have generated most of the common knowledge existing to date. For example, any scientific body of knowledge is the outcome of professional collegial interactions that frequently include disagreement. In scientific communities, the significance of facts and validity of theories are reliant on rigorous challenge and testing to establish the verisimilitude of scientific knowledge (Kaethler, 2019; Niiniluoto, 2018; Popper, 1972; Pyrko, Dörfler, Eden, 2016; Wenger, McDermott, & Snyder, 2002).

The domain of knowledge or learning within a CoP structure is a matter of belonging. The key to bestowing power on a CoPs is providing a safe learning environment, as the interactions of members are voluntary and must encourage trust and mutual respect (Kaethler, 2019; Pyrko, Dörfler, Eden, 2016; Wenger, McDermott, & Snyder, 2002). Diversity among members enriches the learning experiences and allows participants to create common knowledge that establishes a solid foundation for effective collaboration. The knowledge domain reflects authentic issues commonly experienced by the community members, and therefore generates sincere interest in participation that guides the community’s practices. Periodically hot topics generate fresh energy, sustain CoP

engagement and trigger the evolution of practices to adjust members' shared knowledge in light of new circumstances (Kaethler, 2019; Pyrko, Dörfler, Eden, 2016; Wenger, McDermott, & Snyder, 2002).

In terms of their organisational structure, CoPs usually comprise a core group of participants who actively contribute to interactions and peripheral members who rarely contribute to interactions within their CoPs (Kaethler, 2019; Niiniluoto, 2018; Pyrko, Dörfler, Eden, 2016; Wenger, McDermott, & Snyder, 2002). Due to their lack of activity, peripheral members may seem to be passive observers. Generally, peripheral members are less competent in the CoP's domain of knowledge and prefer to learn from more knowledgeable peers (Kozulin, 2011; Vygotsky, 1935, 1962; Wenger, McDermott, & Snyder, 2002). When peripheral members attain sufficient competence in the domain of knowledge, they may transit to the core group or even organise their own CoPs. In this way, CoP activities follow the apprenticeship model of engaging all participants in shared knowledge construction (Kaethler, 2019; Niiniluoto, 2018; Pyrko, Dörfler, & Eden, 2016; Wenger, McDermott, & Snyder, 2002).

Shared practice constructs a discourse for effective communication of ideas among CoP members (Kaethler, 2019; Pyrko, Dörfler, & Eden, 2016; Wenger, McDermott, & Snyder, 2002). In CoPs, shared knowledge construction is usually coupled with development of CoP- specific discourse (Povolná, 2015) as an optimisation mechanism, since it creates interaction shortcuts, for example, context-specific terminology or specialised sentence structures. While this facilitates shared knowledge construction within a CoP, domain-specific discourse can become a major learning obstacle outside a CoP. Returning to the example of a scientific community of practice, science disciplinary discourse is recognised as one of the major obstacles to learning science, because it uses disciplinary conventions that can hardly be understood by

individuals outside the context (Bahar & Polat, 2007; Schleppegrell, 2007; Spires et al., 2018).

Discourse as a Form of Social Practice

Discourse is a form of social practice with multiple manifestations that result in individual literacy acquisition depending on participants' engagement in sociocultural contexts where actions are mediated by language (Gee, 1992; Kimanen & Poulter, 2018). Literacy functions as a source of encoding and decoding building blocks of language and fosters development of many other skills (Heckman, 2005; Snyder, 2008; Spires et al., 2018). In a modern context, literacy also refers to the ability to use a range of technologies to facilitate active learning and places the learner at the centre of the educational process (Allison, 2011; Reynolds, 2016; Scull & Lo Bianco, 2008).

Empowerment through Digital Technology

Technology empowers learners with autonomy and gives them responsibility for selecting and processing information (Ng, 2011; O'Byrne, Stone & White, 2018; Peters, 2000). At the same time, technology enables connections between learners in a CoP, regardless of physical location or time of day (Kaethler, 2019; Pyrko, Dörfler, & Eden, 2016; Wenger, McDermott, & Snyder, 2002). Integrated into a learning context, technology will enrich teaching practices by sharing, collaborating and networking, as well as enhance students' interest and participation in learning the subject (Nicholas & Ng, 2012; O'Byrne, Stone, & White, 2018).

New technologies allow for interaction with educational resources and increase students' exposure to more vivid learning experiences (Ekici & Pekmezci, 2015; Gass & Mackey, 2006; Ryoo; 2015). The integration of technology with science education gives students a better understanding of scientific concepts, since multimodal representations extend the cognitive capacity of the learner's working memory (Ng, 2011). Authentic

technological processes mediate the interactions between the learner's background knowledge and course objectives, allowing students to apply learned concepts to the creation of a product (Hammerman, 2006; Hwang, Nguyen, & Pham, 2019; Liu, Huang, & Chang, 2016). Careful scaffolding that acknowledges the ZPD (Kozulin, 2011; Vygotsky, 1935, 1962) has been shown to improve the outcomes of technology-mediated learning processes (Ashman & Elkins, 2009).

Digital Storytelling as a Mechanism for Shared Knowledge Construction

CoPs have specific mechanisms for sharing knowledge. One of the most powerful is storytelling, because it encourages people to perform activities that they would like to tell stories about in the future (Wenger, McDermott, & Snyder, 2002). Integrated with technology, digital storytelling (DST) or video-making is an achievable, meaningful task (Ashman & Elkins, 2009; Ohler, 2013; Teehan, 2006; Zellner, 2018) that creates a context for students to embed their culture into learning and enables them to construct shared knowledge (Burkhalter, 2016; Teehan, 2006). Hence, engaging students in video-making about particular concepts within a discipline could facilitate the establishment of a CoP.

In this study, DST became a shared practice, whereby the students who engaged in video-making formed an organisational structure and the discourse constructed in the process of making the video became the domain of knowledge. Consequently, DST created an opportunity for contextualised discourse, and with careful guidance was able to trigger and maintain students' disciplinary literacy development and stimulate their interest in engaging with science, technology, engineering and mathematics through a STEM-A learning experience (Bell, Lewenstein, Shouse, & Feder, 2009; Spires et al., 2018).

Summary of Theoretical Considerations

To summarise the key theoretical considerations discussed in this section and illustrate the importance of task design within a social constructivist epistemology, I created the diagram in Figure 2.1 to represent disciplinary literacy development within a diverse classroom context. The figure depicts the cooperative learning process in which each student enriches the shared learning pool with their varied home discourses.

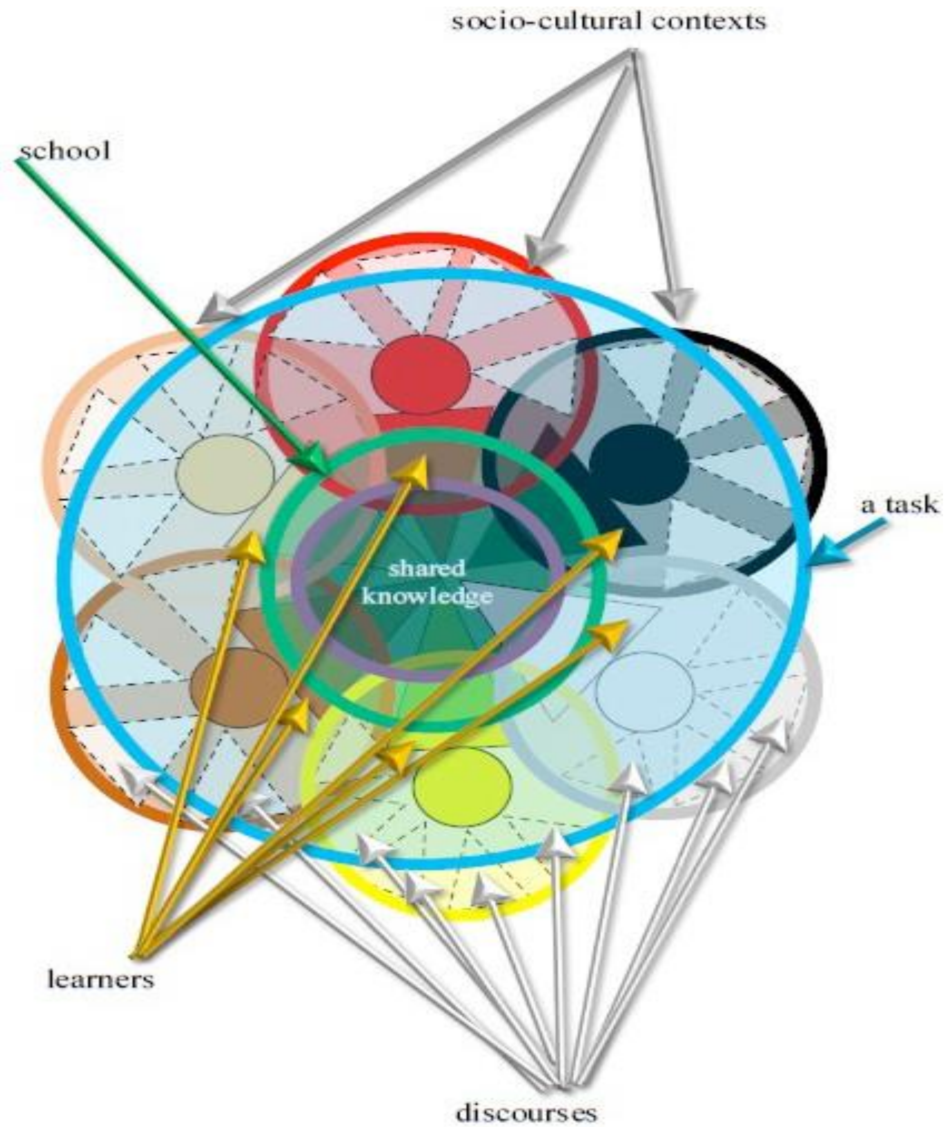

Figure 2.1. Cooperative Learning Model in a School Context

The circles represent the various socio-cultural contexts that students typically engage in throughout their lives. The dashed triangles represent the different discourses that students develop through engagement in different socio-cultural contexts. Therefore,

when students are engaged in a task at school that stimulates the creation of shared knowledge, they perceive new information through the filter of their background knowledge and validate it against the background knowledge of their peers (Kaethler, 2019; Kozulin, 2011; Vygotsky, 1935, 1962). The background knowledge of each individual student comprises the sum of the discourses they have acquired. As their peers might have been exposed to other socio-cultural contexts, group interactions allow for deeper conceptual understandings to emerge from their shared experiences in school-based learning tasks.

Context

This study positioned astronomy as a vehicle for integrating STEM disciplines, essential for exploring astronomical phenomena (Fitzgerald, McKinnon, Danaia, Cutts, Salimpour, & Sacchi, 2018). The teaching approach was student-centred and used technology extensively to engage students in inquiry-based learning experiences. Certain pedagogical approaches towards teaching astronomy have been shown to enhance opportunities for active inquiry (Hamm, 1992; Moyer, Hackett, & Everett, 2007) and stimulate students' comprehension of mathematics and other scientific content knowledge while also promoting literacy development (Ampartzaki & Kalogiannakis, 2016; Hamm, 1992; Krogh & Slentz, 2001; McKinnon, 2013; Razul, Powell, & MacLeod, 2015).

As a science discipline, astronomy (STEM-A) could be perceived as a difficult school subject because it involves complex mathematical calculations and requires a certain amount of knowledge of physics and chemistry, in addition to specific skills in the use of technology that pose educational challenges for both students and teachers. At the same time, it deals with intriguing phenomena, such as the reasons for day and night, moon phases, other objects in the solar system, and fascinating concepts such as black

holes, stars and galaxies, all of which have the potential to engage learners in meaningful scientific inquiry and function as a CoP knowledge domain.

Indigenous Sky Stories

The context for this research was the Australia-wide project, Indigenous Sky Stories (ISS), aimed at engaging culturally diverse student populations in authentic science inquiry (Ruddell, Danaia, & McKinnon, 2016). At the core of the ISS project is a resource package for primary and secondary school teachers, a Journey through Space and Time (JTST), based on a social constructivist teaching approach (McKinnon, 2013). The JTST project proved to engage and improve the science learning outcomes of not only Australians who spoke English as their first language, but also ESL students, including Aboriginal and Torres Strait Islander students. As discussed in the introduction, the researcher assumed that this project would also benefit Kyrgyzstani students who learn English as a foreign language.

For the purposes of this doctoral research, the original JTST package was used as the core resource for developing the interdisciplinary STEM-A course, Secrets of the Stars. The course was aimed at extending the JTST course within an EFL context. The original JTST course was enhanced using a DST teaching approach (Ohler, 2013; Teehan, 2006; Zellner, 2018) in order to support Kyrgyzstani EFL students' engagement in the STEM-A course as a means of enhancing their STEM-A disciplinary literacy in English.

Methodology

My research design was guided by Robert K. Yin's Case Study Research Design and Methods (2014). This seminal work has been the leading authority in case study research for over three decades (Hollweck, 2016). The series of case studies (Yin, 2014) presented in this doctoral thesis are bound together by an action research methodology (Efron & Ravid, 2013; Herr & Anderson, 2015; McAteer, 2013).

Action Research and Conceptual Framework

In education, action research is an inquiry undertaken with the goal of advancing personal teaching practice to enhance student learning, and therefore practice and reflection are its core components (Efron & Ravid, 2013; McAteer, 2013). The approach allows teachers to address problems related to testing language acquisition through classical experimentation with an unidentifiable number of variables that cannot always be controlled in complex social educational settings (Allwright & Bailey, 1991). For example, since participation in this study was voluntary, I did not have control over sampling procedures.

Action research helps to resolve problems at the local level (Allwright & Bailey, 1991), typically within one classroom or with a specific group of students, so that the research is contextually driven. For example, I attempted different sequences of the course in my study and adjusted the extent and types of scaffolding in each of the various research cycles.

Consistent with the cyclical nature of action research, the STEM-A course, Secrets of the Stars, was implemented in four cycles (Figure 2.2). The systematically repeated steps in each research cycle allowed for ongoing refinement based on the immediate attention given to problems that emerged in the classroom. The systematically observed interactions of past EFL students engaged in the DST process led to action being taken in each new cycle to enhance students' learning gains in the STEM-A course.

As this action research was aimed at advancing teaching practices, the first cycle entailed the researcher's transition from teaching TESOL to teaching astronomy. The second cycle involved a pilot study to evaluate the effectiveness of the newly-designed STEM-A course, Secrets of the Stars, for teaching astronomy in English to EFL

students. It was also the researcher's first exposure to teaching astronomy. The results of the pilot study identified common interaction patterns of the EFL students' engagement with video-making. It also showed that video-making created opportunities for enhancing students' STEM-A disciplinary literacy, and therefore, the pilot study served to focus the subsequent research on STEM-A disciplinary literacy development.

To gain further understanding of the STEM-A disciplinary literacy construct and the correlation between DST and STEM-A disciplinary literacy development, the data obtained from the pilot study were analysed against the Structure of the Observed Learning Outcomes (SOLO) taxonomy (Biggs & Collis, 1982; Rembach & Dison, 2016). The analysis showed a positive impact of DST on students' STEM-A disciplinary literacy development in English, and so a new cycle of action research was introduced.

In view of participants' feedback in the pilot study, the course was extended from nine to 10 days, allowing the researcher to reduce each session to two hours instead of the original two hours and 30 minutes. Another refinement was removal of the entry requirement to possess minimal English-language proficiency, to allow for enrolment of a more diverse student cohort with English proficiency ranging from basic to intermediate as defined by the Common European Framework of Reference for Languages (Council of Europe, 2018).

Finally, two sequences of the course were developed (Appendices N and O) in order to identify comparisons, since students' STEM-A disciplinary literacy development in English was measured against the SOLO scores for four questions about moon phases in the ADT (McKinnon, 2013). The first course sequence started with an introduction to the solar system and concluded with the moon phases, while the second course sequence started with the moon phases and concluded with an introduction to the solar system. Data analysis focused solely on students' responses to the four questions

about moon phases and enabled measurement of the impact of the DST intervention on groups engaged and not engaged in video-making.

After the second cycle of the action research, it was clear that the second sequence of the course (starting with the moon phases) increased EFL students' disciplinary literacy and bridged the SOLO-score gap between Australian and non-EFL students as measured by the ADT. Therefore, the final cycle of the action research adopted the second course sequence starting with an exploration of the moon phases. It was also decided to reduce the number of videos made by the students to one video on moon phases. Additionally, the location of the study changed to a Muslim school, where all the research participants derived from the same cultural background but with diverse proficiency in English. This final stage of the action research allowed the researcher to track how the DST facilitated EFL students' learning astronomy in English by establishing a CoP.

Figure 2.2 is a graphical representation of the entire action research process. The model reflects the four cycles of my transition from a TESOL teacher to a teacher of astronomy. It depicts the cycles of the DST-enhanced STEM-A course refinement that supported my transition to an astronomy teacher and shows that becoming an astronomy teacher is an ongoing process, extending beyond the scope of this research. The data obtained from the fourth cycle of the action research has the potential to inform further teaching and research cycles.

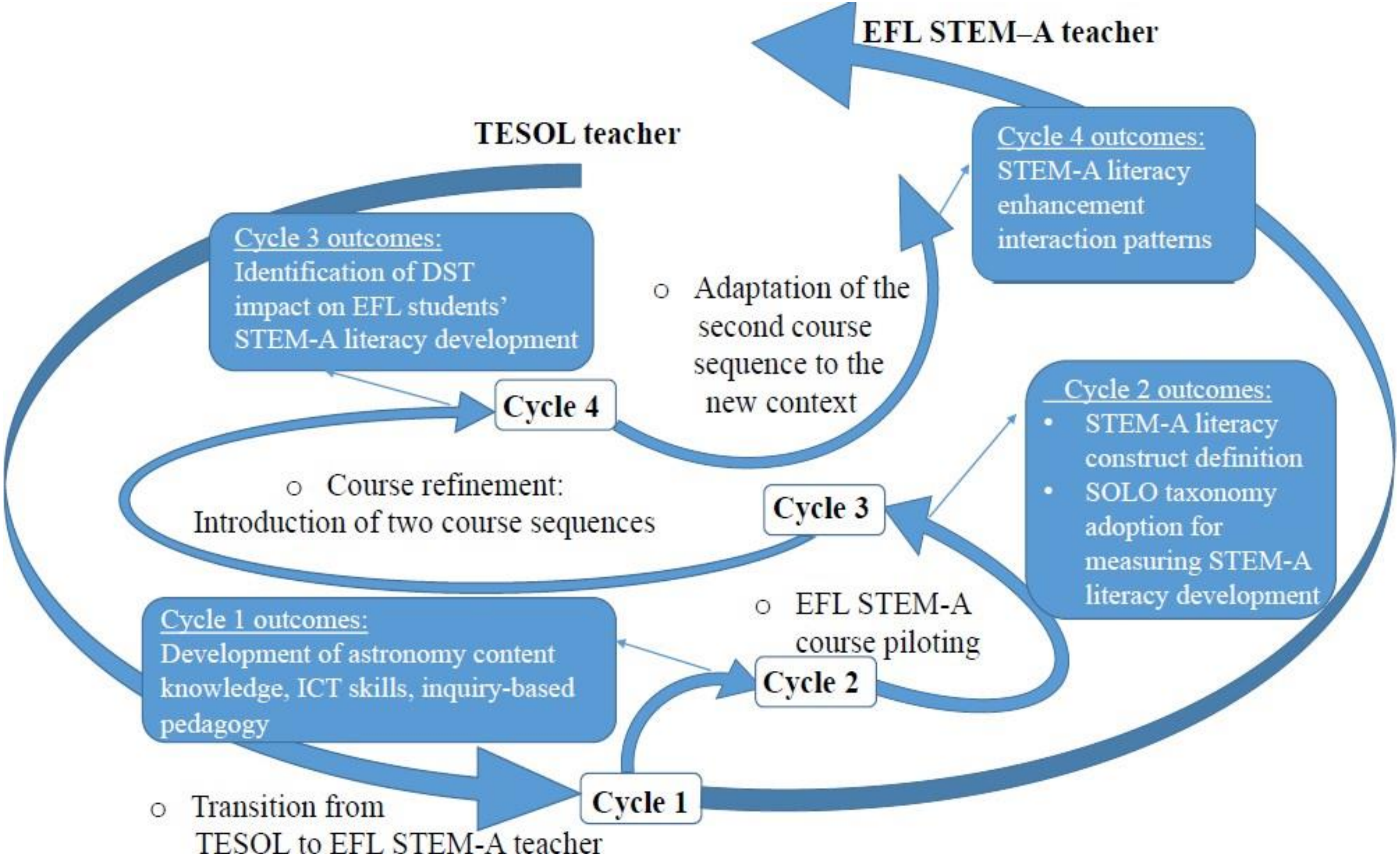

Figure 2.2. Conceptual Model of the Action Research STEM-A Intervention

Research Questions

The overarching research objective was to explore the impact of a DST intervention on EFL students' STEM-A disciplinary literacy development. Action research methodology was implemented in four cycles, each cycle guided by specific research questions. Given the thesis with publication format of this study, research questions were allocated to each of the published papers. Table 2.1 presents the four action research cycles with their corresponding publications and research questions.

Data Collection and Analysis

Data for this research were collected via the Astronomy Diagnostic Test administered at the beginning and end of the course. All classroom interactions were video recorded, and student group interactions during the video-making process were audio recorded and transcribed. Participants' written responses to the four ADT questions about moon phases were converted into SOLO scores (Biggs & Collis, 1982) by the researcher and double blind marked by at least one supervisor to establish interrater reliability.

The coding process assigned 1 to a response at the pre-conceptual level of thinking when the answer repeated a question or was irrelevant to the topic; 2 to a unistructural response when only one piece of relevant information was provided; 3 to a multistructural response when the answer contained two or more pieces of relevant information often connected with "and"; 4 to a response establishing relationships amongst the components of a concept; and 5 to a response that was related to a bigger idea or overarching theory. The absence of a response or no entry was scored as 0. The SOLO scores were then measured with repeated measures ANOVA using the Statistical Package for Social Sciences (SPSS) version 23. Discourse analysis was conducted on the transcripts of students' interactions during video making by identifying and coding commonly occurring patterns and estimating their discursive functions

Table 2.1 *Outline of Action Research Cycles*

Cycle	Publication	Research Question	Number of Participants	Age of Participants	English Proficiency	Research Site	Course Length
1		How does disciplinary literacy develop in the process of transition from TESOL to astronomy teacher?	1	30	Advanced	Kyrgyzstan and Australia	N/A
2	Article 1	**RQ 1**: How does video making in the course affect EFL students' astronomy content knowledge development? **RQ 2:** How do EFL students engage with learning science through the astronomy extracurricular course when it is enhanced with collaborative video making?	9	12-15	Pre-intermediate	Educational centre, Kyrgyzstan	9 days (2.5-hour lessons)
	Article 2	**RQ**: How does an integrated astronomy course enhanced with digital storytelling affect EFL students' disciplinary literacy development in the astronomy context?	6	12-16	Pre-intermediate	Educational centre, Kyrgyzstan	9 days (2.5-hour lessons)
3	Article 3	**RQ 1:** Does the digital storytelling approach influence the EFL students' STEM-A disciplinary literacy development in English?	30	10-16	Varied	Kyrgyzstan	10 days (2-hour lessons)
		RQ 2: If "Yes", how does this happen?	325	10-12	Non-EFL	Australia	20 hours over 10 weeks
4	Article 4	**RQ**: How do EFL students develop their astronomy disciplinary literacy in English when engaged in digital storytelling?	14	10-16	Varied	Muslim school, Kyrgyzstan	10 days (2-hour lessons)

Threats to Validity

Action research imposes certain threats to inferences about research outcomes and may reduce the certainty of causal conclusions (Check & Schutt, 2012; Shadish, Cook, & Campbell, 2002; Tomal, 2010). Therefore, to demonstrate the implausibility of alternative explanations, a range of plausible threats to validity were identified. The next section discusses these threats and the strategies used to control them, based on Shadish, Cook and Campbell's (2002) four types of validity: (a) statistical conclusion validity; (b) internal validity; (c) construct validity; and (d) external validity.

Statistical Conclusion Validity

Statistical conclusion validity is responsible for inferences about the treatment and outcome correlations and covariations (Shadish, Cook, & Campbell, 2002; Vogt, 2005). In this research, major threats to statistical conclusion validity were extraneous variances in the experimental setting and heterogeneity of units (participants). Extraneous variances in the experimental setting threat to statistical conclusion validity refers to the influence of factors other than the treatment that could artificially increase the error variance (Shadish, Cook, & Campbell, 2002). Action research design controls this threat through multiple case studies and multiple-probe design, supported by qualitative data collection.

Heterogeneity of the research participants (Check & Schutt, 2012; Shadish, Cook, & Campbell, 2002) was a major threat to statistical conclusion validity in this research due to natural variation amongst the research participants, as some students may have been more sensitive to the treatment than others. This threat was reduced by controlling the within-subject error of individual participants' pre- and post-test results as opposed to differences between participants. A higher correlation between participants' pre- and post- test results meant a greater reduction of error. The inclusion of a range of case studies in my papers mitigated against extraneous variance.

Internal Validity

Internal validity identifies a causal relationship between an observed covariation in treatment and outcome when they are manipulated or measured (Check & Schutt, 2012; Shadish, Cook, & Campbell, 2002; Tomal, 2010). Major threats to internal validity in action research are selection, history, maturation, attrition/mortality and additive and interactive effects.

Selection threats can result from variations among groups due to the non-randomised nature of action research (Shadish, Cook, & Campbell, 2002; Tomal, 2010). This was controlled by an attempt to collect as much data as possible about the participants prior to the intervention, including demographic characteristics, current knowledge of specific astronomical concepts and STEM-A disciplinary literacy proficiency in English.

History refers to events between pre- and post-tests on content knowledge that are unrelated to the intervention but could have an effect on research outcomes (Check & Schutt, 2012; Shadish, Cook, & Campbell, 2002; Tomal, 2010). Since many factors are beyond the researcher's control, a multiple-probe design using qualitative data reduced this threat.

Maturation was a threat to internal validity because the participants grew older, wiser and more experienced in the period between pre- and post-tests, potentially rendering the observed effects unattributable to the treatment (Check & Schutt, 2012; Shadish, Cook, & Campbell, 2002; Tomal, 2010). However, the relatively short course duration mitigated this risk.

Attrition/mortality was a major threat to internal validity if participants missed classes or quit the course (Check & Schutt, 2012; Shadish, Cook, & Campbell, 2002; Tomal, 2010). This was controlled by the multiple-probe design and regular observations of the research participants' interactions.

Additive and interactive effects refer to combination effects, such as selection-maturation, selection-history and selection-instrumentation that may be incorrectly taken into account in research outcomes (Shadish, Cook, & Campbell, 2002). These were controlled by the multiple-probe quasi-experimental research design supplemented by observation (Article 3).

Construct Validity

Construct validity relates to whether the research constructs accurately represent the research processes (Shadish, Cook, & Campbell, 2002). Here, major threats were construct confounding, novelty or disruption effects, and treatment diffusion.

Construct confounding arises when research involves multiple constructs (Shadish, Cook, & Campbell, 2002) and was alleviated by providing detailed descriptions of all constructs involved.

Novelty or disruption effects occur when participants have an extremely good or bad reaction to the novelty of the treatment (Shadish, Cook, & Campbell, 2002). This was controlled by the longitudinal design of the research and testing diverse groups of students.

Treatment diffusion is when participants experience the influence of conditions other than the treatment (Shadish, Cook, & Campbell, 2002) and was controlled by the longitudinal multiple-probe design of the study.

External Validity

External validity relates to the sustainability of cause-effect over variations in participants, settings, treatment and measurement variables (Salkind, 2010; Shadish, Cook, & Campbell, 2002). Since action research design is aimed at resolving issues at a local level, the results of this study were intended to inform follow-up teaching and learning experiences (Allwright & Bailey, 1991).

Ethical Considerations

Ethics approval for this research was granted by the Human Research Ethics Committee at Edith Cowan University (Australia). The research took place in two sites in Kyrgyzstan: an educational centre and a Muslim school. In accordance with local protocols, the director of the educational centre and the Muslim school principal provided consent for their students to participate in the research. The research participants were enrolled by the managers at each site. Since they were under the age of 18, their parents and guardians were informed of the research objectives and procedures through information letters and asked to sign informed consent forms for their children to participate. Copies of all information letters and consent forms can be found in Appendices A to I. These documents were produced in English and translated into Russian, the language of school instruction in Kyrgyzstan. Participation in this research was entirely voluntary and all participants were advised that they could withdraw at any time. Since the program was conducted as an extracurricular course, participating did not affect students' schooling.

Chapter Summary

This chapter commenced with the theoretical framework based on the nine interrelated theoretical considerations incorporated into the context of my study. I then described the established Indigenous Sky Stories (ISS) educational project (Ruddell, McKinnon & Danaia, 2017) – the initial catalyst for my study. The link between ISS and previous STEM-A research was outlined, followed by the overarching action research methodology employed in this study, the connection between the four papers presented in this thesis and their articulation within the conceptual model. Finally, the chapter concluded with the research questions, data collection and analysis procedures, threats to validity and ethical considerations. The next chapter reviews my transition from TESOL to STEM-A teaching.

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CHAPTER THREE: ACTION RESEARCH CYCLE 1

This chapter reflects on the first cycle of the action research, namely my transition from TESOL teacher to an introductory astronomy course teacher. To contextualise my astronomy disciplinary literacy acquisition in English, the chapter starts with a review of my first encounter with STEM disciplinary literacy and an overview of my apprenticeship in teaching astronomy. It goes on to describe the development of my digital storytelling skills, before concluding with an explanation of the course design, reflections on the course implementation and a chapter summary.

First Encounter with Disciplinary Literacy in STEM Areas

By the time I commenced this doctoral research project I'd had around ten years of experience teaching English as a foreign language and had come to realise that English as a foreign language is an umbrella term that extends beyond merely teaching vocabulary and grammar.

The first time I was exposed to science disciplinary discourse in English and became aware of my lack of proficiency despite being fluent in academic English was when I prepared students for the reading section of the Test of English as a Foreign Language (TOEFL). The test contained short excerpts (one to five paragraphs) from various science disciplines followed by multiple-choice questions. At first, I thought if I learned all the new words in the passages, I would be able to understand the text well enough to answer the questions.

However, this strategy failed, because the sentences in these short excerpts were structured in a specific way that impacted the meaning of the words. Therefore, to prepare for my classes I had to build up a background knowledge about the phenomena discussed in these texts so that I could provide appropriate scaffolding for my students. For example, when working with a TOEFL reading passage about earthquakes, I first asked my students to

share their background knowledge about this phenomenon. Then we worked with the new vocabulary. Initially I asked students to simply guess the meaning of the words. After that I asked them to read the sentences containing these words and try to understand the meaning of the words from the context. After watching a short video in English about earthquakes, I invited students to attempt the actual TOEFL reading test questions.

It was only since undertaking this study about EFL students' disciplinary literacy acquisition that I can understand why reading the TOEFL test was such a challenge. The task is insurmountable when one does not have disciplinary literacy in the subject the text is covering and unfamiliar with the discourse in the discipline. Given that most of my students had similar STEM learning experiences (Chapter 1) and their learning of English was typically limited to grammar and general vocabulary, it was unlikely that they would develop adequate disciplinary literacy in English.

It was also doubtful that English teachers who teach TOEFL preparation courses have sufficient proficiency in STEM disciplinary literacy to provide the necessary scaffolding for EFL TOEFL test takers. Therefore, I believe that my experience of shifting from teaching TESOL to teaching astronomy in English makes an important contribution to the emerging body of knowledge about language teachers' STEM disciplinary literacy acquisition (Hart & Bennett, 2013; Lemley, Hart, & King, 2019; Moje, 2015) and can serve as inspiration for other language teachers.

This chapter provides an overview of the processes that enhanced my transition into the domain of astronomy education in English. It was necessary to reflect on my transition as a factor that shaped the subsequent cycles of my action research project. My reflections were guided by the following research question: How does disciplinary literacy develop in the process of transitioning from TESOL to astronomy teacher?

Apprenticeship in Teaching Astronomy

My original research plan was to join an Australian school that was already participating in the ISS (Ruddell, Danaia, & McKinnon, 2016) project and instruct the participating teachers on how to enhance the course with a DST teaching approach to facilitate Aboriginal and Torres Strait Islanders' performance. I began by studying the JTST (McKinnon, 2013) resources and the Australian science curriculum (Australian Curriculum, Assessment and Reporting Authority, 2015) to identify opportunities for DST integration and enhance my understanding of the context so that I could interpret classroom interactions.

At this time, I was exposed to new discipline-specific terminology. I encountered many new words that I wrote down together with their definitions and translations, but this exercise did not lead to conceptual understanding. While reading the JTST resources I faced the same problem I had as a child at school; the only difference now was another language of instruction. The words did not make sense to me, even though I had a perfect understanding of their meaning and translation.

Luckily, my learning was not limited to reading the course book. In fact, my transition to astronomy teacher followed the apprenticeship model (Lave & Wenger, 1991). My supervisor, the author of the JTST resource package (McKinnon, 2013), employed me as a research assistant. Part of my job was assisting with providing professional development to Australian primary school teachers for implementing the JTST package (McKinnon, 2013). The professional development comprised an interactive half-day workshop, to which all the students from primary schools were invited to participate with their teachers.

Under the expert guidance of my supervisor, my task was to set up the inquiry activities that I'd read about in the JTST resources (McKinnon, 2013). My conceptual shift towards understanding astronomical phenomena happened when I was accompanying the students in their explorations and reasoning of these astronomical phenomena in the process

of active inquiry. It was a unique “aha!” moment for the whole group when they suddenly arrived at the same conclusion, even though everyone had different expectations. In my case, I knew what the expected outcome of our exploration would be, but my understanding of how it was possible to attain this outcome was miraculously synchronised to this “aha!” moment when the other participants gained their understanding.

Assisting with the professional development of other teachers and facilitating the group work with the students enhanced my knowledge of terminology and understanding of the concepts. However, this was not the final stage of my transition to teaching astronomy. Previous research shows that teachers’ ability to transfer their disciplinary literacy knowledge into instructional practices is essential for effective disciplinary literacy instruction (Hart & Bennett, 2013; Lemley, Hart, & King, 2019; Moje, 2008; Zygouris-Coe, 2012). My content knowledge needed to be supplemented with meta-knowledge about discipline-specific discourse practices, since background knowledge and experiences seem to be decisive in framing our instructional practices and pedagogical decisions (Lemley, Hart, & King, 2019).

Even though I felt quite confident about my content knowledge at this point, I was not ready to teach it. Moreover, my astronomy disciplinary literacy in English was only starting to emerge. The next stage of my transition to astronomy teacher was another professional development workshop in astronomy, but this time as a teacher among other teachers participating in professional development, all eager to learn the pedagogy of implementing the JTST educational resource package for primary and junior secondary schools (McKinnon, 2013). The format of the workshop was practical engagement in the inquiry activities of the JTST package. I approached the exploration as a student and simultaneously observed my supervisor facilitating the inquiry activities, as aligned with the apprenticeship learning model (Lave & Wenger, 1991). The workshop gave me insights into

how students learn and showed me how to engage learners in scientific inquiry. At the same time, I was exposed to the discipline-specific discourse patterns for teaching astronomy.

In addition to being an apprentice, I was simultaneously reviewing the literature to situate my newly acquired knowledge about teaching astronomy within the existing body of knowledge. Trained as a TESOL teacher, my primary interest was identifying the role of literacy in teaching science. The review of the literature revealed that language of instruction was one of the barriers to learning science (Grandinetti, Langellotti, & Ting, 2013; Hinde, Popp, Jimenez-Silva, & Dorn, 2011; Zhang, 2016). In particular, science does not often create opportunities for students to construct their own knowledge by relating newly learned material to their background knowledge and authentic inquiry (Zhang, 2016).

At the same time, I was considering potential technologies, since 21st century learners are considered digital natives (Prensky, 2008) with a natural affinity for and interest in technology. Technological innovation also changes the way we approach educational instruction; by mediating learning with technology the teacher's role shifts to guiding learners through a process of self-education (Prensky, 2008). I believed that integrating digital storytelling in the original JTST package would allow students to enhance their astronomy disciplinary literacy development, despite the fact that I was only commencing my own as an instructor. Moreover, in such a DST model, my students and I could support each other's learning.

Digital Storytelling Skills Development

As DST became the central theme of my research project, the next stage of my professional development as an astronomy teacher was mastering the skills of video-making. My supervisory team suggested that I make a video to introduce myself and the course to students who would participate in this research, and at the same time, develop skills for scaffolding the DST intervention. Another reason for making an introductory video was to

establish a connection with the students, as relationship building is an important component of student engagement (Hackling, Byrne, Gower, & Anderson, 2015).

When I commenced this research project, I was not a proficient technology user and did not possess a camera, tablet or smart phone, so making a video was an entirely new skill for me. Besides the technical aspects, I also had to learn the process of video-making. I asked a friend, who had a degree in journalism and experience with shooting movies, advertisements, music videos and animation, to help me make my introductory video. In our first meeting he introduced me to general theory about video-making and taught me the basic concepts of “frame” and “shot”.

In our next meeting, my friend assigned me to write a story about myself. He then introduced me to the next stage of video-making, viz., storyboarding, where I had to fill in grids for time, action and sound. Action referred to the picture on screen, sound was the music or voice that accompanied the picture, and time was the duration the picture was on screen. After completing my storyboard, I had to shoot the video. Guided by my storyboard, I made some video recordings of me and my family and found some pertinent photographs and images on the internet. Then I selected the music to match the visual information.

To combine all my files into a video I had to select an appropriate program for editing. The programs recommended on the internet were expensive and the free-trial versions contained advertisements and had limited functionality. In most cases, they did not allow the user to export the video from the program. By lucky coincidence, the laptop provided by my university incorporated a professional video editor (Adobe Premiere Pro) that was approved by my friend, who showed me how to import the images and video files I wanted to include, how to order them, make transitions, add sound and export the video. As the program was specialised and required great attention to detail, the process was lengthy and time consuming.

Eventually I compiled my files into a video, but was not happy with the outcome because some of the transitions weren't smooth, the subtitles didn't synchronise with the audio and there was background noise on the audio recordings. Since the main selection criteria for my study were cost, ease of use and group accessibility, I discarded this video editor as an appropriate tool for my intervention.

My former research participants were using an iMovie application on their smartphones as video-editing software for their videos about grammar (Chubko, 2017), so I borrowed an iPad mini from the university with the iMovie application pre-installed and set out to re-edit my introductory video. Unlike Adobe Premiere Pro, iMovie was very easy to use, the interface was user-friendly and most commands were straightforward.

Additionally, the iPad mini was a portable device with an inbuilt camera and voice recorder, and provided access to shared storage and the internet. The decisive factor for selecting iMovie as the video-editing software for my research intervention was an opportunity to borrow six iPads mini from the university with the iMovie application and Stellarium Planetarium software (used in the JTST materials) pre-installed for the duration of my data collection.

After going through the process of creating my introductory video (https://ecu.box.com/s/oc9ge33hw5im2bqqv7c0ve8v10quf96t) I was able to use my experience to design scaffolding materials for my intervention. First, I made PowerPoint presentations to summarise the process of video-making (Appendix V) and introduce students to the basics of video editing in the iMovie application (Appendix W). Then I found a video that illustrated the different types of video shots (https://www.youtube.com/watch?v=DVXMQMUDlTs) and modified the template for storyboarding by adding grids for text and notes (Appendix X).

Course Design and Implementation

When it became clear that the intervention in the Australian school would not fit into the PhD timeframe, it was decided to combine the JTST (McKinnon, 2013) and DST intervention in a short-term extracurricular astronomy course for EFL students. Due to the imminent Christmas period and costs associated with course implementation it was not viable to conduct the course in Australia, and therefore my home country, Kyrgyzstan, was chosen to host the project. In addition to my roles as participant observer (Patton, 2002) and teacher of an introductory course in astronomy, I also took on the task of creating specific course materials to include DST. The next section outlines the original course structure for Secrets of the Stars.

DST Integration into the JTST Astronomy Course

The intervention was planned as a three-stage process: (1) raising awareness of the importance of collaboration; (2) introducing the theory behind video-making and video-editing software; and (3) making videos about astronomical concepts.

Raising Awareness of Collaboration

In the first stage of the intervention, it was necessary to raise students' awareness about the benefits of different viewpoints and the importance of collaboration. This stage was intended to establish the context for making videos about astronomy concepts and make students realise the value of others' opinions for gaining a better understanding of situations.

Theory of Video-Making and Video-Editing Software

The second stage introduced students to working with a camera and simple video-editing software, as well as demonstrating a sample introductory video.

Making Videos about Astronomical Concepts

The third stage of the intervention was designed to encourage students to use their culturally grounded knowledge about astronomy to trigger their scientific inquiry. Students were required to make around five videos on astronomy concepts that they would learn during their astronomy lessons.

The DST intervention was expected to challenge the students to think critically (Burkhalter, 2016) about sequencing all the material involved in the production of their videos. Every new video underwent peer- and self-evaluation processes. Based on JTST resources (McKinnon, 2013), the following ten topics were proposed for digital storytelling:

1. Beliefs and assumptions about astronomy
2. How the constellation got its name
3. Why do we have night and day?
4. Why does the moon change shape?
5. The seasons
6. Stellarium video tutorial
7. What do you know about our solar system?
8. What do the planets look like?
9. What’s an ecotect?
10. “Fly me to the Moon… Let me play among the stars”

Beliefs and assumptions about astronomy was obligatory for all students. Making this video was anticipated to reveal students’ background, culturally grounded knowledge about astronomy and their conceptions about various astronomical phenomena.

Lesson-by-Lesson Overview of the Pilot Course

It was decided to make a nine-day pilot course (Appendix L) based on the topics of the assigned videos. The lessons were designed for students to first identify their background

knowledge about an astronomy phenomenon, then participate in an inquiry activity, followed by making a video to explain the phenomenon they observed. Below is an overview of the lessons in the pilot course.

Lesson One

The first lesson was the most critical because it set the stage for the rest of the course. It was also the most intense lesson in terms of the number of set objectives and skills the students were expected to acquire (Appendix L). The first objective was to reveal students' current understanding of astronomical concepts, and to do so they had to take the Astronomy Diagnostic Test (ADT) in English (McKinnon, 2013). First, they were asked to read the instructions for the test. A 30-minute time limit was set, even though the original guide to ADT did not specify a time. Students who completed the test early in the pilot course were asked to underline all new vocabulary for them. The words that caused difficulties for the EFL learners of astronomy at the time of the pre-test were: upright, flagpole, maintain, scale, constellation, occur, axis, tilted, revolve, represent.

The other objective of the first lesson was to raise awareness of the benefits of plural perspectives and introduce the concept of triangulation. Embedded in this was the goal to engage students in scientific inquiry, allow them to explore the unfamiliar object and share their observations and conclusions. Students were given pieces of a puzzle (Appendix U) and after sharing their observations, the missing part of the puzzle was revealed to them. Since the original picture was very different from their interpretations and conceptions, it helped to exemplify the importance of multiple sources of data and clarify the concept of triangulation.

A further goal of the first lesson was to establish a connection with the students and build rapport, as well as transitioning from astronomy to making videos. Therefore, at this point in the lesson, students watched a three-minute introductory video explaining how I became an astronomy teacher. After watching the video, students were asked to think about

the technicalities involved in making the video and what they needed to make a similar video. This discussion was followed by a presentation showing the various stages of video production and different types of shots.

The final objective of lesson one was to develop the skills for making videos. To this end, students worked in groups to make an introductory video about their team, while scaffolding was provided in the form of prompting questions and guidance during each stage of the process.

Lesson Two

The goal of the second lesson was to encourage students to reflect on what they knew about astronomy as a science, and share their astronomy-related beliefs and assumptions and their culturally grounded knowledge. Additionally, they had to complete their videos and master the use of iMovie video-editing software. The class started with a short 20-minute version of the Western Australian Noongar people's creation story.

However, after a few minutes, students started to lose concentration, possibly due to the unfamiliar accent of the narrator, or the lack of visual support or a specific listening task. Simple comprehension check questions at the conclusion of the video revealed that students did not understand much about the story, so the teacher asked questions to help them reconstruct the story and identify key messages.

Next, the students were asked to think about what their culture says about creation and what they thought about it, and present their responses as an interview in a video. Assigned to be interviewers, interviewees and reporters, students were also asked to think about how they could visually enhance their interview by creating a diagram of a table. Since they had not completed their first video from lesson one, they were instructed to combine the two videos into one.

Lesson Three

During lesson three, students participated in a guided internet inquiry about the planets in our solar system and started to familiarise themselves with scale models. First, they watched an introductory video about the solar system. After that, each student received a table with the name of a planet and a list of information they had to find on the internet. They were reminded about the activity of completing a puzzle in lesson one and advised to source information from more than one website. After completing their tables, students shared the information they had found with the whole class by completing a combined table projected on a screen. Then they used the numerical information to make calculations for scale models, and the lesson concluded with making scale models of the planets from playdough and paper.

Lesson Four

Lesson Four was a key lesson for this research. During this lesson, students made a video about the scale model of the solar system. Discourse analysis of students' classroom interactions observed in this lesson during the video-making process allowed to identify the interactional patterns that could facilitate EFL students' disciplinary literacy development in English. The discourse analysis of the process is presented in Chapter 4.

Lesson Five

The main objective of lesson five was to introduce students to colour imaging and allow them to experience the process of turning black-and-white images of celestial objects taken through blue, red and visual (green) filters into colour images. In the first part of the lesson, students were given time to work on their earlier videos or scale models of planets, and during the second part they worked with the photos of the celestial objects taken through colour filters to produce colour images of these objects.

Lesson Six

Lesson six was a turning point in the course – it was the day that students modelled the phases of the moon. Prior to exploring the phases of the moon, students were given time to complete their scale model of the solar system video and explore the concept of a constellation. They were also introduced to the Stellarium Planetarium software that allows users to see a realistic three-dimensional model of the sky and learn the names of the celestial bodies, such as stars and constellations. Stellarium also enables users to establish the exact timing for various celestial phenomena, such as sunset, moon rise or lunar eclipse, by placing information in a calendar and observing how the sky changes.

Lesson Seven

The comprehension check questions at the beginning of lesson seven revealed that the students needed more time to grasp the concept of scaling. Therefore, the instructor deviated from the lesson plan in the pilot and suggested that students draw a water bottle standing in front of them. They were asked to use their pencils as a measuring tool.

Afterwards, students built a scale model of the distance between the earth and the moon, and explored the reasons for having day and night and seasons. At the end of the lesson, they chose the topic for their final videos from three topics covered earlier in the course: Phases of the Moon; Day and Night; and Seasons. After making a choice, they formed groups with other students who chose the same topic and spent some time thinking about the materials and resources they needed to make their videos.

Lesson Eight

The key objectives of this lesson were to identify the features of a good video and develop an evaluation rubric for their videos.

Lesson Nine

At the beginning of this lesson, students were asked to complete a feedback form about their experience participating in the course and then took the post-ADT test. Next, the whole class watched and evaluated the videos produced by the students during the course. Finally, they were asked to speculate about future professions related to STEM.

Course Refinements

After participating in the pilot course, the students indicated that the lessons about moon phases, scale models of the solar system and the colour images of celestial objects were the most interesting. Analysis of the students' classroom interactions revealed that students disengaged when listening to the Aboriginal story of creation. In addition, making a video on Beliefs and Assumptions about Astronomy did not produce the expected outcomes, as students were not motivated to explore this topic and based their videos on general ideas unsupported by evidence. Neither did participation in the production of this video stimulate discussion or argument, an important feature of science discourse. The same can be said for the final topic on careers of the future.

Conversely, students did not have enough time to work on their videos about moon phases and seasons, despite being engaged with exploring these astronomical phenomena. Therefore, the course was restructured in the next cycle of the action research (Appendix N). The Beliefs and Assumptions about Astronomy lesson and the lesson on careers of the future (What's an Ecotect?) were removed to allow more time for the remaining topics. However, judging from the number of students who dropped out of the course at an early stage, the modified version of the course and the post-ADT test performance (Chapter 5), this version of the course was less effective than the pilot. Consequently, a further cycle of action research was undertaken.

Since the students indicated that they liked the lesson about moon phases, and the classroom observations and analysis of their interactions indicated a shift towards disciplinary literacy development at this stage of the course, it was decided to introduce the moon phases earlier (Appendix P). The modified version flipped the course, starting with the exploration of the moon phases and concluding with making scale models of the solar system, and was more effective than the previous versions (Chapter 5). In the final cycle of the action research, it was decided to allocate more time to video production. Hence, the sequence remained the same, but students only made one video (moon phases) during the course. This structure allowed for more scaffolding during each stage of video production and created more opportunities for astronomy disciplinary literacy development (Chapters 5 and 6).

All the changes to the course structure were motivated by my reflections on student feedback and self-evaluating my facilitation of learning in each course. Even though the cycles of action research equipped me with a deeper understanding of astronomy concepts and gave me valuable insights into integrating DST into a STEM-A course for EFL students' disciplinary literacy development in English, my transition to an astronomy teacher was still in progress.

Chapter Summary

This chapter described the first cycle of the action research, involving the experiences that led to my transition from a TESOL teacher to a teacher of astronomy. My exposure to STEM disciplinary literacy acquisition and the processes that contributed to my astronomy disciplinary literacy development in English were outlined. Enhancement of my content knowledge in astronomy was followed by an overview of my apprenticeship in teaching astronomy. After the conclusion of the first cycle and the design of the DST-enhanced STEM-A course, a lesson-by-lesson breakdown was presented, together with the

refinements that were made in the ensuing stages of the action research. The descriptions reflect my teaching journey throughout the intervention and my commitment to engaging students in the STEM-A course. They also provide a context for the subsequent papers produced from the study. The next chapter presents the second cycle of the action research and contains two published articles that describe the outcomes of the pilot course in more detail.

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CHAPTER FOUR: ACTION RESEARCH CYCLE 2

This chapter describes the second cycle of the action research that involved piloting the DST-enhanced STEM-A course and determining a focus for ensuing cycles. It includes two peer-reviewed articles. Article 1 presents the pilot study and explores how the DST intervention impacted on EFL students' astronomy knowledge development and overall engagement with the course. Importantly, the discourse analysis demonstrated students' enhanced engagement with writing as a result of the DST as they reflected on their past experience and newly gained understanding of scientific phenomena.

Since the pilot (Article 1) identified significant gains in EFL students' astronomy content knowledge and high levels of writing engagement during the DST intervention, Article 2 further explored the literacy development of EFL students who used DST and how gains in literacy could be assessed. The paper established the construct of science disciplinary literacy and introduced the Structure of the Observed Learning Outcomes (SOLO) taxonomy (Biggs & Collis, 1982) as a tool for measuring EFL students' astronomy disciplinary literacy development in English. The data for the paper were obtained from the pre- and post-ADT SOLO scores in the pilot case. The results showed that all participants increased their level of thinking in English by the end of the intervention, as reflected in higher post-test SOLO scores, suggesting that DST can enhance disciplinary literacy development.

ARTICLE 1

Engaging adolescent Kyrgyzstani EFL students in digital storytelling projects about astronomy

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, it did not involve students' in-class collaboration and therefore a teacher was unable to monitor students' classroom interaction and provide a required scaffolding for the video making process. Presumably, students' in-class collaboration would enhance students' learning when applied within the EFL context as it would enable a teacher to provide a targeted scaffolding to support EFL students' shared knowledge construction.

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 3.1 shows symbols used during the transcription. 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.

Table 3.1 *Transcription Symbols*

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

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 3.2. 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 3.2).

Table 3.2 *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
Savora	5.0	5.0	0
Stas	5.5	6.5	+1
Talant	3.5	5.5	+2

However, Sayora had missed two lessons (Table 3.3) and participated in the production of only one astronomy content knowledge related video (Table 3.4). The highest progress in ADT performance was achieved by Manas and Elena. Manas had a 100% attendance (Table 3.3) and participated in the highest number of video-making projects (Table 3.4).

Notably, only the last four video projects presented in Table 3.4 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. It is interesting that even though Elena missed three and a half lessons (Table 3.3) and participated in only one astronomy content knowledge related video, she demonstrated the same high ADT gain score as Manas (Table 3.2).

Table 3.3 *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
Savora	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

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.

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 3.3), and lowest participation rate in video making projects (Table 3.4). Hence, more research is needed that will control for other factors, including a student's ability and interest in astronomy.

Table 3.4 *Participation in Video-Making Projects*

	Lead-in Videos		**Astronomy Inquiry Based Videos**				
	Team Introduction	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**
Savora	1	1	0	0	0	1	**3**
Stas	1	1	1	0	1	0	**4**
Talant	1	1	0	0	1	0	**3**

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 here. 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 3.5. Students' answers are presented verbatim.

Table 3.5 *Participants' Feedback about Astronomy Course*

	Prompt Question	Student
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 our 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 study, even though Elena produced the fewest videos, she attained the same high score as Manas, who produced the most 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 Activities in the Secrets of the Stars Course

Type of Classroom			
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 2 min	Viewing 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 people's creation story (Nannup, 2015)	46 min	Listening Discussion Listening Discussion Listening

L#	Task	Time	Interaction Type
	Interview	13 min	Discussion 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 Calculations Making models
L4	Completing projects from other lessons	70 mins	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 existing constellations
	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 hypothesis 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

L#	Task	Time	Interaction Type
	Day and night inquiry	72 min	Scale model of the distance between the earth and the moon Moon phases revision Making inferences Modelling Presentation Comparing models Modelling Filling in 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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ARTICLE 2

SOLO Taxonomy as EFL Students' Disciplinary Literacy Evaluation Tool in a Technology-Enhanced Integrated Astronomy Course

Whilst the role of disciplinary literacy in science, technology, engineering, and mathematics (STEM) education is becoming more prominent, there appears to be little adaptation or allowance made for English as a foreign or second language (EFL/ ESL) students learning science in English, as well as no clear understanding of what comprises disciplinary literacy in science. In this article, we define the construct of disciplinary literacy in science education and justify the use of the *Structure of the Observed Learning Outcome* (SOLO) taxonomy (Biggs and Collis, *Teaching for quality learning at university* 1982) as a tool for measuring EFL students' disciplinary literacy development. This SOLO taxonomy was trialled in a STEM- integrated astronomy course enhanced with a digital storytelling approach. Data were collected from adolescent EFL students' written responses in their pre- and post- Astronomy Diagnostic Test. The results show a positive change in participants' science disciplinary literacy development and contribute to the understanding of the EFL/ESL students' science disciplinary literacy development and assessment.

Keywords: disciplinary literacy, technology, digital storytelling, English as a foreign/ second language (EFL/ESL), assessment.

Introduction

The role of literacy for science, technology, engineering, and mathematics (STEM) education is gaining international recognition (Bauerle et al., 2014; Dutton & Rushton, 2018) that ignites a debate about how to define literacy within and across each of the STEM disciplines. Research recognises that "disciplinary literacy" is a unique and independent phenomenon, but does not provide a clear understanding of what it comprises as an

empirically valid measurable construct that is generalisable within the educational context (Spires et al., 2018). Inconsistency in defining disciplinary literacy creates an assessment issue as the construct is unclear. Therefore, there is a need to establish a definition of the construct in science education in order to develop appropriate instructional and assessment approaches.

This article contributes to the definition of disciplinary literacy within science education and outlines the outcomes of a pilot integrated STEM course targeted at disciplinary literacy development in astronomy, one area of science curriculum content in many educational jurisdictions. This research also trialled a new approach to disciplinary literacy assessment in science education and argues that the Structure of the Observed Learning Outcome (SOLO) taxonomy (Biggs & Collis, 1982) is a valid science disciplinary literacy assessment tool.

The significance of this study is underscored by the growing trends in international student populations around the globe (Langman & Fies, 2010; Taylor, 2014; Williams, 2011), coupled with an increasing demand for English-speaking STEM professionals (Bauerle et al., 2014), a decline in students' engagement in learning science (Goldspink & Foster, 2013), and the poor performance in standardised science literacy tests of EFL/ESL students in comparison with the test results of the students who speak English as their first language (National Assessment Program, 2015; The Nation's Report Card, 2015). Therefore, this study specifically targeted EFL students' disciplinary literacy needs in learning science. This research used digital storytelling (DST) as a teaching approach to develop disciplinary literacy in EFL students enrolled in an astronomy course. This course integrated STEM areas within an inquiry process (Prairie & Buckleitner, 2005) and created opportunities for authentic classroom interactions that scaffold EFL students' shared knowledge construction (Van Aalst, 2009).

Disciplinary Literacy Construct in Science

The recent study by Spires et al. (2018) brings new insights on disciplinary literacy in STEM education and argues that literacy is a multidimensional construct that represents students' competency in reading, writing, and thinking processes. Thus, reading and writing in science are the means by which various phenomena could be explored, described, and explained (Goldman et al., 2016), or that reading and writing reflect students' cognitive processes.

Science has its own discourse conventions distinctive from the discourses of other disciplines in both style and genre (Shanahan & Shanahan, 2008; Yore et al., 2003). Some of the scientific discourse functions are as follows: argumentation, claiming, informing, and aligning a claim to an argument (Yore et al., 2003). Scientific style is usually featured by clarity and brevity of the presented information (Holland et al., 1986).

According to Fang (2013), the major genres of science discourse are as follows: "procedure, procedural recount, description, report, explanation, and exposition" (p. 277). Spires et al. (2018) define disciplinary literacy in science as a combination of fluency in scientific terminology, an ability to synthesise multiple sources such as prose and various graphic representations, for example, graphs or diagrams (Goldman et al., 2016; Shanahan & Shanahan, 2008), and to apply analytical thinking, for example, linking data to arguments and conclusions (Gillis, 2014).

In their research, Spires et al. (2018) identify three core literacies that comprise the disciplinary literacy concept: *source literacy*— an ability to work with sources, for example, identification of an author's point of view; *analytic literacy*— an ability for quantitative reasoning; and, *expressive literacy*— an ability for interpretation of figurative language and rhetorical devices. The authors argue that science disciplinary literacy is mainly a combination of source and analytic literacies, and claim that science teachers are mostly

employing the analytic component of disciplinary literacy since an understanding of authors' claims and data interpretation in science require learners to move between prose and visual representations whilst reading (Spires et al., 2018). Moje's (2008) definition of science disciplinary literacy summarises all of the above- mentioned features and is therefore adopted for the purposes of this study. Hence, science disciplinary literacy is students' ability "to communicate their learning, to synthesise ideas across texts and across groups of people, to express new ideas, and to question and challenge ideas held dear in the discipline and in broader spheres" (Moje, 2008, p. 99).

Literacy Assessment

The increasing complexity in defining "literacy" prompted the evolution of literacy assessment procedures and instruments. Biggs and Tang (2011) argue that the outcomes of students' learning can be traced quantitatively through the amount of detail in students' answers, and qualitatively through the structural patterns they use to organise their ideas. In other words, disciplinary literacy acquisition implies that students shift from memorisation and reproduction to the personalisation of knowledge (Campbell et al., 1998). The Structure of the Observed Learning Outcome (SOLO) taxonomy suggests that this shift in students' knowledge is reflected in their cognitive processes (Biggs & Collis, 1982). Therefore, students' writing could serve as an indicator of the complexity of their disciplinary literacy development.

Hypothesising that the SOLO taxonomy accurately reflects a student's level of thinking, Rembach and Dison (2016) piloted the use of the SOLO taxonomy as a strategy to develop pre-service teachers' disciplinary literacy in the social sciences and in inclusive educational contexts. Familiarising students with the rubric based on the SOLO taxonomy enabled the researchers to gain an insight into students' knowledge construction by encouraging higher order thinking and critical engagement with the discipline (Rembach &

Dison, 2016). They argue that the strength of the SOLO taxonomy lies in its approach to the complexity of human knowledge acquisition that embraces both content and context. However, this is only possible when the assessment tasks are not matched to the learning outcomes in a formulaic way. Otherwise, there is a risk of the mechanical use of the taxonomy to help them create their responses to the assessment task (Rembach & Dison, 2016).

Adopting Moje's (2008) definition of science disciplinary literacy assumes that knowledge transformation will be reflected in students' level of thinking. Therefore, the response could be assessed against the different levels of the SOLO taxonomy (Biggs & Collis, 1982). This will reflect the complexity of the student's thinking processes in responding to the assessment question.

EFL/ESL Students

The increase of foreign student populations in education causes a discrepancy in the academic science performance between the students who learn English as a foreign or second language (EFL/ESL) and monolingual English speakers (National Assessment Program, 2015; National Center for Education Statistics, 2017, 2018). Since literacy is multidimensional (Spires et al., 2018), literacy acquisition may not be a linear process (Shanahan & Shanahan, 2008). The differences in the literacy development process for monolingual and non-monolingual speakers of English suggest that EFL/ESL students may experience more difficulties whilst learning school subjects. Therefore, teachers may need to provide some scaffolding strategies to narrow the literacy gap between their monolingual and EFL/ESL students (Fung & Yip 2014; Kasper, 2000; Menken, 2013; Ryoo, 2015).

Technology in Teaching Science

Considering that the ultimate goal of literacy instruction in STEM education is to empower learners with the ability to critique and modify the already existing disciplinary

knowledge (Office of the Chief Scientist, 2014; NGSS Lead States, 2013), students need to develop an understanding about a process of knowledge construction in a discipline (Lee, 2007) rather than merely memorise information presented by a teacher. This disciplinary literacy acquisition goal could be achieved by integrating technology in the educational process to create a context for sharing, collaborating, and networking (Nicholas & Ng, 2012). Technology can grant independence to students and a responsibility for the selection and processing of information (Anderson et al., 2018; Kasper, 2000; Ng, 2011; Peters, 2000). This may enable students to conceptualise and analyse their understanding of science (Scull & Bianco, 2008), and hence, may be particularly favourable for EFL/ESL students' learning (Anderson et al., 2018).

Digital storytelling creates a context that provides students with control over their learning (Pirbhai-Illich, 2010; Pirbhai-Illich et al., 2009), and teaches them to make informed choices among resources (Ashman & Elkins, 2009; Laycock & Stephenson, 1993; Sprague & Pixley, 2008). Whilst working on their videos, EFL/ESL students become engaged in the authentic decision-making process. This type of students' interactions creates opportunities for disciplinary literacy development, since each decision requires group negotiation, multiple trials, and drafting. In other words, students become responsible for the content of their course and communication of their learning outcomes to various audiences (Kasper, 2000) that provides a scaffolding of disciplinary literacy acquisition in science (Moje, 2008).

Authoring software, such as movie editors, is becoming increasingly accessible to all users (Godwin-Jones, 2000). For example, becoming proficient in using the iMovie video-editing program does not require much time due to the automation of many tedious processes and the user-friendly and intuitive interface (Godwin-Jones, 2000). Thus, it could easily be used to engage students in the process of learning without being too time-intensive

(Gruba, 2006). Nevertheless, despite the increase in interest towards technology-mediated instruction in education and growing accessibility of authoring software, there is little research on the integration of authoring software to enhance EFL students' disciplinary literacy development.

Specifically, an analysis of the existing research revealed that there are no studies that investigate the impact of engaging EFL school students in the process of digital storytelling about the concepts they learn within the context of STEM integrated astronomy course. Therefore, this study addresses the following research question: How does an integrated astronomy course enhanced with digital storytelling affect EFL students' disciplinary literacy development in the astronomy context?

Methodology

Study Design

This research is an extension of an established educational package in astronomy aligned with the Australian science curriculum in primary/elementary and secondary school science: A Journey through Space and Time (JTST) (McKinnon, 2013). The research uses data from a pilot study (Chubko et al., 2019); digital storytelling teaching components were integrated with the original JTST resource package, so that EFL students could not only inquire into the astronomy concepts, but also share and discuss their understanding of these new concepts with their peers. It was expected that approaching the newly acquired astronomy concepts from multiple perspectives through the sequence of the video-making stages such as brainstorming, scriptwriting, story-boarding, shooting, and editing would facilitate EFL students' acquisition of the disciplinary literacy in astronomy. Therefore, this research aligns itself with social constructivist theory (Vygotsky, 1962).

The whole project (Chubko et al., 2019) lasted for 25 h over a 9-day period. It was offered as a bonus course to the EFL students who were graduating from the pre-intermediate level of general English course conducted in one of the extracurricular

educational centres in Bishkek, Kyrgyzstan, during December 2017. Table 3.6 presents the outline of this pilot extracurricular astronomy course The Secrets of the Stars.

Participants

Participants were six Kyrgyzstani EFL students aged between 12 and 16 years. There were three males: Manas, Stas, and Talant; and three females: Diana, Elena, and Sayora. For ethical reasons, students' real names have been substituted with pseudonyms. These students were the recent graduates of a pre-intermediate level English course and had similar entry levels of general English language proficiency. For all of the participants it was the first time they were learning science with English as the medium of instruction. Traditionally, their language of instruction was Russian. None of these students had received any instruction in astronomy prior to their participation in this course.

Ethics Approval and Consent

This research was granted approval from the University's Human Research Ethics Committee (HREC) on March 8, 2017. All participants received an information letter about the project and because of the age of the students, an informed consent document to participate in this research was signed by students' parents or legal guardians. Approval was also sought from the participating site.

Data Collection Tools

The data were collected through pre- and post-qualitative responses extracted from the Astronomy Diagnostic Test (ADT) included in the JTST package (McKinnon, 2013) used in the pilot course (Chubko et al., 2019).

Table 3.6 *Secrets of the Stars Course Program Overview*

Day	Session Title	Goals	Activities
1	Introduction Science Inquiry	• Gaining awareness of the plurality of approaches to science. • Making hypotheses and mastering argumentation. • Collaboration • Work with a camera • Use of video-editing software • Developing interview questions	• Program overview • Astronomy Diagnostic Test • Team building • Creating team introductory videos • Next session preparation
2	Beliefs and Assumptions about Astronomy	• Data search • Planning and organising • Data Management • Video editing	• Listening to the Australian Aboriginal story of creation • Learning the creation stories of other people • Script writing • Collecting and analysing information • Storyboarding • Taking footage • Video editing • Discussion
3	The Solar System	• Learning about the solar system • Calculating scales • Making scale models	• Investigating the structure of the solar system • Building scale models of the solar system • Making a video about the solar system
4	Stars, colour, brightness and life history	• Stellarium software • Understanding the features of the stars • Making colour images of the stars	• Mapping constellations • Making colour images of the stars • Making a video guide for use of the Stellarium software
5	How the constellation got its name	• Research skills • Presentation skills	• Finding a story behind the name of a constellation • Making a video about one of the constellations
6	Phases of the Moon	• Understanding the phases of the moon • Practicing the use of scale models • Keeping a log book of observations • Reporting the observations	• Completing the moon phases observation log book • Making scale models of the earth and the moon • Making a video report to explain the phases of the moon
7	Day, Night and Seasons	• Testing hypotheses • Comparing	• Exploring the reasons behind night and day phenomena • Exploring the reasons for having seasons • Making a video about night and day or seasons

Day	Session Title	Goals	Activities
8	What is an Ecotect?	• Making predictions • Summarising	• Thinking about possible high-demand jobs of the future.
9	My Journey through Space and Time	• Reflecting on the gained knowledge • Presentations and feedback	• Astronomy Diagnostic Test • Demonstration of videos made during the course • Awarding certificates of completion

Previous research about astronomy education used the ADT to explore students' astronomy content knowledge development and students' alternative conceptions about astronomy (Slater et al., 2018). However, as argued in the earlier section of this paper, the SOLO taxonomy (Biggs & Collis, 1982) can also be applied to the written responses of the ADT in order to gain an insight into students' astronomy disciplinary literacy development.

Data Analysis

The *Structure of the Observed Learning Outcome* (SOLO) taxonomy (Biggs & Collis, 1982) measures students' reasoning development, but it does not measure the factual correctness of the answer (Fig. 3.1).

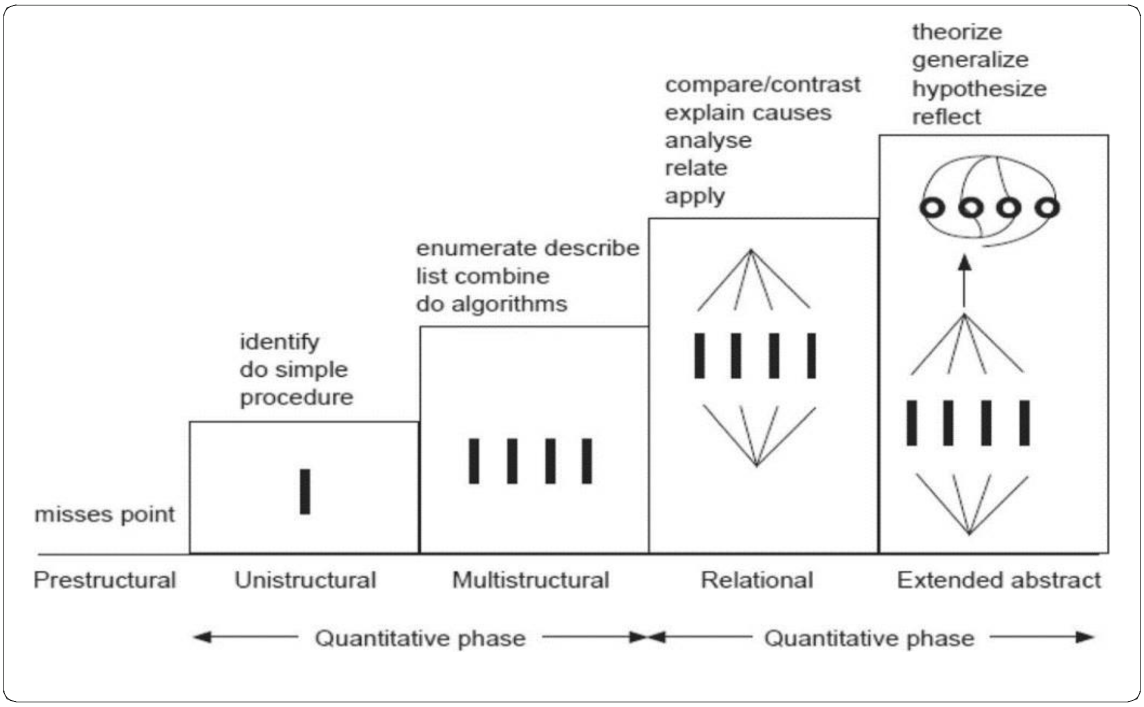

Figure 3.1. SOLO Taxonomy (Biggs, 2003, p. 48)

In this research, students' ADT written entries were assessed on a 0 to 5-point scale based on Biggs and Collis' (1982) taxonomy guidelines:

0 – no entry was made

1 – Prestructural level of thinking – the answer repeats a question or is not relevant to the topic

2 – Unistructural level of thinking – only one piece of relevant information is provided

3 – Multistructural level of thinking – the answer contains two or more pieces of relevant information often connected with "and"

4 – Relational level of thinking – the answer shows the relationships among the pieces of relevant information, and

5 – Extended abstract level of thinking – the answer is connected to the bigger concept or theory.

As a 15-question version of the ADT (McKinnon, 2013) was used, the maximum SOLO score attained by a student could be 75 points, and the minimum– 0 points. The maximum score could be attained only if all the questions would be answered at the extended abstract level of thinking. A 93% inter-rater reliability was achieved using this approach for marking, with two researchers independently assessing students' written entries. Quotations of students' ADT written entries are given verbatim and there- fore may contain original grammatical errors made by the students.

Results

Table 2 presents a summary of each participant's overall SOLO rating (Biggs & Collis, 1982) distribution. Analysis of these data shows that the participants improved their SOLO rating (Biggs & Collis, 1982) between the pre- and post-test occasions, with a minimum shift of +2 and a maximum of +27 points.

However, it is also clear that this increase in SOLO rating was mainly attained due to the students' attempt to explain more answers in their post-test rather than they did in the pre-test (Table 3.7).

Table 3.7 *Overall SOLO Taxonomy Ratings*

Student	Diana		Elena		Manas		Stas		Savora		Talant	
Question	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
1	3	4	3	3	4	5	4	4	3	5	4	4
2	3	3	3	3	3	3	0	5	0	0	4	3
3	5 (R)	4	0	2	2	4	2	4	4 (T)	2	4	4
4	4	5	4	4	4 (R)	4	0	4	3	4 (T)	4	4
5	2	4	2	2	0	3	0	0	1	1	1	0
6	2	4	0	3	0	4	4	4	4	4	0	3
7	0	5	0	0	0	5	0	2	4	4	0	3
8	2	4	0	2	4 (R)	5	0	2	0	5	0	4
9	2	3	0	2	0	0	0	0	0	0	0	0
10	0	2	0	2	0	2	0	0	4 (T)	2	0	0
11	0	4 (T)	0	0	0	2	0	3	0	3	4	4
12	2	2	4	0	0	1	0	4	1	2	2	2
13	4	0	0	0	1	2	0	1	0	2	5	0
14	3	0	0	2	0	0	0	0	0	3 (T)	0	0
15	3	0	0	0	0	5	0	2	0	4	1	0
Total	35	44	16	25	18	45	10	35	24	41	29	31
Change		+9		+9		+27		+25		+17		+2

(R) – Russian language; (T) – Use of a term in Russian

Therefore, in this case, the gain score is not an accurate reflection of students' disciplinary literacy enhancement. To gain an understanding of EFL students' disciplinary literacy development, all non-English and non-paired entries were removed from the sample. Out of the 90 paired entries, possible if each participant made a written entry to all pre- and post-test questions, 33 matched entries were left. This new matched sample was exported to SPSS and analysed (Table 3.8). The Cohen's d effect size was calculated from the difference between pre- and post-test scores, where d = 0.41. This means that there was a moderate change in students' disciplinary literacy that might be attributed to involvement in the astronomy course enhanced with video-making.

Table 3.8 *Descriptive Statistics*

	N	Minimum	Maximum	Mean	Std. Deviation
Pre-test	33	1	4	2.97	1.045
Post-test	33	1	5	3.39	1.029
Valid *N* (listwise)	33				

Overall, the results suggest that there is a moderate improvement in students' disciplinary literacy development. Even though the participants were allowed to use Russian, their L1, in cases where they struggled to find an appropriate way to express their answers to the ADT questions in English, it should be noted that there were no entries in Russian in the post-test and only three entries in Russian in the pre-test throughout the whole sample; one made by Diana, and two made by Manas (Table 2). These responses in students' L1 allow tracking the shift occurring in students' disciplinary literacy as a result of engagement with this astronomy course enhanced with the DST teaching approach. One of the examples is Diana's reasoning of her answer to question 3. This question contained a diagram representing an observation of Moon Phases changing over a week. To answer this question, students had to explain the cause of such an observation. In her pre-test, Diana answered:

> Так как тень от Земли падает на Луну под разными углами, мы не всегда видим луну полностью, а только её освещенную часть. Этот процесс (изменения видимой части) называют лунным циклом.
>
> [Translation: Since the shadow from the Earth falls on the Moon under different angles, we do not always see the whole Moon, but only its lit part. This process (the process of changing of the visible part) is called the Moon cycle.]

Although this written response provided by Diana in Russian is obviously an alternative conception, it was rated as a five on the SOLO taxonomy (Biggs & Collis, 1982).

In her answer, Diana first establishes a *shape* to *angles* relation, and then she generalises her answer to the bigger idea, *Moon cycle*, which is indicative of Extended Abstract level of thinking. In her post-test, Diana answered the same question (question 3) in English and scored only four points on the SOLO taxonomy (Table 3.7):

> She saw the Moon in different shapes, because the Moon has 8 faces, which changes in a certain order every day.

Even though in her post-test entry Diana abandons her alternative conception about the shadow of the Earth causing the phases of the Moon, her reasoning now only presents the facts and is not generalised to the overarching concept. Nevertheless, in her post-test written entry to question 7 (Table 3.7) on the scale model of the Earth-Moon system, Diana demonstrates that she actually has the ability to present an argument at the Extended Abstract level of thinking in English (Fig.1) that did not occur earlier in her pre-test. In her answer to question 7, Diana uses the same structure as she used in her L1 answer to question 3:

> I depend on calculating at the process of scailing (sic). For this case it's calculation will be 9 m.

Diana takes her answer to the Extended Abstract level of thinking by referring to the generalised overarching concepts of *Moon cycle* in L1 answer to question 3 and *scaling* in her English answer to question 7. During this pilot astronomy course, Diana did not participate in making a video about Moon phases even though she participated in the Moon phases inquiry activities along with all other students. However, Diana was engaged in the video-making about Scale Models of the Solar System (Table 3.6) and this possibly helped her to develop an understanding about the scale model of the Earth-Moon system and equipped her with the terminology to argue about this concept in her post-test entry in English.

During the course, Manas was engaged in making a video about Seasons (Table 3.6). Two of his pre-test entries were written in his L1; his answer to question 4:

> Земля наклонена и та сторона которая наклонена к солнцу там лето, а та сторона которая отклонена от солнца там зима.
>
> [Translation: The Earth is tilted and that side that is tilted to the Sun, there is summer, the side that is further from the Sun, there is winter.]

and his answer to question 8:

> У нас есть времена года потомучто Земля наклонена, а если она не будет наклонена то времен года не будет.
>
> [Translation: We have seasons because the Earth is tilted, but if it were not tilted we wouldn't have seasons.]

Both of these answers were rated as four out of five. In his English post-test answer to question 4, Manas demonstrated the same level of thinking as in his L1 (Table 3.7):

> Earth is tilted on 23o and the side wich (sic) is facing the sun there
> is summer and the part that is away from sun there will be winter.

His answer to post-test question 8 scored one-point higher (Table 2):

> because of the tilt Earth has seasons but without (sic) this we would just have day and night.

The comparison of Manas' answers in his L1 and in English demonstrates that Manas was familiar with the concepts prior to the course, but did not have enough technical vocabulary to explain his understanding. Most probably Manas acquired the concept of a tilt during the process of making the video about Seasons that helped him to present his argument in English.

Discussion

The present study was designed to determine the effect of a digital storytelling approach on EFL students' disciplinary literacy development in astronomy when taught in English. The overall results showed that engaging EFL students in making videos about their learning during the astronomy course had a positive effect on their disciplinary literacy development. All of the research participants had a positive gain between their pre- and post-ADT performance when coded against the SOLO taxonomy scale (Biggs & Collis, 1982). This means that they attained a more advanced level of expressing their thinking, and therefore, enhanced their disciplinary literacy in a foreign language.

Very little was found in the literature on the question of what comprises disciplinary literacy in science (Moje, 2008; Spires et al., 2018). Therefore, this finding broadly supports the existing research on the effect of technology on EFL students' learning of science (Godwin-Jones, 2000; Nicholas & Ng, 2012; Ng, 2011; Pirbhai-Illich, 2010; Pirbhai-Illich et al., 2009; Scull & Bianco, 2008) and contributes to our understanding of science disciplinary literacy as a measurable construct generalisable within the educational context. The positive outcome from this pilot study (Chubko et al., 2019) provides a stable foundation for the replication of the research with a larger sample. This will allow for an enhanced exploration of the true potential of this instructional approach towards disciplinary literacy development.

Another important finding from this research was that the EFL students enhanced their disciplinary literacy in a foreign language. In the pre-test, the participants left many questions unanswered, which might be a result of the students not understanding the questions being asked. During the astronomy course, the EFL students were engaged in making videos covering key astronomy concepts associated with the ADT test. Whilst the

students made multiple edits on their videos, they participated in ongoing discussions about the astronomy concepts with their peers.

As a result of the interactions, the students improved their post-ADT scores. As mentioned in the literature review, there is a literacy gap between EFL/ESL and monolingual students (Fung & Yip, 2014; Kasper, 2000; Menken, 2013; Ryoo, 2015). Given that prior studies noted the importance of mediating teaching with some scaffolding strategies (Fung & Yip, 2014; Kasper, 2000; Menken, 2013; Ryoo, 2015), a possible explanation for the EFL students' post-ADT test results was that students received appropriate scaffolding from the DST experience. The findings revealed an increase in students' disciplinary knowledge enhanced by using a DST approach to teaching. Further research will focus on a greater understanding of the relationship between video- making and science disciplinary literacy development in a foreign language.

Limitations

In this study, it was impractical to attempt a control of diverse external factors (e.g. sickness, end of school year examinations, evening classes, and distance from home), which influenced the participation of students in the astronomy course. Additionally, the course might have encouraged some participants to read more widely beyond the confines of the classroom. Consistent with the small participant sample, generalisability does not apply, but the next research phase should engage a larger sample of EFL learners. Despite the small sample size used in the original research pilot, the outcomes provide a valuable indicator of the disciplinary literacy development in EFL students and a foundation for further research.

Implications

We propose to complement students' standardised evaluations with the SOLO taxonomy approach, so that teachers can measure shifts in students' level of thinking to gain a better understanding of their disciplinary literacy development. Using SOLO (Biggs &

Collis, 1982) or similar taxonomies may prevent teachers from confusing disciplinary literacy with content knowledge acquisition, where the former reflects students' cognitive processes and the latter is limited to factual information acquired or memorised by the students. The development of disciplinary literacy will allow students to acquire the necessary information; whilst in the case of gaining the content knowledge, students may only be relying on their memory. The outcomes of this study suggest that incorporation of DST in teaching repertoire would be beneficial for EFL students. Even though this study is restricted to astronomy context, we believe that this strategy could be integrated into other disciplines to bridge EFL and non-EFL students' learning outcomes.

Conclusions

The aim of this research was to explore how the integration of digital storytelling within the astronomy course would influence EFL students' astronomy disciplinary literacy development in English. Overall, this pilot showed that engaging EFL students in a DST-enhanced course helps to scaffold their disciplinary literacy development in a foreign language. Changes observed in the participants' pre- and post-test SOLO ratings indicate that they attained a more advanced level of expression in a foreign language; and, therefore enhanced their disciplinary literacy in a foreign language. The positive increase in students' knowledge using the DST teaching approach creates an argument for further research into understanding the relationship between video- making and science disciplinary literacy development.

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CHAPTER FIVE: ACTION RESEARCH CYCLE 3

The article presented in this chapter describes the third cycle of the action research. It covers implementation of the same STEM-A course as in the pilot study, but with a larger population, and subsequent refinement of the course to better support students' disciplinary literacy development. Based on the positive impact of video-making on EFL students' astronomy disciplinary literacy development in English (Article 2), the third paper employed a Type IV Case Study design (Yin, 2014) and compared Kyrgyzstani cases to an Australian case. The key difference was that the Krygzstani EFL students were exposed to the DST component of the astronomy intervention, whereas the Australian case included participants who were native English speakers and undertook the same inquiry activities, but did not use DST. For this paper, data were collected from the pre- and post-ADT SOLO scores and analysed with a repeated measures ANOVA test. The results showed that DST significantly enhanced EFL students' SOLO scores and decreased the performance gap between EFL and non-EFL students. It also allowed for identifying a course structure that resulted in the greatest STEM-A disciplinary literacy gains for students.

ARTICLE THREE

Digital Storytelling as a Disciplinary Literacy Enhancement Tool for EFL Students

This research explores how a digital storytelling (DST) educational technology intervention in a Science, Technology, Engineering and Mathematics (STEM) integrated astronomy course influenced disciplinary literacy acquisition for students who learn English as a foreign language (EFL). A total of 30 students aged between 12 and 16 from Kyrgyzstan participated in the research. The research was designed as a Type IV Case Study (Yin, *Case study research: Design and methods* 2014). The Kyrgyzstan case study was compared to Australian students (N=328), who participated in the same astronomy course but were not exposed to the DST intervention. Data were collected from written responses to the pre- and post-Astronomy Diagnostic Test (ADT), which were coded against the Structure of the Observed Learning Outcomes (SOLO) taxonomy (Biggs and Collis, *Teaching for quality learning at university* 1982) and analysed using ANOVA with repeated measures on the occasion of testing. The results showed a positive effect of the DST intervention on EFL students' astronomy disciplinary literacy acquisition. The significance of this research is in exemplifying how the DST teaching approach could be used to bridge the gap between EFL and non-EFL students' disciplinary literacy in STEM areas.

Key words: disciplinary literacy, English as a foreign language (EFL), digital storytelling (DST), video, STEM and astronomy education

Introduction

English is becoming a language commonly taught in schools internationally (Lamb, 2017) not only as an elective, but also as the language of instruction (Morton, 2018). Fleckenstein, Leucht, Pant, and Köller (2016) address the issue of the divide between native and non-native speakers of English. The authors conclude that students of English as a foreign language (EFL) are competitive with native English speakers in the global job

market. English as a Foreign Language students are proficient in social, economic and academic English literacy. However, while educational statistics report a gap between native and non-native English speakers' test performance (Department of the Prime Minister and Cabinet, 2018; National Assessment Program, 2015; The Nation's Report Card, 2015), recent research in linguistics underscores the misleading nature of such comparisons. While native speakers as a group usually outperform non-native speakers (Somers, 2017; Fleckenstein et al., 2016), there is a high variability within groups (Dąbrowska, 2019; Hulstijn, 2019). The majority of observed individual differences in both native and EFL speakers can be attributed to education (Dąbrowska, 2019).

This research sought to explore pedagogical practices that could bridge the gap in native and EFL speakers' disciplinary literacy in Science, Technology, Engineering and Mathematics (STEM) disciplines. This is because STEM subjects pose additional challenges for both EFL and non-EFL students including the complexity of the academic language and lack of authentic learning experiences that prevent students from drawing connections between school and their everyday life (González-Howard & McNeill, 2016; González-Howard, McNeill, Marco-Bujosa, & Proctor, 2017; Grandinetti, Langellotti, & Ting, 2013; Stevenson, 2015; Zhang, 2016). Subsequently, this research sought to compare the disciplinary literacy acquisition of students who experienced two different pedagogical approaches in learning STEM through astronomy (STEM-A).

The first approach came from an Australian study, the *Indigenous Sky Stories* (ISS) program, which was conducted with Australian primary school students aged 10-12 years (Ruddell, Danaia, & McKinnon, 2016). In the ISS program, astronomy serves as a context for learning where local Indigenous and western scientific perspectives are brought together in the classroom to create a cultural 'middle ground' (Aikenhead, 1996; Nakata, 2018; Ruddell, Danaia, & McKinnon, 2016). This study demonstrated how an integrated

curriculum could engage students in scientific inquiry and encourage active shared knowledge construction (Ruddell, Danaia, & McKinnon, 2016).

The current Kyrgyzstan study explored how a digital storytelling (DST) or video-production (Angay-Crowder, Choi, & Yi, 2013; Rubino, Barberis, & Malnati, 2018) in the educational design might enhance EFL students' learning and promote their astronomy disciplinary literacy acquisition. The study was conducted with students aged 10-16 years and used the same astronomy teaching materials as the ISS program (Ruddell, Danaia, & McKinnon, 2016), but also included collaborative video making as part of the learning experience.

This article compares differences in astronomy disciplinary literacy acquisition between Kyrgyzstani students who had DST as part of an educational technology enhanced design with Australian students who completed the same astronomy course intervention, but were not engaged in making videos. The guiding research questions for this analysis were: Does DST influence the EFL students' astronomy disciplinary literacy development in English? If "yes", how does this happen? The findings contribute to the existing body of knowledge about pedagogies that support EFL students' disciplinary literacy acquisition in STEM areas.

Bridging Literacy and Science Education

Several decades of studying the role of a language in learning and teaching across various content areas have resulted in a 'cross-border dialogue' that bridges literacy and science education research internationally (Díaz Pérez, Fields & Marsh, 2018; Fujimoto-Adamson & Adamson, 2018; Morton, 2018; Tang & Danielsson, 2018). The acknowledgment of the role of disciplinary literacy in science triggered the emergence of English for Specific Purposes (ESP) courses where English teachers focus on delivering content-related English (Yang, 2016). However, this approach has drawn criticism from

language teachers who have limited understanding of the disciplinary discourse related to the subject content knowledge (Arno-Macia & Mancho-Bares, 2015; Morton, 2018). Consequently, Content and Language Integrated Learning (CLIL) has emerged, where content instructors take over from the language instructors (Díaz Pérez et al., 2018; Jendrych, 2013). Initially, CLIL programs were developed as a way to meet the needs of the globalised job market and also as a response to the growing diversity of students in modern classrooms around the globe (Madrid & Cañado, 2018; Yang, 2016). It resulted in CLIL becoming a broad term referring to any classroom setting where a subject is taught in a language that is not the students' native language (Díaz Pérez et al., 2018; Yang, 2016), and has been readily embraced in North America and many European countries (Tang & Danielsson, 2018; Yang, 2016).

In general, CLIL research has reported positive outcomes (Somers, 2017). However, recent large-scale CLIL program evaluation in Spain revealed a lack of egalitarianism or social inclusion that were outlined among the key principles of CLIL education (Cañado, 2018). CLIL materials and teaching resources were also criticised for their lack of authenticity and scarce integration of technology (Cañado, 2018). While CLIL is a start towards an integrated curriculum for EFL students, more attention is needed in enhancing inclusiveness and authenticity in EFL students' learning (Cañado, 2018; Darío, 2014).

Disciplinary Literacy in Science as a Social Practice

Many students do not value science lessons because the 'laboratory' nature of learning is removed from their everyday context (Aikenhead, 1998; González-Howard & McNeill, 2016; Meyer & Crawford, 2015). This separation between learning and life is increased in conventional science education, which usually adheres to didactic or knowledge transmission pedagogies and does not prioritise students' engagement in learning

(González-Howard & McNeill, 2016; González-Howard et al., 2017; Haydock, 2011; Meyer & Crawford, 2015; Zhang, 2016). However, research suggests that EFL students' literacy development requires students to be encouraged to question their current knowledge and extend and adapt it to other contexts (Angay-Crowder, Choi, & Yi, 2013).

For EFL pedagogy, a major advancement is a shift towards the recognition of literacy as a 'form of social practice' rather than the linguistic medium for delivering scientific concepts to students, which appears to be a result flowing from the interdisciplinary collaboration of CLIL (Díaz Pérez et al., 2018; Tang & Danielsson, 2018). The sociocultural nature of disciplinary literacy suggests the transition from the explicit focus on language towards one where inquiry learning is focused on shared knowledge construction. Hence, recent research spotlights disciplinary literacy that focuses on engaging students from various backgrounds in scientific inquiry so that they can construct their conceptual understanding about science (Tang & Danielsson, 2018). Tytler, Prain & Hubberet, 2018) argue that science literacy development also requires engaging students in inquiry into diverse representations of knowledge and which is also important in shared knowledge construction. By creating and critiquing various representations of science concepts such as a model to represent the cause of Day and Night, students develop a meta-representational competence and deepen their awareness about the concept (Tytler, et al., 2018).

Recognising disciplinary literacy as a sociocultural phenomenon implies that learning is the outcome of engagement in various activities contextualised to the social setting and has a synergy with research into 'communities of practice' (Lave & Wegner, 1991; Mercieca, 2017; Wegner & Nückles, 2015). The key features of such a community of practice are: mutual engagement, joint enterprise, and shared repertoire (Mercieca, 2017; Wegner & Nückles, 2015). When working in groups, students exchange their interpretations

of a given phenomenon, arguments and thus construct shared knowledge (Van Aalst, 2009). Hence, learning happens as a result of social interactions and ongoing negotiation of concepts.

Digital Storytelling and Science Disciplinary Literacy Development

Innovations in technology are also changing teacher pedagogy and educational design. Educational technology has resulted in traditional storytelling evolving into DST, which is defined as the multi-literacies practice of storytelling mediated by digital tools (Angay-Crowder, Choi, & Yi, 2013; Castaneda, Shen, & Claros Berlioz, 2018; Rubino, Barberis, & Malnati, 2018). The integration of DST in various formal educational contexts, including Kindergarten-Grade 12, higher education and professional education (Rossiter & Garcia, 2010; Rubino, Barberis, & Malnati, 2018) has highlighted that DST interventions facilitate collaborative writing for all students, including EFL/ESL students (Angay-Crowder, Choi, & Yi, 2013; Papadopoulou & Vlachos, 2014; Rubino, Barberis, & Malnati, 2018).

DST creates a middle ground for EFL students to explore and combine their multiple literacies and social identities (Angay-Crowder, Choi, & Yi, 2013) enhanced through multiple representational and communication modes. For example, making videos about scientific phenomena creates the context for disciplinary discourse and, with careful guidance, could trigger and maintain students' science disciplinary literacy development and encourage their interest in the STEM disciplines (Bell, Lewenstein, Shouse, & Feder, 2009).

Despite some early evidence of successful learning outcomes and positive experiences in past interventions (Pirbhai-Illich, 2010; Pirbhai-Illich, Turner, & Austin, 2009), DST is still an emerging trend in STEM education. School instructors remain cautious about including DST in their classroom practices because of curriculum and time constraints (Pirbhai-Illich, Turner, & Austin, 2009). However, the well-planned integration

of video-making projects does not take significant time away from curriculum implementation and has positive outcomes for students (Morgan, 2015; Zellner, 2018) with concomitant reports of improvement in students' presentation and writing skills (Niemi, Niu, Vivitsou, & Li, 2018). When working on their videos, students are encouraged to undergo a 'self-audit' process, and actively reflect on areas for improvement in their language and learning skills (Sprague & Pixley, 2008). Hence, the current research aligns with previous studies showing that a DST intervention can enhance disciplinary literacy. The current research aimed to highlight DST as an effective strategy for bridging EFL and non-EFL students' STEM-A disciplinary literacy development.

Astronomy as a Context for DST intervention

Astronomy covers intriguing phenomena that can engage learners in meaningful scientific inquiry (Zellner, 2018). Moreover, STEM-A explorations require students to comprehend other science content (e.g., physics and chemistry) and mathematics (Ampartzaki & Kalogiannakis, 2016; Razul, Powell & MacLeod, 2015), which makes it an ideal field of study for STEM education. In Australia, the *Journey through Space and Time (JTST)* educational astronomy project (McKinnon, 2013) was designed as a remedy for disengaged primary school students and their teachers in learning science (McKinnon & Geissinger, 2002). The JTST package (McKinnon, 2013) contained support resources for teaching astronomy, differentiated for teachers' diverse experience and content knowledge in the area. This project found that engaging in STEM-A resulted in students' attainment of the curricular goals while gaining a first-hand learning experience and developing a scientific understanding of the real-life phenomena (McKinnon & Geissinger, 2002). Additionally, engagement with this project helped students to identify and replace their alternative conceptions about various astronomy concepts. The curricular value of participation in this project could be exemplified in the scaffolding activities that allowed

students to comprehend more advanced mathematical concepts such as scale models (McKinnon & Geissinger, 2002). In a follow-up project, the power of storytelling was explored.

Noteworthy in terms of student and community engagement was the ISS program described by Ruddell, Danaia, and McKinnon (2016). Besides the regular components of the bigger ISS research project, which included supplying the participating schools with an 8-inch reflecting telescope, an iPad mini with preinstalled Stellarium planetarium software, inquiry-based learning and teaching resources (JTST) (McKinnon, 2013) and professional training with ongoing support for the teachers to assist with project implementation, ISS also provided access to an Aboriginal storyteller to share Indigenous stories about the sky. The school and community collaboration encouraged students' sharing of their own sky stories that they had learned from their families. The analysis of students' interviews showed that their participation in this ISS project allowed them to establish strong connections between their cultural stories and concepts presented in western science (Ruddell, Danaia, & McKinnon, 2016).

Advances in technology have led to the digitalisation of storytelling and have resulted in the emergence of DST, a multi-literacy practice of storytelling mediated by digital tools. In most cases this process results in the creation of a video output (Angay-Crowder, Choi, & Yi, 2013; Castaneda, Shen, Claros Berlioz, 2018; Ohler, 2013; Rubino, Barberies, & Malnati, 2018; Teehan, 2006; Zellner, 2018). Zellner (2018) piloted a DST intervention with her college students enrolled in the introductory astronomy course. Participation in this intervention empowered them to assume ownership of their learning process because they could explore the astronomical topics that aligned with their personal interests. In other words, the design enabled students' learning by conferring a degree of learning autonomy (Smith, Kuchah, & Lamb, 2018). Zellner (2018) reported that this DST

intervention supported her students' development of creativity and extended their astronomy content knowledge, as well as developing additional skills in collaboration and technology use that were transferrable beyond the astronomy disciplinary context.

Other research also highlights the potential of DST for integrating multiple disciplines and therefore allowing students to develop skills in higher order thinking (Anderson, Chung, & Macleroy, 2018). Additionally, Anderson, Chung, and Macleroy (2018) emphasise that DST is effective in drawing students' attention to their language use while being engaged in the creation and sharing of their personalised stories (Anderson, Chung, & Macleroy, 2018). However, despite the reported positive outcomes of DST intervention, most of DST research was conducted in the students' mother tongue, usually English. Thus, there is a gap in understanding the DST impact on the development of foreign or community languages (Anderson, Chung, & Macleroy, 2018).

There is a need to further explore the role of DST in multilingual contexts, with the overarching goal of developing students' STEM-A disciplinary literacy in English. This need has emerged from problems related to students' language development (Anderson, Chung, & Macleroy, 2018) enhanced by the increasing demand of English in STEM-A areas (Plo-Alastrué & Pérez-Llantada, 2015) as well as the economic divide between EFL and non-EFL speakers (Fleckenstein, Leucht, Pant, & Köller, 2016). Previous research has shown a positive impact of DST in teaching astronomy (Ruddell, Danaia, & McKinnon, 2016; Zellner, 2018). Therefore, this research sought to explore the impact of DST on disciplinary literacy acquisition in astronomy by EFL students, with the aim of benefitting their learning experiences in STEM areas.

Method

Adopting Yin's (2014) research design classification this project was conducted as a Type IV embedded multiple-case study as embedded designs involve multiple units of

analysis, including quantitative and qualitative measures derived from student tests and field notes (Yin, 2014). Such designs also use multiple cases. In this investigation, the two cases are an Australian case (Case 1) and the Kyrgyzstani case (Case 2). While the focus of each case was slightly different, with the Australian case aiming to improve astronomy content knowledge and the Kyrgyzstani case aiming to improve student astronomy disciplinary literacy, the similarities between the two cases make them appropriate for comparison.

There are three reasons why comparisons can be made. First, both cases used the same content in their intervention (outlined in research background). Second, they used the same instrumentation to measure students' content knowledge (outlined in data collection instrumentation). Third, the length of the intervention (in hours) was similar between the two case studies (outlined in research background).

There were, however, two key differences between the cases. First, unlike the Australian case study, the Kyrgyzstani study enhanced the intervention with DST. Second, there was a difference in participants' language background: the Australian study included non-EFL learners, but the Kyrgyzstani participants were all EFL learners. Consequently, analysis of the two cases was conducted to answer the research questions: Does the DST approach influence the EFL students' STEM-A disciplinary literacy development in English? If "yes", how does this happen?

Research Background

Both cases use resources from the JTST educational package (McKinnon, 2013), which was developed within a constructivist theoretical framework to encourage students' learning through active inquiry (McKinnon, 2013). This resource package was developed to support Australian primary and secondary teachers and therefore was aligned with the Australian science curriculum standards (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2018).

The data for the first case study (Case 1) was extracted from the Western Australian research project known as *Cultural Sky Stories* (CSS), which is an extension of the ISS project (Ruddell, Danaia, & McKinnon, 2016). The aim of CSS was to improve the astronomy content knowledge of students, aged 10-12 years, by integrating culturally-grounded knowledge (including Indigenous stories) with western scientific understandings about the sky (Slater, Morris, & McKinnon, 2018). In this integrated approach, the emphasis was on creating a cultural middle ground to engage a diverse range of students in science learning (Aikenhead, 1996; Nakata, 2018).

The Kyrgyzstani study (Case 2) also used the JTST astronomy package (McKinnon, 2013) to explore how a DST pedagogical approach might promote STEM-A disciplinary literacy acquisition in a foreign language. The study was conducted with students aged 10-16 years in both an educational centre and in regular school settings through extracurricular courses. While all Case 2 participants experienced engagement with DST, there were a number of embedded cases where the intervention processes were refined during the research.

Kyrgyzstani embedded case studies were conducted in two research sites: educational center (Groups 1-3) and a school (Group 4). The intervention for Groups 1 and 2 started with the exploration of the scale models of the Solar System and concluded with the reasons for Day and Night, Moon phases, and seasons. Groups 3 and 4, experienced the reversed course sequence, which started with the reasons for Day and Night, explored Moon phases, and seasons, and then moved on to the exploration of the Solar System and the construction of scale models. Consequently, throughout the course Groups 1 and 2 were focused on making videos about the individual planets of the Solar System, using various Internet resources as their references, while Groups 3 and 4 were making videos about Moon Phases with their videos based on the knowledge and experience they gained through

exploration and inquiry. The Australian students were engaged in the same inquiry activities integrated into their regular science lessons at school and sequenced in the same way as for Groups 1 and 2 but were not involved in DST.

Australian participants from CSS project (Slater, Morris, & McKinnon, 2018) worked through the JTST astronomy package (McKinnon, 2013) for approximately two hours per week over one school term (i.e., approximately 20 hours). Based on a 2017 Kyrgyzstani pilot (Chubko, Morris, McKinnon, Slater, & Lummis, 2019), the length of intervention lessons for the Kyrgyzstani participants (Case 2) was reduced from 150 minutes to 120 minutes implemented over 10 days to fit with other extracurricular courses provided by the participating educational centre. Consequently, both the Australian and the Kyrgyzstani interventions were 20 hours in length.

All four groups in Kyrgyzstan were taught by the first author who received the same professional development as the classroom teachers participating in CSS (Slater, Morris, & McKinnon, 2018) who delivered the astronomy course in Australia. Additionally, the teacher for the Kyrgyzstan study (Case 2) had a Teaching English to the Speakers of Other Languages (TESOL) qualification. Prior to the intervention, the first author received training in DST and the use of video-editing software, including iMovie that was selected as the video editor for this intervention.

Sample

The sample for this analysis comprised 30 Kyrgyzstani students who learned English as a foreign language (EFL) and 325 non-EFL Australian students. Groups 1-3 from Kyrgyzstan spoke Russian as their first language (L1), while the majority of students from Group 4 used Kyrgyz as their L1. Their teacher (first author) was fluent in Russian, but she had only a basic proficiency in Kyrgyz. Kyrgyzstani sample contained two participants from Group 1 who could speak only Russian with all other Kyrgyzstani participants' (28) level of

proficiency in English according to the Common European Framework of Reference for Languages (Council of Europe, 2018) ranging from having an elementary (A2-B1) to intermediate (B1-B2). Groups 1-3 had access to online dictionaries on their personal mobile devices or the mini-iPads provided by the teacher throughout the course. Group 4 could not use their personal mobile devices and did not have any internet connection on the mini-iPads provided by the teacher during the course because of restricted access to the internet in the school.

The first three groups from Kyrgyzstan (Groups 1-3) were mixed-gender groups enrolled in the same educational centre and were taught on the same premises during the summer vacation in 2018. Group 4 comprised only female students enrolled in a Muslim school with separate classes for boys and girls. The girls were invited by their school principal to join the after-school astronomy course in October, 2018, during the first term of the school year. The Australian students were enrolled in four mixed-gender schools in the Australian case study. While it is likely that some students in this sample were multilingual, their schooling was conducted in English and students were considered to have English as their L1. The Australian sample is labelled as Group 5.

The participants from both countries were aged between 10 and 16 years. In addition to being engaged with inquiry activities about astronomy from JTST (McKinnon, 2013), all four groups from Kyrgyzstan were exposed to the DST intervention that required the students to participate in making videos in English about the astronomy concepts they were learning during the course.

Informed consent: Informed consent was obtained from all individual participants included in the study as well as from their parents as required by the Ethics in Human Research Committee at the university where the first author was enrolled as a PhD student.

Data Collection Instruments

Textual data were collected from the written responses to the Astronomy Diagnostic Test (ADT) included in the JTST resource package (McKinnon, 2013), which was administered at the beginning and again at the end of the course. That is to say, the design was a repeated measures pre-post enterprise. All Kyrgyzstani students and most of the Australian students (N=200) completed the 15-question version of the ADT. However, the rest of the Australian sample completed a slightly shorter 11-question version with four of the 15 questions being removed. In both versions, the first four questions asked students to draw a picture to explain a particular phenomenon and to write their reasoning for their answer. The remaining questions asked students to select their answer from multiple choice options and to write their reasoning for their answers.

Importantly, as the aim of this research was to identify the shift in EFL students' astronomy disciplinary literacy in English, Kyrgyzstani groups were not directly instructed to use English when providing reasons for their answers to the ADT questions. It was assumed that by giving EFL students the choice of language it would enhance the authenticity of their argumentation rather than drawing their attention to language. Additional data for the Kyrgyzstani sample also included a number of videos produced by the students in the DST approach, and material recorded by the researcher in field notes.

Data Analysis

Due to the significant difference between Australian (325) and Kyrgyzstani (30) sample sizes, an Analysis of Variance (ANOVA) with repeated measures on the occasion of testing was computed using Group membership as the independent variable to test the ability to compare these two groups. To ensure that the distributions of the data met the mathematical assumptions of the statistical approach, the homogeneity of the covariance matrices was computed to ensure that both the individual and joint distributions of the

groups were normally distributed. Box's test of the equality of the covariance matrices was used to test the null hypothesis that the observed covariance matrices of the dependent variables were equal across groups. The Box's M statistic was not significant (*Box's M*= 16.309, *F* (12,1739.32)= 1.170, *p*= 0.299); thus, statistical results could be interpreted with confidence despite the difference in sample size.

The written responses provided by the students were assessed against the *Structure of the Observed Learning Outcome* (SOLO) taxonomy (Biggs & Collis, 1982). The coding employed was: 1 for a response at the pre-conceptual level of thinking; 2 for a unistructural response; 3 for a multistructural response; 4 for a response establishing relationships among the components of a concept; and 5 for a response related to a bigger idea or an overarching theory. If no entry was made a response was scored as a 0.

Both versions of the ADT test had four questions specifically about Moon phases. Groups 3 and 4 of Kyrgyzstani case made videos about the Moon phases, while the other participants did not make videos about the Moon phases. Therefore, the analysis examined students' written responses to these four questions alone to investigate any differential effects of the DST intervention on EFL students' disciplinary literacy development in English. Consequently, a scale of SOLO performance was investigated for reliability. Cronbach's alpha on the pre-occasion of testing was 0.649. On the post-occasion, Cronbach's alpha was 0.740. The analysis showed that the four items could be added to produce a summed scale. Tukey's estimate of the power to which observations should be raised to achieve additivity was 0.906. This value is close enough to 1 to allow the individual scores to be added without further mathematical transformation. The higher value of Cronbach's alpha on the post-occasion of testing is not surprising given that the students had investigated aspects of the phenomenon and knew more about what causes Moon

phases. Analysis of the data was conducted using the Statistical Package for Social Sciences (SPSS) version 23.

Since there were a few Kyrgyzstani students who provided some or all of their written answers in Russian, and the focus of this research was on the disciplinary literacy in English it was decided that the responses in Russian could be assigned a very small value of 0.0001 that had a minimal effect on the mean scores employed in the repeated measures analysis. This was done to maximise the number of cases in the paired analyses in the pre-post design. This small value should not be confused with the 0 value assigned for a non-response. This approach allowed all of the students' data to be employed in computing a SOLO scale total while simultaneously also allowing an analysis of the frequency of Russian language use in their total scores.

Results

Table 5.1 shows the mean SOLO scores and standard deviation for each of the five groups on both the pre- and post-testing occasions. All groups increased their mean SOLO scores for the four questions related to the Moon phases from the pre- to the post-ADT testing occasion (shown in Table 5.1).

Table 5.1. *Pre- and Post- ADT SOLO total mean scores for the four Moon phases questions*

		Pre-Test		Post-Test	
Group	N	Mean	Std. Deviation	Mean	Std. Deviation
Group 1	5	3.20	4.324	3.60	3.361
Group 2	8	2.75	2.549	2.87	2.949
Group 3	5	3.40	3.715	6.20	3.271
Group 4	12	2.75	3.361	6.50	4.482
Group 5	328	3.74	2.705	4.52	2.864
Grand Means	358	3.67	2.757	4.56	2.965

The two Kyrgyzstani groups who made videos about Moon phases (Groups 3 and 4) showed the greatest gains in SOLO mean scores. The remaining two Kyrgyzstani groups (Groups 1 and 2), who did not make videos about the Moon phases, demonstrated lower

level gains. These groups were comparable with the Australian students (Group 5) who did not experience the video intervention but who were native speakers of English.

Table 5.2 shows that there is a significant main effect due to the occasion of testing (F (1, 353) = 18.720, $p < 0.001$). There is also a significant first-order occasion-by-groups interaction (F (5,353) = 5.838, = $p < 0.001$). This interaction indicates that the different groups are behaving in significantly different ways between the pre- and post-test occasions.

Table 5.2. *Summary output of the ANOVA with repeated measures by Group membership*

Source	Occasions	Type III Sum of Squares	df	Mean Square	F	Sig.
Occasions	Linear	50.506	1	50.506	18.720	0.00002
Occasions * Group	Linear	62.998	4	15.749	5.838	0.00147
Error (Occasions)	Linear	952.378	353	2.698		

In order to interpret the significant first-order interaction between occasion of testing and group membership, the mean scores of each group are plotted in Figure 5.1.

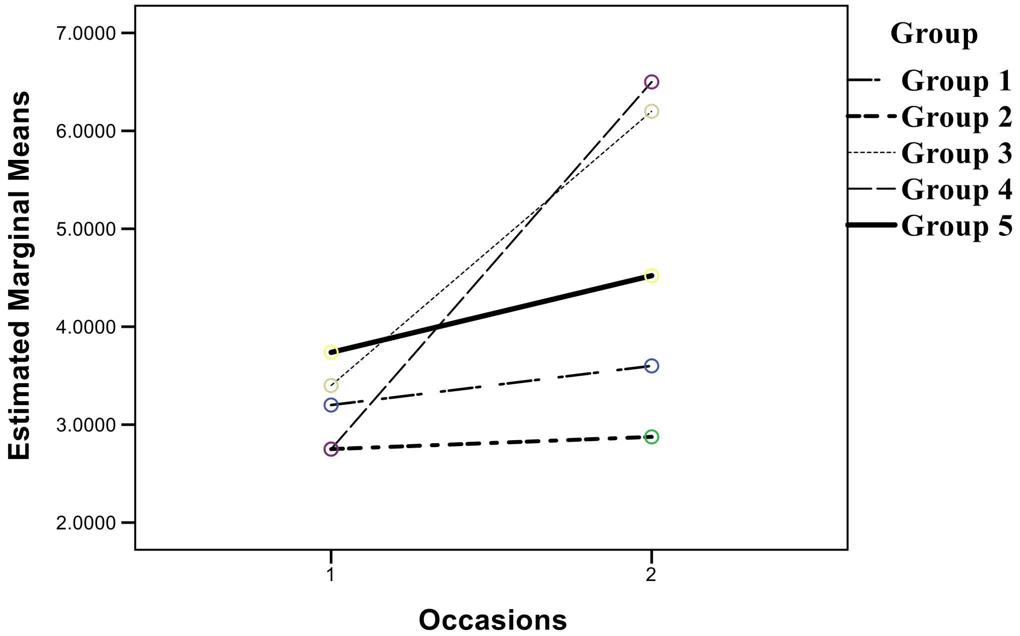

Figure 5.1. Pre- and Post-ADT SOLO total mean scores for the four Moon-Phases questions by Group

This shows that Groups 1, 2 and 5 increased their mean scores in a modest fashion while Groups 3 and 4 had much larger gains shown by the steeper gradients. Figure 5.1 also shows that the two EFL groups who focused on the Moon phases video production (Groups 3 and 4) outperformed the Australian non-EFL students (Group 5) and the other two EFL groups (Groups 1 and 2) in their ability to express their ideas in English. It is likely that this significant first-order interaction is due to the marked differences in gradients representing the pre- and post-occasion mean SOLO scores. Importantly, the different treatments appeared to have significant effects on students' ability to explain their reasoning in English, and especially when English was not their native language.

As an example, below are the pre- and post- test answer excerpts of a student not making a video about Moon phases (Excerpt 1) followed by the answer to the same question given by the student participating in a video production about Moon phases, (Excerpt 2). Both students used Russian to answer this question during the pre-test and then swapped to English in their post-test. Students' entries are included as verbatim transcripts.

Excerpt 1

Pre-test	Post-test
Из-за того что луна вращается вокруг Земли, а Земля так же вращается вокруг Солнца, небольшие промежутки времени лучи падают на Луну. Если Луна скрылась за Землей, то лучи на нее не падают. (Translation: *Because the Moon orbits the Earth, and the Earth also revolves around the Sun, small intervals of time the rays fall on the Moon. If the Moon hid behind the Earth, then the rays don't fall on it.*)	Looking at what position the earth depends on how the rays hit th moon

Excerpt 2

Pre-test	Post-test
В пасмурный день мы смотрим на небо там темно, луны нет. Через некоторое время узнаём что её закрыли тучи и постепенно небо освещается, видим звезды. Бывают полнолуния когда луна кажется очень близко и очень яркая. (Translation: *In a cloudy day we look in the sky it is dark there, no Moon. After a while we learn that it was covered by the clouds and gradually the sky brightens, we see stars. There are eclipses when the Moon seems very close and very bright.*)	Moon has 7 phaces. I draw theys. When sun shines fall to the moon and he is changing every day and shape also.

While the first student basically translated her earlier idea from Russian to English, the second student adopted the whole new approach to the question as well as supplementing her answer with visualisation (her drawing of the model), one of the attributes of the science disciplinary literacy (Goldman et al., 2016; Shanahan & Shanahan, 2008; Spires, Kerkhoff, Graham, Thompson, & Lee, 2018).

Another student, who was working on a Moon phases video, was initially more proficient in English than the student examples given above. However, we can see the transition from Level 3 to Level 4 on SOLO taxonomy, as the student attained conciseness due to the effective use of terminology and exclusion of redundancy (Excerpt 3). Whereas in her pre-test answer reasoning this student wrote an additional sentence that simply restates the idea of the previous sentence and does not provide any new information. Indeed, this student possessed an alternative conception about what causes the phases on the pre-occasion. This is commonly called the “eclipse conception” or “shadow of the Earth” and

this appears to have been changed to the correct and concise explanation in the post-test response. Conciseness is another feature of the science disciplinary literacy (Spires et al., 2018). Indeed, this is what most of the students attained in these two Groups scoring a 4 or 5 on the SOLO taxonomy in their post- test answers.

Excerpt 3

Pre-test	Post-test
Since the moon circulates around the earth, the shadow of the earth on the moon changes too, and we only see the parts of the moon that the sun rays reach. The dark parts we don't see are the parts where the sun rays are blocked by the earth.	The way the moon looks to us (the phases) depend on the angle of it to the sun.

Table 5.3 shows that the total of written responses for the four Moon phases questions in English by the end of the intervention in Kyrgyzstani case increased from 49 to 63 while the total of written responses in Russian remained the same (34). Overall, the number of non-responses reduced from 37 to 23.

Table 5.3. *Frequency of occurrence of Kyrgyzstani students' responses by language*

	Pre-Test					Post Test				
	Q3	**Q6**	**Q13**	**Q14**	**Totals**	**Q3**	**Q6**	**Q13**	**Q14**	**Totals**
Nothing Written	4	9	11	13	**37**	4	3	9	7	**23**
Russian	10	8	8	8	**34**	10	8	8	8	**34**
English	16	13	11	9	**49**	16	19	13	15	**63**

Discussion

The aim of the current research was to explore how a DST intervention within a STEM-A course impacted EFL students' astronomy disciplinary literacy acquisition in English. The results of this analysis align with findings from a pilot study (Chubko et al., 2019). It can be concluded that the DST educational technology covaried with a positive

influence on EFL students' astronomy disciplinary literacy development in English and on their discipline knowledge. All of the research participants demonstrated a positive change in their post-ADT written responses by the end of the course, often shifting from unstructured to multistructural or relational levels of thinking (Biggs & Collis, 1982). The largest gains were obtained by the two Kyrgyzstani groups who were engaged in making videos about Moon phases at the beginning of their course (Groups 3 and 4). These findings support research on the role of DST to enhance students' writing (Angay-Crowder, Choi, & Yi, 2013; Papadopoulou & Vlachos, 2014; Rubino, Barberis, & Malnati, 2018) and STEM disciplinary literacy development (Niemi, Niu, Vivitsou, & Li, 2018). However, the magnitude of the gains were not achieved when students were engaged in inquiry tasks that did not include DST about Moon phases (Groups 1, 2, & 5). Within this study, scientific inquiry has a positive effect on students' learning, but their concept acquisition covaried significantly with the use of DST as shown in Figure 5.1.

In their responses, all participants attempted more questions in the ADT on the post-test occasion. There was also an increase in English language use by Kyrgyzstani students to answer the post-ADT questions, while the number of responses in Russian remained the same and the frequency of non-response questions reduced. This is an unexpected outcome since the research participants in the Kyrgyzstani groups were all given the choice of language they used (English or their native language) when answering the ADT questions. The observed frequency of responses in Russian implies two outcomes, which require further exploration. First, EFL students have a positive attitude about learning in English and are not worried about attempting responses in English. Second, they developed disciplinary literacy in English and therefore, felt more comfortable to express themselves in the second language because they do not have enough discipline-based terminology in their L1 to be able to translate their conceptual understandings.

In order to explore the differences in disciplinary literacy between EFL and native English speakers, SOLO responses of the Kyrgyzstani and Australian samples were compared. The results confirmed the performance gap between native and non-native speakers as a group (Dąbrowska, 2019; Hulstijn, 2019; Menken, 2013), but also revealed that course design could bridge the learning outcomes of students with various levels of target language proficiency. The groups of EFL students making videos about Moon phases attained a significantly higher SOLO score on their ADT post-test than the Australian and Kyrgyzstani samples who only participated in the inquiry activities about Moon phases.

The positive outcomes of two Kyrgyzstani groups (Groups 3 and 4) suggest that DST intervention supports EFL students' disciplinary literacy in English. What is of particular interest in the context of EFL pedagogy is the improvement in EFL students (Group 4) with the lowest target language proficiency at the beginning of the course. Group 4 slightly outperformed Group 3, despite both groups being exposed to the same course structure. Group 4 students made the largest improvement in their SOLO scores, even though the participants did not receive any explicit literacy instruction throughout the course. It is possible that this outcome is related to the change of the educational context as Groups 1-3 participated in the intervention in the educational centre context, but Group 4 in the school context. Therefore, while Groups 1-3 only met each other during the intervention, Group 4 students knew each other prior to the intervention. It is possible that Group 4 students may have had more trust in each other due to the strong sense of collaboration and a well-established community of practice (Lave & Wegner, 1991) in their school. This may have increased the amount of time they spent in sharing concepts rather than in negotiating collaboration or in developing relationships. Additionally, all Group 4 students were female students that could also affect their classroom interaction style and reinforce the establishment of the community of practice (Lave & Wegner, 1991).

The gains could also be a result of the amount of time spent on video production. Group 4 students worked on their videos throughout the whole course, for approximately 10 out of the 20 hours of the course. Group 3, like Groups 1-2, only spent three to five hours on the video component of the course. It is also possible that Group 4's gain in content knowledge could be linked to prior knowledge about the Moon, as the Muslim religion follows the lunar calendar; however, this was not explicitly measured in the current research.

The DST educational technology appears to engage students in inclusive multimodal learning practices (Angay-Crowder, Choi, & Yi, 2013; Madrid & Cañado, 2018; Cañado, 2018; Rubino, Barberis, & Malnati, 2018). By assigning EFL students to make a video explaining their understanding of a specific astronomical phenomenon, the teacher is empowering students to own their learning by giving them autonomy. It also creates a context for collaboration among the students if the task is assigned to groups. Making a video can become a meaningful task when students are encouraged to form a community of practice (Lave & Wegner, 1991; Wegner & Nückles, 2015) as they construct shared knowledge (Van Aalst, 2009) through the process of making the video to present their final conceptual understandings. Since all EFL students have different life experiences and sociocultural backgrounds as well as different proficiencies in the target language, DST becomes a middle ground (Aikenhead, 1996; Nakata, 2018; Ruddell, Danaia, & McKinnon, 2016) for the EFL students' negotiation of the concepts being studied. Therefore, this research supports the argument that to improve students' conceptual understanding they need to adapt their prior knowledge to a new context (Wegner & Nückles, 2015). In the current study, DST served as a tool for adapting EFL students' prior beliefs and assumptions about STEM-A to a new learning context. In addition, DST encouraged EFL students to build new knowledge based on their inquiry experiences and collaborative experiences with

other students who had a diverse understanding of the astronomical phenomena being studied.

Limitations

Even though this research overall had a reasonable number of the participants from Kyrgyzstan, the number of students in each of the intervention groups was low. Therefore, the main limitation of this research is the small sample size that was treated with a multiple case-study design. There were some differences in the interventions as well, which limits the interpretation from the comparison of the two cases. Additionally, the option to use their L1 in the ADT was necessary to maximise paired-cases, but this has implications for the interpretation of differences between responses written in EFL students' L1 compared to English. Finally, the impact of students' gender was not considered in the current data analysis; however, given that the highest gains were attained by the Group 3 with the dominating number of female students and female-only Group 4, further research is needed to incorporate students' gender as an independent variable within the data analysis.

Conclusions

This study exemplifies how DST could be integrated with the STEM-A as an effective educational technology for enhancing EFL students' disciplinary literacy, as this teaching approach has not yet been examined within an EFL context. One of the positive aspects of this study was the relationship building and collaboration among the EFL students that covaried with a shared knowledge construction. Over time, this collaboration evolved into a community of practice. In this study, technology was used as a vehicle to encourage students to communicate and to provide an authentic context for learning.

Implications and Further Research

In contrast to some CLIL programs (Lucietto, 2008; Mashilla & Gardner, 2005; Cañado, 2018; Yang, 2016), the DST intervention emphasises a collaborative learning

environment that intentionally shifts the focus from teachers' expertise in subject knowledge to an active inquiry approach involving students' construction of shared knowledge. The DST pedagogical approach is a student-centred approach that provides a middle ground for shared knowledge construction between students, which also could be accommodated in CLIL programs. Therefore, the teacher should be ready to enter a community of practice with their students and engage in disciplinary knowledge construction together with the students. The multimodal nature of the DST educational technology aligns with the integration of technology in STEM-A, and thus has the potential to be used in order to create an authentic learning context for all students, regardless of their background.

Further research is needed to explore the effect of the DST intervention on disciplinary literacy development with native-speakers of English. The role of students' gender in DST collaboration is also unclear and requires further investigation. Finally, this research poses a question of disciplinary literacy transferability between EFL students' native and foreign languages.

Ethical approval: "All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards."

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CHAPTER SIX: ACTION RESEARCH CYCLE 4

This chapter presents the fourth cycle of the action research study, the aim of which was to develop a deeper understanding of students' classroom interactions in the revised course structure. The revised course structure was implemented in a new learning context (a Muslim school) in order to determine the transferability of the course. Resulting from this cycle, the fourth paper explored how making videos about astronomy concepts engaged EFL students in a community of practice, given that the key feature of the DST intervention was its capacity to facilitate shared knowledge construction in a learning context.

This paper presented a discourse analysis of the classroom interactions on the video-making activities of Group 4, since this case attained the highest SOLO scores for the DST intervention described in the previous paper (Article 3). Consequently, this case was selected for a separate publication over the other three groups (Groups 1-3), to further explore how community of practice could support increased disciplinary literacy for this sample of students.

Discourse analysis of this case showed that students frequently engaged in knowledge stewardship (Wenger, McDermott, & Snyder, 2002), a key feature of CoPs. From this analysis, an eight-stage classroom interaction pattern was devised, exemplifying the coaching that occurred in this case, where less knowledgeable peers were consistently supported by their more knowledgeable peers in the CoP.

ARTICLE FOUR

Digital Storytelling as a Trigger for EFL Students' Disciplinary Literacy Development: Emerging Communities of Practice in an Astronomy Context

This paper explores how engaging EFL students in digital storytelling (through making videos about astronomical phenomena) enhances their astronomy disciplinary literacy in English. A comparative Kyrgyzstan-Australia case study (Chubko et al., 2019) revealed one of the key features of digital storytelling was facilitating shared knowledge construction in a learning context. This article is an in-depth exploration of the classroom interactions of one Kyrgyzstani case with 14 multilingual EFL girls aged 10 to 16 years in a Muslim school. The discourse analysis of the girls' engagement with video making about moon phases showed patterns of disciplinary literacy development emerging from the integration of digital storytelling with an astronomy course. Specifically, this research identified processes of shared knowledge construction that enhanced students' disciplinary literacy development as a result of digital storytelling, manifesting as a domain for development of a community of practice.

Key words: EFL/EFL, community of practice, digital storytelling, disciplinary literacy, STEM-Astronomy education

Introduction

A Kyrgyzstan-Australian comparative study (in review) revealed that digital storytelling (DST) facilitated disciplinary literacy acquisition in both native and non-native (EFL/ESL) speakers of English (Chubko, Morris, McKinnon, Slater, & Lummis, 2019a). Specifically, DST was observed to create a context for shared knowledge construction (Mercieca, 2017; Van Aalst, 2009). Hence, the assumption was that the effect obtained from engaging EFL students in group work to make videos about astronomy concepts covered

during the course was due to DST functioning as a "domain" in a community of practice (CoP) (Mercieca, 2017; Wenger & Lave, 1998; Wenger, McDermott, & Snyder, 2002).

The aim of the current study was to gain a better understanding of the process of EFL students' CoP development around DST. As one of the Kyrgyzstani cases engaged in the digital storytelling intervention outperformed the other three Kyrgyzstani cases and matched the disciplinary literacy acquisition of Australian native speakers (Chubko et al., 2019a, in review), it was purposefully selected for discourse analysis. This article addresses the following research question: How do EFL students develop their astronomy disciplinary literacy in English when engaged in digital storytelling?

EFL and Non-EFL Students' Learning Needs

To obtain international recognition and move beyond discourse in their own local communities, most experts from non-English backgrounds have to undergo a process of "secondary socialisation" in order to develop their own disciplinary literacy in English (Povolná, 2015). However, the learning resources designed for EFL students frequently do not encourage participation in an authentic L2 environment (Al-wossabi, 2016). As language acquisition is a socially enhanced process (Allison, 2011), students need to be engaged in the socio-cultural practices of a discipline (Al-wossabi, 2016; Ashman & Elkins, 2009).

Given that students (including non-EFL learners) (Aikenhead, 2001; Aubusson, 2011; DeBoer, 2000; Haydock, 2011) generally perceive learning in STEM areas as challenging, EFL students experience an even greater challenge, since they have to extend both their language acquisition and conceptual understandings. This assumption has been the catalyst for several remedial programs, such as English for Specific Purposes (ESP) courses and Content and Language Integrated Learning (CLIL), which are supposed to provide language instruction to support content learning (Díaz Pérez, Fields & Marsh, 2018;

Yang, 2016). However, there is no explicit instructional approach that results in learning *as* knowledge, defined as not only a compilation of isolated facts, but also an ongoing process of reconstruction (Wegner & Nückles, 2015).

Shared Knowledge Construction within a Community of Practice

The assumption that learning is context-dependent and enhanced by learners' prior knowledge and socio-cultural backgrounds emphasises the strength of collaborative learning (Wegner & Nückles, 2015). Wegner and Nückles (2015) argued that knowledge is not a personal attribute, but an ongoing process of constructive development. It could therefore be reasoned that membership of a Community of Practice (CoP) can shift an individual's conceptualisations and enhance learning. This shift results in shared knowledge construction, aimed at the overall development needs of a community (Mercieca, 2017; Van Aalast, 2016; Wegner & Nückles, 2015).

Positioning knowledge development as a process means that knowledge acquisition can most efficiently be attained through teacher-student collaboration, where teachers contribute their expertise to the overall development of a community (Wegner & Nückles, 2015). Leadership is essential (Reaburn & McDonald, 2017) in a CoP, comprised of a group of people who collaborate in order to improve their performance in a certain area. Accordingly, collaborative learning encourages teachers to take on a leadership role, as well as delegating leadership roles to students rather than simply facilitating learning or transmitting all knowledge themselves (Wegner & Nückles, 2015).

The apprenticeship model of CoP (Mercieca, 2017) ensures constant opportunities for mentoring and coaching, which means that leadership is not fixed and can be shared among participants. Thus, CoP members establish links to their past life experiences, current CoP needs and the learning resources developed through the CoP's learning history (Mercieca, 2017; Wenger, 2012). It is therefore essential to establish rapport among

participants in the early stages of forming a CoP, especially when they come from diverse backgrounds (Mercieca, 2017; Wenger-Trayner, 2014).

To ensure that a CoP develops into a learning organisation, participants need to pursue individual self-inquiry while regularly checking their conceptual perceptions against expert practices (Reaburn & McDonald, 2017; Senge, 2006). Individuals are expected to contribute their personal vision to the group objectives, which is progressively refined through group discussions (Reaburn & McDonald, 2017; Senge, 2006).

The central component of a CoP is the domain that stimulates people to group around it, even when in other circumstances they might not necessarily be interested in interacting with each other (Mercieca, 2017; Wenger, McDermott, & Snyder, 2002). Membership in a CoP stimulates authenticity in experience sharing and, over time, leads to the development of a shared repertoire or shared practices that usually contain experiences, problem-solving strategies and stories that are continuously refined. In that way, membership results in the production of shared knowledge (Mercieca, 2017; Wenger, McDermott, & Snyder, 2002). CoPs have a complex structure containing the key elements of a domain of knowledge, shared practice, and a group of people. Given this complexity, it is essential to establish the right balance between CoP elements, avoiding ill-defined domains as well as ensuring the need for meaningful practice (Mercieca, 2017; Wenger, McDermott, & Snyder, 2002).

Digital Storytelling as a Context for Establishing a Community of Practice

Recent research emphasised that the gap between EFL and non-EFL students was only observed in groups of students and could not be localised to individual learning outcomes (Dąbrowska, 2019). Moreover, task design was reported to have a significant impact on learning outcomes (Dąbrowska, 2019). Unlike other tasks assigned to students, such as preparing a report or making a PowerPoint presentation, digital storytelling (DST)

allows students to elevate their levels of thinking beyond Bloom's Taxonomy (Ohler, 2013). In this way, students not only comprehend the information, but must internalise concepts by interweaving their perspectives into a story (Teehan, 2006). The effect of a DST teaching approach emerges as early as the planning stage, because students approach the content with the purpose of telling a story to a specific audience rather than simply finding and presenting information (Ohler, 2013; Teehan, 2006). By the time the final stage of digital storytelling has been reached, students have not only familiarised themselves with the concepts, but also developed an ability to think about them at a deeper level.

DST is recognised for its capacity to both engage and stimulate participation at an individual level (Westman, 2012). Being a blend of a broad variety of media, DST creates an authentic context for meaningful engagement in various social practices. As a domain within a CoP, DST actually empowers CoP formation and ensures participants' engagement (Mercieca, 2017). However, DST should not only be seen as a domain for the establishment of a CoP, but also as a new artefact contextualised in a particular time and space (Westman, 2012). The variety of concepts that can be sourced from STEM astronomy (STEM-A) courses may be able to extend the DST domain.

Considering DST's potential to unite participants from diverse socio-cultural backgrounds into a CoP that leads to a shared repertoire, it could then also serve as a pedagogical tool for disciplinary literacy enhancement. Torres, Ponce and Pastor (2012) argued that DST stimulates the development of all four language skills (listening, speaking, reading and writing) while continuously sustaining EFL students' attention and interest (Ohler, 2013). Over time, members consolidate their mutual respect and trust that can inspire lifelong learning beyond merely the course (Mercieca, 2017).

Methodology

Research Site

This research took place in one of the Kyrgyzstani Muslim schools with separate classes for male and female students. Shortly before the intervention the school had moved to a new location, so there was ongoing construction work in and around the school premises throughout. During the first visit to the research site the school principal organised a tour around the building.

The centrally located science classroom with adjoining rooms was chosen for implementation of the project. The principal confirmed that the adjoining areas could also be used, however, they were occupied throughout the intervention. When not used as a regular classroom, the adjoining rooms were occupied by younger girls doing their homework. The corridor-like passage leading from the intervention class to the storage room was usually occupied by students preparing for Olympiads or doing homework tasks. Consequently, students from other classes frequently interfered with the research participants' engagement in the course.

The classroom where the research took place was spacious, with cells leading to the windows stretching along both sides of the room. The windowsills were often used as storage shelves for books or stationery. In between the entrance door and the door leading to the former staff room was a huge green chalkboard that could be flipped over and used as a screen or a whiteboard. The furniture comprised non-customised desks, benches and chairs that could be easily rearranged in any desired layout. In the corner opposite the entrance door was a locked cabinet with glass doors where equipment for chemistry and physics lessons was stored. At the other end of the class opposite the chalkboard was a corridor with doors on each side leading to different storage rooms.

Participants

The school had separate classes for boys and girls, and the school principal had suggested that females participate in the course. The course was offered to students as a privilege and those who had misbehaved were not permitted to attend. Prior to commencing the course, the instructor met with the students, informed them about the project and distributed information letters and consent forms for their parents or guardians. Initially, 26 female students from Years 6 to 9 (10-16 years old) enrolled in the experimental extracurricular introductory astronomy course (STEM-A). However, after the first lesson, where students were asked to complete an Astronomy Diagnostic Test (ADT) in English (McKinnon, 2013), the number of students decreased to 14. Eventually, the students formed two groups to work on their video projects: (1) older girls group aged 13-16 (S1, 2, 3, 4, 6, 7 and 8), and (2) younger girls group aged 10-12 (S5, 9, 10, 11, 12, 13 and 14). Each of the two groups had regular members who not only worked in that group but also switched from group to group. Out of the 14 girls, only three (S2, 7, 9) attended all ten days of the course. It is also important to acknowledge that the Muslim religion follows the lunar calendar, and therefore participants in this study may already have acquired some culturally grounded background knowledge about moon phases, even though this knowledge was not explicitly measured in the study.

Ethics

This research project (15076) was approved by the Human Research Ethics Committee (HREC) of Edith Cowan University on March 8, 2017.

Muslim School Environment

The atmosphere within the school was like that of a big family, where everybody looked after one another, helped to maintain their "house" and fulfilled various duties and "house chores". Children were responsible for cleaning and could be enrolled in other

school events instead of attending regular lessons, such as the astronomy intervention. During the breaks there was a lot of noise as the girls ran around, jumped, fought and teased each other. It also appeared that the floor where the research took place was for boys, so at times there were some curious boys trying to join our activities.

Students had restricted access to the Internet. The Wi-Fi network could only be accessed through a portable USB modem, so that students could not access social media or other mobile apps at school. Students were also not permitted to use mobile phones at school, and if they needed to contact their parents they had to ask the principal or another adult to call them.

Language of Instruction

Kyrgyz was the first language for most students in the school, and while Russian was common, some were unable to speak it. Most of the teachers used Kyrgyz as the language of instruction and English was taught as a foreign language. In this group, students had different levels of proficiency in English. Even though earlier research revealed a need to translate some of the teaching resources, the school principal requested that all teaching instruction and materials be in English. Thus, the researcher only spoke English with the girls, while they were observed to interact with each other in three languages: Kyrgyz, Russian and English. While the videos for the research project were presented in English, the girls mainly spoke a combination of Kyrgyz/Russian during the DST development, and attempted to speak English when interacting with the teacher.

Procedures

The STEM-A lessons were conducted three times per week in the afternoon. During the first lesson, students completed the Astronomy Diagnostic Test (McKinnon, 2013). In lesson 2 students were introduced to the theory of video making and conducted an exploration of the causes of moon phases. From lesson 3 to lesson 7, the girls worked

mostly on their DST about moon phases in the early stages of the class. In the second half of the lesson they usually explored new astronomy concepts. This pattern was adopted by the teacher since only a few students always arrived on time; most were usually late due to the school culture that encouraged students to engage with different school and family- related duties, like cleaning the classroom or helping a teacher. Most of the girls had younger siblings studying at the same school, so they were expected to take care of them, buy them lunch and take them home after school. For example, a participant asked permission to leave one class early because she had to look after her younger siblings as her mother had to attend a parents' meeting.

Method

This research applied a qualitative approach, as its aim was to conduct an in-depth exploration of the mechanisms involved in EFL students' STEM-A disciplinary literacy development as a result of their engagement in digital storytelling. The research was designed as a Type II Case Study (Yin 2014), since the data were collected from two different groups of students in the same class: (1) older girls, and (2) younger girls.

Data Collection

The data on EFL student interactions during the process of video making were collected by placing digital voice recorders on the desks where students were sitting during the group work. Additionally, two small video cameras were placed unobtrusively on opposite sides of the classroom (i.e., next to the entrance and at the back of the class). Data were selectively extracted from the lessons when the two participating groups of students were working on their videos, as well as from the audio recordings, which were first transcribed by the author, also the course facilitator and observer. Data from the video recordings were used to triangulate the data from the audio recordings to gain a better

understanding of the context of the interactions. Table 6.1 presents the symbols used by the researcher in coding the transcripts. Students' interactions were transcribed verbatim.

Table 6.1. *Transcription Symbols*

Symbol	**Interpretation**
S	Student
T	Teacher
XXX	Incomprehensible utterance
Bold italics	Utterance in Russian
Normal font	Utterance in Kyrgyz
Normal italics	Utterance in English

Data Analysis

The transcripts of students' classroom interactions were analysed using discourse analysis (Jones, 2012). For the purposes of this analysis, the discourse was viewed as "chunks" of spoken language produced by the students and the teacher while making their videos about the moon phases (i.e., the astronomy phenomenon they had investigated earlier in the course). The analysis focussed on the discourse functions of the EFL students throughout their classroom interactions related to the digital storytelling process. This research was preceded by a pilot study (Chubko, Morris, McKinnon, Slater, & Lummis, 2019b) from which 43 classroom interaction patterns had emerged from EFL students' overall STEM-A course engagement. Those data were used as baseline data to inform the discourse analysis in the current study.

Data analysis involved inductive qualitative coding of the audio recording transcripts. These were later triangulated against the codes developed during the pilot study (Chubko et al., 2019b). After assigning codes, key themes were identified and explored in the discourse analysis (Jones, 2012; Schiffrin, 1994) with the aim of identifying patterns during EFL students' engagement with DST that resulted in their increased STEM-A disciplinary literacy development in English.

Results

Since the scope of the discourse analysis in this research was confined to students' classroom interactions in the process of DST, it allowed for more precise coding. Coding nine hours of classroom interactions among the 14 female EFL students engaged in making videos about moon phases resulted in 58 major discernible patterns, exceeding the baseline data by 14. However, the increased number was not only a result of more detailed coding, but also a reflection of the different approaches towards DST demonstrated by the participants in the two studies.

One reason for this difference was the simultaneous engagement of two different groups (older and younger girls' groups) in the production of a video on the same topic (moon phases) throughout the entire course. In the pilot study there were instances when two or more groups were making a video at the same time, but each group had their own topic and did not interact with other groups during the DST. Therefore, in the current study, additional codes such as *inter-group cooperation and inter-group comparison* emerged (Table 6.2). Additionally, conducting the research in a Muslim school resulted in the emergence of a *cultural reference* theme (Table 6.2).

In the discourse analysis, the 58 classroom interaction patterns were assigned to 11 key categories or speech acts: *collaboration, content, culture, expectations, feedback, language, storytelling, task, time, technology,* and *video production*. Table 6.2 elaborates the communicative functions of each of these speech acts and lists the themes for each of the categories.

Some of the themes were assigned to more than one category. For example, *task interpretation* simultaneously matches three categories: task, cooperation and language.

Table 6.2. *Speech Act Categories around EFL Students' Engagement with Video Making*

Speech Act	Communicative Function
Collaboration	Exemplifies how EFL students interact with each other within their group or with other groups or with a teacher in order to improve or scaffold their group's performance. The themes in this category are: *brainstorming, coaching, inter-group comparison, help request, inter-group cooperation, leadership, planning, progress report, role allocation, role nomination, shared knowledge construction, shooting, task allocation, task interpretation* and *task nomination.*
Content	Relates to the utterances referring to astronomy content. The themes in this category are: *arranging information and resources, content inquiry, content negotiation, content writing, establishing connections, misconceptions,* and *reasoning.*
Culture	Reflects EFL students' assumption that their interlocutors have sufficient background knowledge about Muslim religion, Kyrgyz culture, school culture, or popular culture to understand their utterance and effectively participate in the interaction. The themes in this category are: *cultural reference, greeting, personal questions, and singing.*
Expectations	Reflects EFL students' planning process and relate to the utterances when EFL students were making queries about task objectives or speculating about what approaches towards the task they need to adopt. The themes in this category are: *clarifying expectation, clarifying task format, clarifying the audience, reference to teacher's talk, setting objectives,* and *task anticipation.*
Feedback	Refers to the utterances when EFL students were seeking feedback from their peers or a teacher, were attempting to draw attention of their group members to their work or were expressing their attitude about their own work or the work of their peers. The themes in this category are: *attitudes, feedback request, group's feedback request, inter-group comparison, self-criticism,* and *self-praising.*
Language	The themes grouped under this category mainly have two distinct communicative functions bridging students' languages with the language of instruction, and focusing on language skills. The themes in this category are: *clarifying teacher's talk, content writing, establishing the language, language support request, reading, rehearsal, task interpretation, terminology, translation*, and *voice recording*.
Storytelling	Indicates that EFL students' utterances contain the distinct features of a narrative. The themes in this category are: *storytelling in English and storytelling in Russian.*
Technology	Reflects EFL students' interactions aimed at understanding, exploring, or exploiting the technology, iPads. The themes in this category are: *surprise* and *technology.*
Task	Reflects EFL students' attempts to engage with the task. The themes in this category are: *comprehension check, establishing connections, focus on task, task clarification, task interpretation and task timing.*

Speech Act	Communicative Function
Time	Includes the themes where EFL students' inquiry about the overall timing of the lesson, or emphasise that they need to focus on task more in order to complete it on time. The themes in this category are: *lesson timing* and *task timing*.
Video production	Reflects stages and processes involved in video-production. The themes in this category are: *arranging information and resources, brainstorming, drawing, planning, resources, scriptwriting, shooting, storyboarding* and *voice recording.*

An example is shown in excerpt 1 (lesson 3) below to show that this overlap is an outcome of complex classroom interactions where the students are attaining three communicative functions.

Excerpt 1 (Lesson 3)

Line	Speaker	Original Utterance	Translated Utterance
1	S1	*Чего?*	What?
2	S2	*У?*	An interjection that has a communicative function of a request to repeat the question
3	S1	Эмне деп айтты?	What did she say?
4	S3	XXX ким жакшы кылса, ошо	Those who do well, they will
5	S1	Биз ушул жакка келебиз?	Will we come here?
6	S3	Ооба	Yes
7	S2	Жок, бизге эмне керек болсо, үйдөн мына алып келебиз, өзүбүз даярдайбыз. Азыр жаз, фильм кандай болот, фильм кандай даярданабыз.	No, what do we need, we will bring it from home, XXX. Now we should write what kind of film we will have, how we will prepare for making a movie.

In lines 1 and 3 of excerpt 1, S1 asks her groupmates to interpret the teachers' words (*language*), thus opening the door for *cooperation* and signalling for her groupmates to contribute their knowledge so that she can effectively participate in the group *task*. In line 4, S3 translates the teacher's utterance in Kyrgyz. However, in line 5, S1 asks for clarification of a piece of information she is not certain about. Line 5 demonstrates the uncertainty expressed by S2 in line 2. Even though the initial inquiry by S1 was perceived

by S2 as being vague, S3 tries to help her friend. However, from the way S3 approaches S1's request for help, translating the teacher's utterance suggests that S3 was also uncertain about the specific information S1 was asking for. However, in line 5, S1 clarifies the information she missed. This helps S3 to conclude that she does not need to translate the full utterance of the teacher, as S1 is only confused about a certain part of the task.

Further, in line 7, S2 assumes that both of her group mates have misinterpreted the task and explains that they need to focus on planning so that they can find the necessary resources at home. Thus, excerpt 1 exemplifies how three students shared their understanding of the task assigned by the teacher. They started their interpretation with a general translation, followed by focussing on a specific gap in their understanding.

Demonstrating Community of Practice

Excerpt 2 below is an example of group work with five girls primarily engaged in speech acts involving video production, specifically, making a voice recording. As previously stated, particular themes could relate to more than one speech act, hence, excerpt 2 exemplifies a classroom interaction with multiple themes occurring simultaneously. These data demonstrate that video production was only one of the 11 speech acts in the classroom interactions around video making about moon phases, with much more complex patterns emerging. Primarily, the interaction is between two girls: the older girl, S4, coaching a younger girl, S5, to convey the text from their storyboard, while other girls, S4's group mates in the DST task, are actively observing the interaction.

Excerpt 2 illustrates which students took the term to a new level by *coaching* a younger girl in another group to use the term in order to produce a quality voice recording to add to their video about moon phases and potentially impress the younger girls. This example of shared knowledge construction, by passing on the group's knowledge to the less

knowledgeable, younger friends/team members, is a demonstration of CoP behaviour (Reaburn & McDonald, 2017; Wegner & Nückles, 2015) in a classroom setting.

Excerpt 2 (Lesson 6)

Line	Speaker	Original Utterance	Translated Utterance	Comments
1	S4	*Ты можешь это прочитать? 'Do you know?'*	Can you read it? 'Do you know'?	Older girls asked the younger girl to record her voice for their video help S5 to read difficult words
2	S5	*'Do you know?' А где?*	Do you know?' Where? Is it?	S5 asks where is the text she should read
3	S4	*That*		
4	S5	*Do you know that*		
5	S6	*Ты же не будешь говорить*	But you will not talk	S6 addresses S4
6	S5	*Moon is*		
7	S4	*Natural*		
8	S5	*Natural*		
9	S4	*Satellite of the Earth*		
10	S2	*Satellite*		
11	S5	*Satellite of the Earth*		
12	S7	*А теперь сама*	Try yourself now	
13	S2	*'Do you know'* айталган	Say 'do you know'	
14	S8	'*Do you know' мы же сказали уже*	But we already said 'do you know'	
15	S5	*That moon*		
16	S4	Is natural		
17	S4	*Satellite, of the Earth*		
18		XXX		
19	S6	*Подожди, давай русскими буквами напишем*	Wait, let's spell it with Russian letters	
20	S5	*Для меня*	For me	
22	S7	*Может ты просто будешь говорить так*	Maybe you will just speak this way	
23	S5	*Natural satellite*		
24	S2	*Moon is natural satellite of the Earth.*		

Line	Speaker	Original Utterance	Translated Utterance	Comments
25	S2	*Э, что ты опять пишешь?*	What are you writing again?	S2 asks S4
26	S5	*That moon is natural*		
27	S4	*Natural satellite*		
28		*XXX*		
29	S8	*Сюда говоришь* ok, мага айтты	Talk to here, ok, talk to me	
30	S5	*Угу*	Ok	
31	S8	*Зачем ты пишешь на английском?*	Why do you write in English?	
32	S5	*Тут непонятно*	It's not clear in here	
33	S4	*Earth, Earth*		
34	S2	*XXX знаешь? Знаешь такую букву на арабском?*	Do you know XXX, do you know such a letter in Arabic language?	
35	S5	*Эту не знаю*	This one I don't know	
36	S7	*Earth, Earth*		Girls start laughing
37	S6	*Earth, Earth, Earth*		
38	S5	*Moon is natural*		
39	S4	*Natural*		
40	S5	*Natural, э*	э- interjection that indicates the incomplete utterance where the speaker takes a pause for thinking how to continue the utterance	
41	S2	*Satellite*		
42	S5	*Satellite, of the Earth*		
43	S2	*Earth, Earth, Earth*		
44	S5	*Earth*		
45		*XXX*		S5 keeps practicing her speech
46	S4	*Не волнуйся, теперь ты просто повтори*	Don't worry, now simply repeat	S8 makes a voice recording of S5
47				Everybody applauds

What is interesting about this particular interaction is that the word "satellite", a new term for all of the group members, frequently occurs in excerpt 2. Earlier in the lesson

they had enquired about this word and eventually asked the teacher for help – this interaction is documented in the excerpt below (excerpt 3, line 20).

Excerpt 3 (Lesson 6)

Line	Speaker	Original Utterance	Translated Utterance	Comments
1	S6	*В начале начать типо,* Moon*, это спутник Земли.*	At the beginning we may start like, Moon is the Earth's satellite.	
2		XXX		
	S8	*Она сказала, всё своё надо сделать.*	She said we should make our own.	
3		XXX		
4	S8	*Вот всё, do you know that Moon is, сейчас спросим.*	That's it, do you know that Moon is, we will ask now.	
5	S7	*Спутник*	Satellite	
6	S2	*Of Earth, do you know*		
7	S8	*Do you know that*		
8				Girls keep rehearsing to utter the phrase 'do you know' with different intonations.
9	S7	*Сгуглим?*	Can we google it?	
10		XXX		
11	T	Do you need any help?		
12	S7	Do you know, we left one half, one half hour but we did say, 'do you know' listen, it's like baby said		
13		XXX		
14	T	Don't listen to what you say. First record everything, then you can listen		
15	S7	Do you listen to		
16	S2	Ал деп айтты, карабай жөнө деп еле, а, сүйлө иштеке болбойт.	She said, don't look, just speak, otherwise it will not work.	
17	S8	*Нам что заново что ли всё делать?*	Are we supposed to redo everything?	
18	S2	*Нет,* болду коркпойчу	No, don't be afraid.	
19	T	*What is your next picture?*		

Line	Speaker	Original Utterance	Translated Utterance	Comments
20	S8	*Do you know that, do you know, what спутник is?*	*Do you know that, do you know, what* ***satellite*** *is?*	S8 smiled after she pronounced 'do you know' for the first time.
21	T	*Satellite*		

It is evident that students are familiar with the concept of a satellite from the beginning of this interaction (excerpt 3, line 1), and in line 4 they reach a consensus that they need to ask someone for help in order to translate the term into English (*help request*). However, in line 7 the girls are still seeking an alternative solution to make sure there is no other option left besides asking the teacher. Since the teacher had been monitoring the students' progress, and at that specific point in the lesson, had the impression that they might need some scaffolding, she offered them assistance in line 11. Instead of immediately asking for a translation, the students first criticised the pace of their work. Line 12 illustrates multiple speech acts: feedback, since students reflect on the progress of their work; timing, since students criticise the pace of their work; collaboration, since this type of utterance indicates that they are ready to collaborate with a teacher in order to improve their progress; and expectations, since students positioned the overall group objectives, leading to an invitation for the teacher to contribute her expertise. It was only after students clarified their overall position in this collaboration that they asked for help, in the form of translating a term that hindered further development of their disciplinary discourse in English (line 20).

After receiving the required input, specifically a translation of the term *satellite* from the teacher (line 21) the students were able to add this term to their storyboard. Presumably, if they had simply written the word down or repeated it after the teacher, the concept might not have been understood in English. However, the need to use the term in their video created opportunities for multiple repetitions (excerpt 2).

Collaborative Knowledge Acquisition Pattern

Based on the data derived from the transcripts of students' interactions, it was evident that the process of video making supported the girls to establish a specific collaborative knowledge acquisition pattern, exemplified in excerpt 3. The complete cycle of this pattern consisted of eight stages, as shown in Figure 6.1. This pattern was evident throughout the entire data set and shows how a community of practice was operating within the STEM-A course.

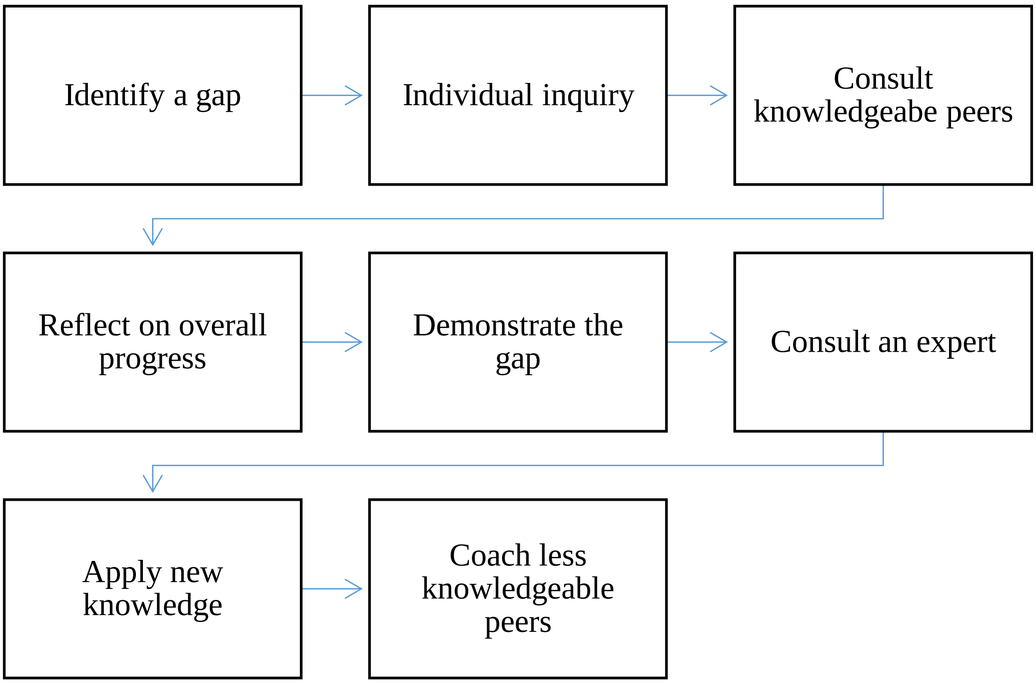

Figure 6.1. Collaborative Knowledge Acquisition Pattern

First, students identified the gap in their knowledge. Second, they attempted to cover the gap through individual inquiry. When they couldn't cope with the task on their own, they first addressed their more knowledgeable peers. This took students to the pool of collective knowledge. As a group, they reflected on the overall progress and considered whether their collective knowledge could cover the gap. When the collective pool of knowledge did not contain the required information, the students engaged in discourse that restated the gap and then consulted an expert, in this case the teacher, for the missing

information. Thus, rather than merely asking for a new word (excerpt 3), the girls demonstrated accountability for their work to make good use of the information received. After obtaining the missing information, they applied it to fill the established gap. Finally, the more knowledgeable students coached their less knowledgeable peers to apply this information, as an example of knowledge stewardship that typically occurs in CoPs (Wenger, McDermott, & Snyder, 2002)

Leadership

Leadership was one of the most significant themes identified in this dataset as it governs the establishment of a collaborative knowledge acquisition pattern (Figure 1), illustrated in excerpt 4. At first, S9 compared the group's work to that of the older girls (line 2). Later in the dialogue, S10 concluded that the work of the girls in the other group should be better because they are older (lines 5-7). Additionally, S10 expresses her belief that older people are smarter (line 7), probably stemming from Central Asian culture where elderly people are highly honoured and respected.

Excerpt 4 (Lesson L5)

Line	Speaker	Original Utterance	Translated Utterance
1	S10	*У них классно получилось.*	They made it very well.
2	S9	*Да, чем у нас.*	Yes, in comparison to ours.
3	S10	*Картинки, слишком детские.*	Pictures are too childish.
4	S9	*Да*	Yes
5	S10	*Ну они же все такие старше нас, и умнее, а мы такие молодые, да? Шучу, мы все молодые, но они*	Well, they are all older than us, and smarter, and we are so young, right? I'm joking, all of us are young, but they are
6	S9	*Старше?*	Older?
7	S10	*Умнее нас и старше*	Smarter than us and older.

Storytelling in Video-Making

Storytelling was another important theme to emerge from the data and typified an authentic approach to knowledge exchange (Ruddell, Danaia, & McKinnon, 2016) as encouraged by DST. Consistent with the pilot study (Chubko et al., 2019b), the need for

storytelling was triggered by a task where students were expected to explain the concept of moon phases to a younger sibling or friends. Therefore, students had to internalise the information (Teehan, 2006) and adjust their information delivery mode to relate to their specific audience. An ability to do so is regarded as a disciplinary literacy attribute (Moje, 2015). Excerpt 5 is an example of storytelling speech acts of the younger girls involved in this research. In line 1 we can see a typical fairy tale opening: "once upon a time" (*storytelling in English*) used together with repetitive adjectives ("dark-dark night"), another stylistic device commonly used in fairy tales.

Excerpt 5 (Lesson L3)

Line	Speaker	Original Utterance	Translated Utterance
1	S11	*Как-то раз XXX мы попали в XXX потом, когда был темный-темный вечер, мы хотели посмотреть на Луну.*	Once upon a time XXX then, when it was a dark-dark night, we wanted to look at the Moon.
2	S12	*Но Луны мало, не было.*	But there was little of the Moon, the Moon was not there.
3	S13	*Но Луна была полукарамыслом. XXX И мы посмотрели на Луну и увидели Луну полнлстью.*	But the Moon was as a half-beam. XXX And we looked at the Moon and saw whole of the Moon.
4	S12	*Давайте сделаем это, у нас в классе были фазы Луны на-на-на на-на-на. И нам дали домашнее задание.*	Let's do the following, in class we had Moon Phases, etc. And we were given a home task.
5		XXX	
6	S13	*Потом, плохо учились. Вспомнили когда уже пришли, и рассказывали друг другу фазы Луны.*	Then we did not study well. Remembered only when we came, and told each other about Moon Phases.
7		XXX	
8	S14	*А! Давайте типо,типо такой будет, Луна будет разговаривать. Еще Земля будет разговаривать. А потом она типо у Солнца спросит, 'ты знаешь все мои фазы?' А Земля отвечает, 'нет'.*	Ah! Let's make it like, like the Moon will speak. The Earth will also speak. And then it will kind of ask the Sun: 'do you know all my phases?' And the Earth will answer: 'no'.
9	S14	*А может Земля? Земля скажет, 'почему я тебя иногда вижу половину, а иногда целиком?'*	Maybe the Earth? The Earth will say: 'Why sometimes I only see a half of you, and sometimes the whole of you?'

Line	Speaker	Original Utterance	Translated Utterance
10		XXX	
11	S11	*Давайте вот, по английскому нужно.*	We need to make it in English.
12	S13	*Земля*	The Earth
13	S14	*Moon. You know my, как было?*	*Moon. You know my, how was it?*
14	S12	*Eight*	
15	S14	*Нет, My?*	No, My?
16	S11	*Phases*	
17	S14	*You know my?*	
18	S11	*Eight phases? You know my eight phases?*	
19		XXX	
20	S11	*Давайте на новом листке напишем, побольше.*	Let's write on a new piece of paper. Let's write more.

In this opening utterance, the girls adopted an insider perspective (Teehan, 2006), reflected in their selection of the first person narrative pronoun: "we" (lines 1 and 3). Additionally, they share their real-life experiences about observing the moon (lines 2 and 3).

In line 4 students attempt to connect their background life experiences with the newly acquired knowledge by affirming that they learned about moon phases at school (*establishing connections*). Animating key characters and endowing them with human features is another technique commonly used in fairy tales to introduce children to complex concepts. In lines 8 and 9, the sun, the earth and the moon are having a personified conversation. An important attribute in terms of shared knowledge construction is evident in line 9, when a human-like earth poses a question to a human-like moon. Here, students signal a problem that needs a solution and create a hook to attract the attention of their audience: The earth asks why, at different times, she sees the moon differently.

Developing the hook made the students return to the objective of the task that is, producing a video in English. From line 11, they start to integrate English into their discussion. In lines 13-18 we see another example of a shared-knowledge construction,

where students collaboratively acquire the term “phase”. Excerpt 6 shows the interactions of the older group completing the same task in a different approach to storytelling.

Excerpt 6 (Lesson 6)

Line	Speaker	Original Utterance	Translated Utterance
1	S8	*One day*	
2	S1	*Once upon a day вообще-то*	Actually, once upon a day
3	S8	*Это трейлер*	It’s a trailer
4	S4	*Вот это лучше, вот такой вот фон.*	It’s better, this kind of background
5	S8	*Это трейлер*	It’s a trailer
6	S4	*Да, знаю*	Yes, I know
7	S6	*Это лучше, к нам подходит больше*	It’s better, fits us more
8	S8	*Я тоже умею так делать, просто нам сказали movie делать.*	I also know how to make it this way, but we were asked to make a movie.
9	S2	*Нам сказали movie делать,* дейт.	She said, we were asked to make a movie.
10	S8	*Трейлер и так сделаем*	We will make a trailer anyway
11		XXX	
12	S1	*Лучше все написать.* Жаз ошону, жаз.	It’s better to write everything. Write, write this one.
13	S8	*Так, давайте, что-нибудь делайте*	Ok, you should do something
14	S7	*Текст дайте мне, А4.*	Give me text. A4.
15	S8	*А4,* мына.	A4, here you are.
16	S7	*В начале об игре, да, будем говорить?*	First, we’ll talk about the game, right?
17	S2	*На английском информацию*	Information in English
18	S7	*Что это такое вообще?*	What is this, at all?
19	S8	Это куда они попали	This is a place they got to
20	S2	*Earth and Moon*	
21	S7	*Were friends*	
22	S8	*Нет, мне нужно информацию*	No, I need information
23	S4	*У меня тут все написанно*	I have everything written here
24	S1	Мына, *перепиши*	Here you are, copy from here
25	S7	*Так, вначеле о чём будем говорить? О луне же, да?*	Ok, what about we will talk first? About the Moon, right?
26	S2	*Да*	Yes
27	S7	*Или о Земле?*	Or, about the Earth?
28	S2	*О Земле*	About the Earth

Line	Speaker	Original Utterance	Translated Utterance
29		XXX	
30	S4	*Я этот, я вообще о Земле ничего не писала, я только о Луне писала*	I, I didn't write anything about the Earth at all. I've only written about the Moon.

Although the older girls initially attempted to use a similar opening technique for their storytelling as the younger one (lines 1-2), they became more focused on the technical aspects of movie making (lines 3-15) rather than developing their story, only returning to the storytelling in line 16. In line 17 the older girls also propose code-switching their storytelling to English, signalling that the theme of "establishing the language" was a common feature in the discourse of both groups in this intervention (excerpt 5, line 11 and excerpt 6, line 17). However, while the older girls were more focused on the content of their story and explicitly stated that they needed information to continue their storyboarding (excerpt 6, lines 17 and 22), the younger girls were more focused on creating a story and were naturally incorporating the content as they spoke on behalf of the characters (excerpt 5, lines 13-18).

Discussion

The aim of this article was to explore the processes involved in a Kyrgyzstani Muslim school of EFL female students' STEM-A disciplinary literacy development facilitated by engagement with DST, and was guided by the research question: How do EFL students develop their astronomy disciplinary literacy in English when engaged in digital storytelling?

Discourse analysis of the students' interactions showed that DST functioned as a community of practice where students engaged with DST were CoP members (Mercieca, 2017; Wenger, McDermott, & Snyder, 2002; Wenger & Lave, 1998). The theory of CoP was applicable to this particular case of DST intervention because it embodied three key CoP elements: astronomy inquiry as the domain of knowledge; DST as a shared practice,

and volunteer EFL female students from a Muslim school as a group of people (Reaburn & McDonald, 2017; Wenger, 1998). What made this CoP structure different from learning language and content in other educational contexts is that participation was not enforced and participants were free to choose the duties and responsibilities they were willing to undertake to contribute to the groups' progress, as well as the extent of their contribution to these activities (Reaburn & McDonald, 2017).

A key finding to emerge from the interactions in this CoP exploration was the essential role of collaboration. The duration of this STEM-A course was only 10 days and it is therefore unlikely that the CoP formation was caused *by* the intervention. Presumably, elements of CoP were already nurtured in the school, and the DST intervention triggered a translation of existing CoP elements to the new circumstances. It could therefore be concluded that the short digital storytelling intervention will effectively enhance students' disciplinary literacy if integrated in a context with existing CoP-like structures, for example, where there were pre-existing relationships between individuals. The role of collaboration and CoP relationships in this study is consistent with other CoP research that asserts there should be time for participants to socialise and develop trust in order to create belonging within the community (Reaburn & McDonald, 2017).

In this DST intervention, video production comprised only one of the 11 speech acts identified from the Muslim girls' classroom interactions around moon phases and suggests that making the videos acted as a vehicle for complex speech acts about the content whereby students developed their disciplinary literacy. Importantly, the category of collaboration was tightly intertwined with other key speech acts, further contributing to the argument that learning is a socially enhanced process (Allison, 2011; Wegner & Nückles, 2015) and better attained through collaboration.

The girls from the Muslim school in Kyrgyzstan were familiar with each other and shared the same culture and language background prior to joining this astronomy course. Engaging with making videos during the STEM-A course reinforced their collaboration and facilitated their STEM-A literacy development, as demonstrated by the older girls helping the younger girls during the entire course even though they were working in two independent age-based groups. Students demonstrated the importance of leaders within collaborative activities, whereby more knowledgeable CoP members become established role models through personal excellence and willingly support their less knowledgeable peers in order to attain the common goal of their CoP.

Analysis identified collaboration as an essential factor in developing students' discipline literacy and was a key finding in this research, where the collaborative knowledge construction model was representative of knowledge stewardship in an established CoP (Wenger, McDermott, & Snyder, 2002). This model was employed by the girls in acquiring new knowledge, and differs from the usual teaching approaches in remedial English language programs that are aimed at supporting content learning through explicit language instructions (Díaz Pérez, Fields & Marsh, 2018; Yang, 2016). The important difference of the model in this study is the students' ability to consciously identify gaps in their individual knowledge. This is the point where a CoP develops into a learning organisation (Senge, 2006; Reaburn, & McDonald, 2017) and learning becomes meaningful and authentic for the participants, as they feel a need for individual improvement in order to sustain their CoPs functionality (Mercieca, 2017; Wenger, McDermott, & Snyder, 2002). Personal motivation to improve was seen in the speech acts in all excerpts, including rehearsing key terms and addressing more knowledgeable peers to enhance content writing.

While not explicitly described in the selected excerpts, the CoP structure in this study held every member accountable for their own learning as each was responsible for

contributing to the overall project. Coded as task allocation or task nomination, this kind of individual accountability, attained from the integration of DST into STEM-A course, was essential for the overall success of the group (Westman, 2012). DST engaged EFL students in authentic and meaningful writing as they prepared a storyboard to be able to film and produce their movie. Everybody was responsible for writing text for a particular shot, at the same time contributing to the bigger project. Moreover, the practice of knowledge stewardship (Wenger, McDermott, & Snyder, 2002) maintained the continuity of learning, whereby the less knowledgeable students benefited by learning from more knowledgeable peers through the appropriate amount of scaffolding (Kozulin, 2011; Vygotsky, 1935, 1962).

Limitations

One challenge was transcribing these interactions due to the low audibility in the audio and video recordings given the number of children in the classroom and construction work outside. This limitation was resolved by audio editing the recordings in Adobe Premiere Pro 2019 video editing software that allowed for compression of the background noise and emphasised the voices of the speakers in the immediate proximity of the recording device.

Other limitations were the small sample size and lack of control groups – these were alleviated by the embedded case study design. Although the results of this study cannot be generalised to other contexts, they nevertheless provide a unique understanding of the classroom interactions among EFL students during video making and contribute to the body of knowledge about disciplinary literacy acquisition in a foreign language. The risk of participant observation creating bias in the data interpretation was mitigated against through triangulation with the pilot study and using multiple sources of data.

Conclusions

The major factor that can explain the success of the STEM-A intervention in the Muslim school is the CoP-like culture that was already established among the girls prior to their participation in this intervention. The voluntary nature of students' participation in the course and the succession order established among the older and younger girls served to nurture the CoP among the research participants. In the process of making videos the girls demonstrated collaborative knowledge construction patterns that could explain the gains made in their STEM-A literacy development, particularly enhanced through leadership and negotiating the process of DST. Collaboration and its associated speech acts were the greatest factor evident in the analysis of the data and provide credible evidence to support CoP development for STEM learning in an EFL context.

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CHAPTER SEVEN: CONCLUSIONS

In response to the global trend of increased cultural and linguistic diversity among student populations combined with a growing demand for English-speaking STEM professionals, this study incorporated the design and development of an extracurricular STEM-A course in English enhanced with DST. It was aimed at evaluating the capacity of digital storytelling as a pedagogical approach to bridge the disciplinary literacy divide between EFL and non-EFL students. Specifically, the study examined Kyrgyzstani EFL students' STEM-A disciplinary literacy development in English.

To gain an in-depth understanding of EFL students' STEM-A literacy acquisition and refine the integration of a DST teaching approach, the study was executed in four action research cycles. The first cycle initiated the researcher's apprenticeship in a STEM-A teaching career, a critical point in the study, as it informed the ensuing research and made an important contribution to the emerging body of knowledge on teachers' STEM disciplinary literacy development (Hart & Bennett, 2013; Lemley, Hart, & King, 2019; Moje, 2015).

The main outcome of the first cycle was the adoption of an inquiry approach to teaching (Prairie & Buckleitner, 2005), a deviation from the conventional science education model focused on scientific community knowledge transmission (Aikenhead & Huntley, 1999; Haydock, 2011). Instead, the teaching approach engaged students in authentic science inquiry (McKinnon, 2013; Prairie & Buckleitner, 2005). The skills developed during the four phases of transition (content knowledge acquisition, active inquiry, pedagogical knowledge acquisition, and technology skills acquisition) facilitated evolution of the researcher's pedagogy from identifying key scientific terms in English STEM-related texts (Aikenhead & Huntley, 1999; Rezai, Derkhshan & Bagherkazemi, 2011) and explaining them to EFL students to one that nurtured students' ability to create a digitally-supported context for engaging in scientific inquiry.

The second action research cycle was a small-scale pilot case study (Yin, 2014). It provided evidence of the impact of engaging adolescent Kyrgyzstani EFL students' in a STEM-A course enhanced with DST, with positive results on their astronomy content knowledge acquisition in English as reflected in their post-ADT scores. The pilot also identified a correlation between higher ADT scores and higher numbers of videos produced.

The discourse analysis of the lessons in the pilot study revealed that DST created an authentic need for students to do their writing in English (Chubko, 2017; Laycock & Stephenson, 1993; Ohler, 2006; Sprague & Pixley, 2008). This occurred by shifting the need for students to accomplish a big piece of writing on their own to a collaborative writing process in order to produce a video. In this way, writing in English became process driven. Since students had control over the choice of information being presented, they were encouraged to share their revelations with their peers and voluntarily engage in exploratory peer-edited English writing. Besides facilitating their engagement in English writing, the students also improved their STEM-A disciplinary literacy, reflected in their pre- and post-ADT SOLO ratings (Biggs & Collis, 1982). Positive gains in SOLO scores indicated that students transitioned to more advanced levels of English expression and therefore enhanced their disciplinary literacy in a foreign language (Biggs & Tang, 2011; Campbell, Smith, & Brooker, 1998; Rembach & Dison, 2016).

The third cycle of the action research did not reveal the same positive impact of the DST intervention as the pilot study. The key limitation was the sequence of the course that did not allow sufficient time for DST topics linked to the ADT-test and therefore did not provide an accurate measure of the DST impact. This necessitated that the course be revised to a flipped model.

The data obtained from the third cycle showed that DST intervention can reduce the disciplinary literacy gap between EFL and non-EFL students (Department of the Prime

Minister and Cabinet, 2018; Fleckenstein, Leucht, Pant, & Köller, 2016; The Nation's Report Card, 2015). Moreover, the EFL students who attained the best SOLO scores were students from a Muslim school. Consequently, the fourth cycle explored the language interactions in this case in order to identify the reasons for the students' disciplinary literacy gains, the greatest of all the EFL cases, and narrowed the gap between native English speakers (shown through comparison with the Australian sample).

The classroom interactions of the female EFL students at the Muslim school showed they were following an eight-stage interaction pattern that facilitated a deeper conceptual acquisition of English when engaged in DST about moon phases. Additionally, the discourse analysis showed their interactions incorporated the key features of a CoP (Lave & Wenger, 1991), the most prominent of these being knowledge stewardship (Wenger, McDermott, & Snyder, 2002). Exemplified in this research, this was enabled through the eight-stage classroom interaction pattern whereby more knowledgeable peers acted as leaders and coached their less knowledgeable peers. Engagement with DST encouraged the students to translate their existing school CoP culture to the STEM-A context that facilitated collaborative learning and improved their STEM-A disciplinary literacy development in English.

Recommendations

The data suggest that STEM-A literacy development of EFL students can be fostered through an eight-stage classroom interaction pattern that encourages knowledge stewardship. Integrating DST with STEM-A offered multiple opportunities for social interaction and for students to practice their disciplinary literacy in English, resulting in both literacy and content knowledge gains. DST supported shared knowledge construction, and over time, established a CoP that fostered knowledge stewardship. Based on these conclusions, the following recommendations are made:

1. Disciplinary literacy development should be supported by programs that meaningfully integrate English learning in context, as this study showed greater gains in disciplinary literacy when engaged in a STEM-A context.

2. Writing in English can be encouraged by using process-driven approaches with EFL learners rather than product-driven learning. In this study, EFL learners were positively engaged in English writing when they had autonomy over the task and the product was not assessed.

3. Digital storytelling is a viable teaching approach for engaging EFL learners, not only because of the way in which language learning becomes process-driven, but also because of the social and collaborative opportunities it affords students for practicing their English-speaking skills.

4. ESOL teachers require training in content areas if they are to adequately teach disciplinary literacy. Understanding the meaning of terms is not enough if teachers are to help students correctly define and use English terms in their disciplinary STEM-A learning. Consequently, TESOL teachers require support to develop their own disciplinary literacy so that they can, in turn, support students.

Limitations

The small sample size and non-randomised sampling procedures limit interpretation of the research outcomes to the unique contexts described in this research. However, the action research design and multiple data sources allowed for triangulation of the outcomes and strengthened their validity and reliability. Hence, this research offers unique insights into the process of EFL students' astronomy disciplinary literacy development in English mediated by digital storytelling.

Implications

This research contributes to the body of knowledge on integrating technology in STEM education. It exemplifies the process of STEM-A course design and refinement. In addition, the study enhances our understanding of classroom interaction patterns that enhance EFL students' disciplinary literacy development while making videos about astronomical phenomena. The data suggest that a collaborative learning environment, leading to shared knowledge construction and engagement in authentic inquiry are critical to EFL students' success.

Further Research Recommendations

This research established a solid background for understanding the construct of scientific disciplinary literacy and validated the use of the SOLO taxonomy (Biggs & Collis, 1982) as a tool for measuring it. However, the definition of scientific disciplinary literacy adopted in this research reflects only the research in education. The argument that the level of thinking can be measured by the increase in the complexity of the sentence structure of students' reasoning and establishes a ground for linking this research to the research about cognitive flexibility (Schommer-Aikins. & Easter, 2018; Spiro, Collins, & Ramchandran, 2007; Spiro, Feltovich, Jacobson, & Coulson, 1991) to enable a more holistic understanding of this construct. Hence, I recommend further explorations of the construct of scientific disciplinary literacy from the perspective of the cognitive psychology.

As the sample size was one of the major limitations to this research, I suggest it would be necessary to conduct this intervention with a larger number of research participants, controlling for the age groups, language and culture backgrounds, and students' gender. Implementing a longer timeframe could also allow tracking the mechanisms of the CoP formation among students who were not familiar with each other prior to their participation in the research. Additionally, I suggest that a DST teaching approach can be

applied beyond the astronomy context and can be equally beneficial for both, EFL and non-EFL students.

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APPENDIX A

Executive Director of Continuing Education Centre
INFORMATION LETTER

Project title:
Engaging Year 4-7 English Language Learners with Making Videos to Enhance their Literacy and Content Knowledge in Astronomy

Invitation

Dear Executive Director of Continuing Education Centre [Name],

I would like to invite the Continuing Education Centre to participate in my PhD research *project Engaging Year 4-7 English Language Learners with Making Videos to Enhance their Literacy and Content Knowledge in Astronomy* that I would like to conduct during school winter holidays 2017-2018. This project will look at the science literacy development outcomes of engaging EFL/ESL (English as a foreign or second language) students in making videos about their learning of Astronomy.

Before the Continuing Education Centre decides whether or not you wish to participate in this study, please take the time to read the following information carefully and discuss it with others if you need.

1. What is the purpose of this study?

The context for this research comes from the Australian Cultural Sky Stories (CSS) project and extends the CSS project with the video-making intervention. This project will explore how making videos while learning Astronomy could improve students' engagement with learning science and enhance their science literacy and content knowledge.

2. What does this study involve?

I would be a facilitator of a 10-day workshop during which I would like to introduce students to working with a video camera and video-editing software and encourage them to create a series of videos about the concepts they learn during the CSS project. I anticipate that during this project students will be able to create 5- 9 videos about astronomy concepts.
I will audio and video record participating students' classroom interactions during my lessons

and will use classroom observation checklists to analyse their science literacy development and engagement in the process of making videos.

Ideally, students will work in groups of four, or three, to discuss what they learn during the science lessons and create a video about their understanding of what they learn. Results of the collected audio and video data will only be seen by myself and my university supervisors.

3. Are there risks or benefits in taking part in this study?

There are no foreseeable risks associated with you taking part in this project. I anticipate that participation in the project will increase the school students' engagement with learning science, increase their understanding of Astronomy and enhance their literacy.

4. To what extent is participation voluntary, and what are the implications of withdrawing participation?

Participation in this research project is entirely voluntary. If any member of a participant group decides to participate and then later changes their mind, they are able to withdraw their participation at any time. There will be no consequences relating to any decision by an individual, other than those already described in this letter. Decisions made will not affect the relationship with the researchers or Edith Cowan University.

5. What will happen to the information collected, and is privacy and confidentiality assured?

Information that identifies anyone will be removed from the data collected at the earliest stage possible. The data will then be stored securely in a locked cabinet at Edith Cowan University and will only be accessed by the researchers. The data will be stored for a minimum period of 5 years, after which it will be destroyed.

Participants can withdraw from the research project at any time. In case of a withdrawal, they will be given the option for their classroom observation checklist data to be destroyed

immediately. However, it will not be possible to destroy the audio and video recordings taken before their decision to withdraw their child(ren) from the research project because it has the data from other participants.

The identity of participants and the Centre will not be disclosed at any time, except where the researcher is legally required to disclose that information or under the Department of Education *Child Protection* policy. Participant privacy, and the confidentiality of information disclosed by participants, is assured at all other times.

Research findings will be reported in the PhD thesis and will be published in peer-reviewed educational journals.

6. Is this research approved?

Edith Cowan University Human Research Ethics Committee has approved the research, and permission has been obtained from the Department of Education to conduct this project. A copy of the research approval letter to indicate this project has met the policy requirements of the Department of Education is enclosed.

7. Does the researcher have a Working with Children Check?

Yes. The Chief Investigator has a current Working with Children Check that will be presented to the school prior to the beginning of data collection.

8. What should I do if I would like to participate?

If the school would like to participate could you please sign the informed consent document attached and return it in via email or in person.

If you would like further information please contact:

Researcher:

Ms Nadia Chubko, MA in TESOL
School of Education
Edith Cowan University, Perth WA
Phone: [redacted]
E-mail: [redacted]

Principal Supervisor:

Dr Julia Morris, PhD
Edith Cowan University, Perth WA
Phone: (08) 6304 6289
E-mail j.morris@ecu.edu.au

If you have any complaints or reservations about the ethical conduct of this project, you may contact:

Research Ethics Officer
Edith Cowan University
270 Joondalup Drive
JOONDALUP WA 6027
Phone: 6304 2170; Fax: 6304 2661
Email: research.ethics@ecu.edu.au

Thank you for considering this invitation. This information letter is for you to keep.

APPENDIX B

Principal of the School
INFORMATION LETTER (English)

Project title:
Engaging EFL/ESL Year 4-7 School Students with Making Videos to Enhance their Literacy and Content Knowledge in Astronomy

Invitation

Dear Principal [Name],

I would like to invite your school to participate in my PhD research *project Engaging EFL/ESL Year 4- 7 School Students with Making Videos to Enhance their Literacy and Content Knowledge in Astronomy* that I would like to conduct in September 2018. This project will look at the science literacy development outcomes of engaging EFL/ESL (English as a foreign or second language) students in making videos about their learning of Astronomy.

Before your school decides whether or not to participate in this study, please take the time to read the following information carefully and discuss it with others if you need.

1. What is the purpose of this study?

The context for this research comes from the Cultural Sky Stories (CSS) project and extends the CSS project with the video-making intervention. This project will explore how making videos while learning Astronomy could improve students' engagement with learning science and enhance their science literacy and content knowledge.

2. What does this study involve?

I would be a facilitator of a 10-day workshop during which I would like to introduce students to working with a video camera and video-editing software and encourage them to create a series of videos about the concepts they learn during the CSS project. I anticipate that during this project students will be able to create 1-5 videos about astronomy concepts.

I will audio and video record participating students' classroom interactions during my lessons and will use classroom observation checklists to analyse their science literacy development and engagement in the process of making videos.

Ideally, students will work in groups of four, or three, to discuss what they learn during the science lessons and create a video about their understanding of what they learn. Results of the collected audio and video data will only be seen by myself and my university supervisors.

3. Are there risks or benefits in taking part in this study?

There are no foreseeable risks associated with you taking part in this project. I anticipate that participation in the project will increase the school students' engagement with learning science, increase their understanding of Astronomy and enhance their literacy.

4. To what extent is participation voluntary, and what are the implications of withdrawing participation?

Participation in this research project is entirely voluntary. If any member of a participant group decides to participate and then later changes their mind, they are able to withdraw their participation at any time. There will be no consequences relating to any decision by an individual, other than those already described in this letter. Decisions made will not affect the relationship with the researchers or Edith Cowan University.

5. What will happen to the information collected, and is privacy and confidentiality assured?

Information that identifies anyone will be removed from the data collected at the earliest stage possible. The data will then be stored securely in a locked cabinet at Edith Cowan University and will only be accessed by the researchers. The data will be stored for a minimum period of 5 years, after which it will be destroyed.

Participants can withdraw from the research project at any time. In case of a withdrawal, they will be given the option for their classroom observation checklist data to be destroyed immediately and no further video recordings will be made. However, it will not be possible to destroy the audio and video recordings taken before their decision to withdraw their child(ren) from the research project because it has the data from other participants.

The identity of participants and the center will not be disclosed at any time, except where the researcher is legally required to disclose that information or under the Department of Education *Child Protection* policy. Participant privacy, and the confidentiality of information disclosed by participants, is assured at all other times.

Research findings will be reported in the PhD thesis and will be published in peer-reviewed educational journals.

6. Is this research approved?

Edith Cowan University Human Research Ethics Committee has approved the research.

7. Insurance policy

All equipment provided for the research is covered by ECU insurance policy.

8. What should I do if I would like to participate?

If the school would like to participate could you please sign the informed consent document attached and return it in via email or in person.

If you would like further information please contact:

Researcher:
Ms Nadia Chubko, MA in TESOL
School of Education
Edith Cowan University, Perth WA
Phone: [redacted]
E-mail: [redacted]

Principal Supervisor:
Dr Julia Morris, PhD
Edith Cowan University, Perth WA
Phone: (08) 6304 6289
E-mail j.morris@ecu.edu.au

If you have any complaints or reservations about the ethical conduct of this project, you may contact:

Research Ethics Officer
Edith Cowan University
270 Joondalup Drive
JOONDALUP WA 6027
Phone: 6304 2170; Fax: 6304 2661
Email: research.ethics@ecu.edu.au

Thank you for considering this invitation. This information letter is for you to keep.

APPENDIX C

Information Letter Principal of the School (Russian)

ИНФОРМАЦИОННОЕ ПИСЬМО ДЛЯ ДИРЕКТОРА ШКОЛЫ

Название проекта:

Участие учеников 4-7 классов школ с изучением английского языка как второго/иностранного в создании видеороликов для повышения их уровня знаний и грамотности в области астрономии

Приглашение

Уважаемый директор [ФИО],

Я бы хотела пригласить возглавляемую Вами школу принять участие в моем исследовательском проекте в рамках соискания степени доктора философских наук (PhD). Проект под названием «*Участие учеников 4-7 классов школ с изучением английского языка как второго/иностранного в создании видеороликов для повышения их уровня знаний и грамотности в области астрономии*» будет проведен в сентябре 2018 года. Проект направлен на выявление того, как создание учениками на занятиях по астрономии видеороликов по пройденному материалу влияет на их результаты обучения и уровень знаний.

Прежде чем Вы примете решение об участии в данном исследовании, прошу Вас внимательно ознакомиться с информацией, приведенной ниже, и, если необходимо, обсудить Ваше решение с другими лицами.

1. Цель проекта

Идея данного исследовательского проекта основывается на австралийском образовательном проекте «Cultural Sky Stories»[1]. Отличием моего проекта является возможность создания учащимися видеороликов о том, что они изучают. Цель проекта

[1] Проект направлен на понимание учащимися начальной и средней школы связи между наукой, технологиями, инженерией и математикой в контексте астрономии.

заключается в том, чтобы понять, как создание видеороликов на занятиях по астрономии может повлиять на повышение научной грамотности, усвоение предмета, а также знание учащимися содержания преподаваемого материала.

2. Содержание проекта

Данное исследование будет проходить в рамках 10-ти дневного курса по астрономии. В ходе этого курса я буду обучать детей работе с видеокамерой и программами для редактирования видеоматериалов с целью создания роликов о пройденном за время урока материале.

Ожидается, что за время курса ученики смогут создать от 1 до 5 видеороликов о том, что они узнали на занятиях по астрономии.

Аудио- и видеозаписи занятий, а также данные наблюдений в классе будут использоваться мной для анализа повышения уровня знаний учащихся в процессе создания видеороликов.

Предположительно, учащиеся, объединившись в группы по 3-4 человека, будут обсуждать изученный материал и затем создавать видеоролики, отражающие их понимание темы. Доступ к аудио- и видеозаписям буду иметь только я и научные руководители данного проекта.

3. Риски и выгода от участия в проекте

Участие в данном исследовательском проекте не предполагает каких-либо рисков. Я ожидаю, что участие в проекте повысит интерес учеников к изучению точных наук, поможет им освоить основы астрономии и улучшит их знание данного предмета.

4. Добровольный характер участия в проекте

Участие в этом исследовательском проекте полностью добровольное. Учащиеся, принявшие решение об участии в проекте, могут изменить свое мнение в любой момент и прекратить участие в проекте. Принимаемые решения не влекут за собой никаких последствий, кроме участия или неучастия в проекте. Они также никоим образом не влияют на отношения с исследователями и Университетом имени Эдит Кован.

5. Конфиденциальность и анонимность

Вся информация, связанная с идентификацией личности, будет удалена из собранных данных на начальных этапах анализа. После этого информация будет храниться в сейфе Университета имени Эдит Кован и будет доступна только исследователям. Срок хранения информации до полного ее удаления составляет пять лет.

Учащиеся могут прекратить участие в проекте в любое время. В этом случае мы сможем удалить все его/ее данные из контрольного перечня наблюдения за уроком. Однако, видео- и аудиоматериалы, созданные до принятия решения об отказе от участия, удалить будет невозможно, так как они будут содержать ценную информацию об опыте изучения астрономии других участников.

Личности участников исследования не будут разглашены, кроме тех случаев, когда этого требует закон или Отдел по защите прав ребенка. Во всех остальных случаях конфиденциальность и анонимность данных участников гарантируется.

Результаты данного исследования будут опубликованы в докторской диссертации, а также научных педагогических журналах.

6. Процесс утверждения

Комитет по исследовательской этике Университета имени Кована утвердил данное исследование. Копия соответствующего письма, подтверждающего, что проект соответствует требованиям политики Департамента образования, прилагается.

7. Политика страхования

Все оборудование, предоставленное для проведения исследования, застраховано в рамках политики страхования Университета имени Эдит Кован.

8. Как принять участие в проекте?

Если Ваша школа желает принять участие в исследовании, пожалуйста, подпишите прилагаемую форму информированного согласия и передайте ее мне лично или перешлите по электронной почте.

За дополнительной информацией, пожалуйста, обращайтесь к:

Исследователю:
Чубко Надежда, магистр гуманитарных наук в области преподавания английского языка как иностранного (MA in TESOL)
Педагогический факультет
Университет имени Эдит Кован,
Перт, Западная Австралия
Тел.: [redacted]
Эл. почта: [redacted]

Руководителю проекта:
Др. Моррис Джулия, доктор философских наук (PhD)
Университет имени Эдит Кован,
Перт, Западная Австралия
Тел.: (08) 6304 6289
Эл. почта: j.morris@ecu.edu.au

В случае возникновения жалоб или вопросов касательно этического аспекта данного проекта, пожалуйста, свяжитесь с сотрудником Комитета по исследовательской этике Университета имени Эдит Кован:

Адрес: 270 Joondalup Drive
JOONDALUP WA 6027
Эл. адрес: research.ethics@ecu.edu.au
Тел.: 6304 2170 Факс: 6304 2661

Благодарю за внимание!

Сохраните данное письмо в целях информации.

APPENDIX D

CONSENT FORM (Principal)
English

EDITH COWAN UNIVERSITY
SCHOOL OF EDUCATION

Research Project Title:

Engaging EFL/ESL Year 4- 7 School Students with Making Videos to Enhance their Literacy and Content Knowledge in Astronomy

I,____(PLEASE PRINT)
Principal of the School [Name:]

give consent to participation by myself and the school in the research project titled: *Engaging EFL/ESL Year 4- 7 School Students with Making Videos to Enhance their Literacy and Content Knowledge in Astronomy.*

The purpose of the research has been explained to me. I understand that I am free to withdraw my participation, and that of my school in the research, at any time.

I understand that any information or personal details gathered during this research about me are confidential and that neither my name nor any other identifying information will be used or published without my written permission. Additionally, I understand that data obtained during this research will be securely stored by Edith Cowan University for a period of five years.

Digital data will be deindentified and stored on a password-protected computer.

The Edith Cowan University Ethics in Human Research Committee has approved this study. I understand that if I have any complaints or concerns about this research I can contact:

Research Ethics officer
Edith Cowan University
270 Joondalup Drive; JOONDALUP WA 6027

Phone: 6304 2170; Fax: 6304 2661; Email: research.ethics@ecu.edu.au

I understand that any issues raised will be treated in confidence and investigated fully and I will be informed of the outcome.

Signature:________________________________Date:___________________________

APPENDIX E

CONSENT FORM (Principal)

Russian

УНИВЕРСИТЕТ ИМЕНИ ЭДИТ КОВАН
ПЕДАГОГИЧЕСКИЙ ФАКУЛЬТЕТ

Название исследовательского проекта:

Участие учеников 4-7 классов школ с изучением английского языка как второго/иностранного в создании видеороликов для повышения их уровня знаний и грамотности в области астрономии

ФОРМА СОГЛАСИЯ ДИРЕКТОРА ШКОЛЫ НА УЧАСТИЕ В ИССЛЕДОВАТЕЛЬСКОМ ПРОЕКТЕ

Я,____(ПЕЧАТНЫМИ БУКВАМИ)
Директор школы [ФИО:]

настоящим даю согласие на свое участие и участие возглавляемой мною школы в исследовательском проекте под названием *«Участие учеников 4-7 классов школ с изучением английского языка как второго/иностранного в создании видеороликов для повышения их уровня знаний и грамотности в области астрономии»*.
Я был (-а) проинформирован (-а) о цели настоящего исследования. Я понимаю, что могу в любой момент прекратить свое участие/участие школы в проекте.

Я понимаю, что вся информация и мои личные данные, собранные во время этого исследования, являются конфиденциальными и что ни мое имя, ни какая-либо другая идентифицирующая информация не будут использоваться или публиковаться без моего письменного разрешения. Кроме того, я понимаю, что данные, полученные в ходе этого исследования, будут находится на хранении Университета имени Эдит Кован в течение пяти лет с соблюдением всех процедур надежного хранения. Цифровые данные не будут содержать идентифицирующей меня/школу информации и будут храниться на компьютере, защищенной паролем.

Комитет по исследовательской этике Университета имени Эдит Кован утвердил данный исследовательский проект. Я понимаю, что в случае возникновения у меня жалоб или вопросов по этическому аспекту данного исследования, я могу связаться с сотрудником Комитета по исследовательской этике имени Эдит Кован:

Адрес: 270
Joondalup Drive
JOONDALUP
WA 6027

Эл.адрес: research.ethics@ecu.edu.au

Тел.: 6304 2170

Факс: 6304 2661

Я понимаю, что любые поднимаемые мной вопросы будут рассмотрены с соблюдением конфиденциальности, полностью изучены, и я буду проинформирован (-а) о результатах рассмотрения.

Подпись:________________________________Дата:_________________________

APPENDIX F

PARENT/GUARDIAN INFORMATION LETTER

English

Project title:

Making Videos about Learning during the Astronomy Lessons

Invitation

Dear Parent/ Guardian,

My name is Nadezhda Chubko and I am a PhD student within the School of Education at Edith Cowan University (ECU). I am writing to invite your child(ren) to take part in an educational research project that will engage students in making videos about their learning of Astronomy.

Before you decide whether or not you wish your child(ren) to participate in this study, please take the time to read the following information carefully and discuss it with others if you need to do so.

1. What is the purpose of this study?

The context for this research project comes from the Cultural Sky Stories (CSS) project and extends the CSS project with a video-making intervention. This project will explore how making videos while learning Astronomy could improve students' engagement with learning science and enhance their science literacy and content knowledge.

2. What does this study involve?

I will facilitate the 10-day program about astronomy. During this program I will introduce students to working with a video camera and video-editing software and they will make videos about the astronomy concepts that they learn during the CSS project.

I will audio and video record students' lessons of science and will use classroom observation checklists to analyse these recordings and explore students' science literacy development in the process of making videos.

All the audio and video recordings made during this research will be confidential. Only me and my supervisory team will be able to see them.

3. Are there risks or benefits in taking part in this study?

There are no foreseeable risks associated with you taking part in this project. I anticipate that taking part in this project will increase students' engagement with learning science, increase their understanding of Astronomy and enhance their subject literacy.

4. How will confidentiality be protected?

Information that identifies anyone will be removed from the data collected at the earliest stage possible. The data will then be stored securely in a locked cabinet at Edith Cowan University and will only be accessed by the researchers. The data will be stored for a minimum period of 5 years, after which it will be destroyed.

If you decide to withdraw your child(ren) from the research project at any time, you will be given the option for their classroom observation checklist data to be destroyed immediately and no further video recordings will be made. However, it will not be possible to destroy the audio and video recordings made before your decision to withdraw your child(ren) from the research project because it includes data from other participants.

The identity of participants will not be disclosed at any time, except where the researcher is legally required to disclose that information or under the Department of Education *Child Protection* policy. Participant privacy, and the confidentiality of information disclosed by participants, is assured at all other times.

5. What will happen to the information collected?

Research findings will be reported in the PhD thesis, and also published in peer-reviewed educational journals.

6. How to opt-out from this project?

Participation in this research is entirely your choice. If you decide not to participate, you may withdraw from the project at any time without giving a reason. You will also be given the option of destroying immediately the data that identifies your child(ren), except the video data that contain other research participants, and no further video recordings will be made.

7. What should I do if I want to participate?

If you want your child(ren) to participate, please sign and return the enclosed consent form to your child(ren)'s teacher.

If you would like further information please contact:

Researcher:

Ms Nadia Chubko, MA in TESOL
School of Education
Edith Cowan University, Perth WA
Phone: [redacted]
E-mail: [redacted]

Principal Supervisor:

Dr Julia Morris, PhD
Edith Cowan University, Perth WA
Phone: (08) 6304 6289
E-mail j.morris@ecu.edu.au

If you have any complaints or reservations about the ethical conduct of this project, you may contact:

Research Ethics Officer
Edith Cowan University
270 Joondalup Drive
JOONDALUP WA 6027
Phone: 6304 2170; Fax: 6304 2661
Email: research.ethics@ecu.edu.au

Thank you for considering this invitation. This information letter is for you to keep.

APPENDIX G

PARENT/GUARDIAN INFORMATION LETTER

Russian

ИНФОРМАЦИОННОЕ ПИСЬМО ДЛЯ РОДИТЕЛЯ/ОПЕКУНА

Название проекта:

Создание видеороликов на занятиях по астрономии

Приглашение

Уважаемый родитель/ опекун!

Меня зовут Чубко Надежда. Я являюсь кандидатом на получение степени доктора философских наук (PhD) в области педагогики в австралийском университете имени Эдит Кован (Edith Cowan University). Я приглашаю Вашего ребенка (детей) принять участие в образовательном исследовательском проекте, в рамках которого учащиеся будут создавать видеоролики по изученным на занятиях по астрономии темам.

Прежде чем Вы примете решение об участии Вашего ребенка (детей) в данном исследовании, прошу Вас внимательно ознакомиться с информацией, приведенной ниже, и, если необходимо, обсудить Ваше решение с другими лицами.

1. Цель проекта

Идея моего проекта основывается на австралийском образовательном проекте «Cultural Sky Stories»[1]. Отличием моего проекта является возможность создания учащимися видеороликов о том, что они изучают. Цель проекта заключается в том, чтобы понять, как создание видеороликов на занятиях по астрономии может повлиять на повышение научной грамотности, усвоение предмета, а также знание учащимися содержания преподаваемого материала.

[1] Проект направлен на понимание учащимися начальной и средней школы связи между наукой, технологиями, инженерией и математикой в контексте астрономии.

2. Содержание проекта

Данное исследование будет проходить в рамках 10-ти дневного курса по астрономии. В ходе этого курса я буду обучать детей работе с видеокамерой и программами для редактирования видеоматериалов с целью создания роликов о пройденном за время урока материале.

Аудио- и видеозаписи занятий по астрономии, а также данные наблюдений в классе будут использоваться мной для анализа повышения уровня знаний учащихся в процессе создания видеороликов.

Я гарантирую конфиденциальность всех аудио- и видеозаписей. Только я и научные руководители данного проекта будут иметь доступ к этим записям.

3. Риски и выгода от участия в проекте

Участие в данном исследовательском проекте не предполагает каких-либо рисков. Я ожидаю, что участие в проекте повысит интерес учеников к изучению точных наук, поможет им освоить основы астрономии и улучшит их знание данного предмета.

4. Конфиденциальность

Вся информация, связанная с идентификацией личности, будет удалена из собранных данных на начальных этапах анализа. После этого информация будет храниться в сейфе Университета имени Эдит Кован и будет доступна только исследователям. Срок хранения информации до полного ее удаления составляет пять лет.

Если Вы решите прекратить участие Вашего ребенка (детей) в проекте, мы сможем удалить все данные Вашего ребенка (детей) из контрольного перечня наблюдения за уроком. Однако, видео- и аудиоматериалы, созданные до принятия Вами данного решения, удалить будет невозможно, так как они будут содержать ценную информацию об опыте изучения астрономии других детей.

Личности участников исследования не будут разглашены, кроме тех случаев, когда этого требует закон или Отдел по защите прав ребенка. Во всех остальных случаях конфиденциальность и анонимность данных участников гарантируется.

5. Использование данных

Результаты данного исследования будут опубликованы в докторской диссертации, а также научных педагогических журналах.

6. Отказ от участия

Решение об участии в данном проекте зависит только от Вас. Вы можете прекратить свое участие в исследовании в любой момент без объяснения причины. В случае прекращения участия вся информация о Вашем ребенке (детях), кроме видео- и аудиоматериалов, содержащих информацию о других детях, будет удалена.

7. Как принять участие в проекте?

Если Вы хотите, чтобы Ваш ребенок (дети) принял (-и) участие в этом исследовательском проекте, пожалуйста, подпишите прилагаемую к данному письму форму согласия на участие и передайте ее мне или преподавателю Вашего ребенка (детей).

За дополнительной информацией, пожалуйста, обращайтесь к:

Исследователю:
Чубко Надежда, магистр
гуманитарных наук в области
преподавания английского языка
как иностранного (MA in TESOL)
Педагогический факультет
Университет имени Эдит Кован,
Перт, Западная Австралия
Тел.: [redacted]
Эл. почта: [redacted]

Руководителю проекта:
Др. Моррис Джулия, доктор
философских наук (PhD)
Университет имени Эдит Кован,
Перт, Западная Австралия
Тел.: (08) 6304 6289
Эл. почта: j.morris@ecu.edu.au

В случае возникновения жалоб или вопросов касательно этического аспекта данного проекта, пожалуйста, свяжитесь с сотрудником Комитета по исследовательской этике Университета имени Эдит Кован:

Адрес: 270 Joondalup Drive JOONDALUP WA 6027
Эл. адрес: research.ethics@ecu.edu.au Тел.: 6304 2170 Факс: 6304 2661

Благодарю за внимание!

Сохраните данное письмо в целях информации.

APPENDIX H

CONSENT FORM (Parent/Guardian)
English

EDITH COWAN UNIVERSITY
SCHOOL OF EDUCATION

Research Project Title:
Making Videos about Learning during Astronomy Lessons

I allow my child:

(Print Name)………………………………………………………………………………..

to take part in this research and I give my consent freely.

I understand that the research will be done the way it is described in the Information Letter, and I have kept this Information Letter.

I understand that my child can stop taking part in this research, at any time, and I do not have to explain my reasons.

I understand that my child's real name will not be used in the research publications.

I understand that the information collected during this research will be stored securely by Edith Cowan University for a period of five years after the research is finished. After the research is finished, all video and audio recordings will be stored so that nobody will be able to see them.

I have had the opportunity to have questions answered to my satisfaction.

Print Name……………………………………………………………………………….

Signature…………………………………………………………………Date………………

APPENDIX I

CONSENT FORM (Parent/Guardian)
Russian

УНИВЕРСИТЕТ ИМЕНИ ЭДИТ КОВАН
ПЕДАГОГИЧЕСКИЙ ФАКУЛЬТЕТ

Название исследовательского проекта:
Создание видеороликов на занятиях по астрономии

ФОРМА СОГЛАСИЯ РОДИТЕЛЯ/ОПЕКУНА НА УЧАСТИЕ **РЕБЕНКА В ИССЛЕДОВАТЕЛЬСКОМ ПРОЕКТЕ**

Настоящим я предоставляю добровольное согласие на участие моего ребенка

____
(ФИО ребенка печатными буквами)

в этом исследовательском проекте.

Я понимаю, что исследование будет проходить в соответствии с процедурами и правилами, описанными в информационном письме, копию которого я получил(-а).

Я понимаю, что мой ребенок может отказаться от участия в данном исследовании в любой момент без объяснения причины.

Я понимаю, что настоящее имя моего ребенка не будет использоваться в публикациях, связанных с данным исследованием.

Я понимаю, что информация, полученная в ходе данного исследования, будет храниться Университетом имени Эдит Кован на протяжении пяти (5) лет с момента окончания проекта. После завершения исследования доступ к аудио- и видеоматериалам будут иметь <u>только</u> автор и научные руководители этого исследовательского проекта.

Мне были предоставлены все необходимые контактные данные для того, чтобы задать интересующие меня вопросы о проведении данного исследования, и я получил (-а) удовлетворительные ответы на все мои вопросы.

ФИО родителя/опекуна печатными буквами:

____

Подпись…………………………………………………………………………………… Дата…………………………………………………

APPENDIX J

Astronomy Diagnostic Test (ADT)

Northern Hemisphere Edition Version

We ask for your name to see if there are any changes in responses to the questions. Please print your name, you school, and your teacher's name clearly and neatly.

This is NOT a TEST. We want to find out what you think you know about Astronomy.

Student Name ________________________ **Teacher Name** ________________________

School you go to: ________________________ **Grade level you are in:** ________________________

I am a (Tick only ONE of these.)

☐ Girl

☐ Boy

Directions

- The first four questions ask you to create a drawing to explain something that happens in space and then to write a few words to explain your drawing.
- The rest of the questions ask you to **tick** a box beside what you think is the correct answer.
- **If you do not know the answer, please leave the question blank. Do not GUESS.**
- You may tick **only one box** for each of questions 5 to 15. If you make a mistake, put a cross X over the tick. Place your tick in the new box.
- After each question, there is space for you to give reasons for your answer to the question. If you do not know, then please leave the space blank.
- Please be sure to tick a box for each question ***only if*** you think you know the answer.

1a. **Draw a picture of the Earth and the Sun in the space below to show why day-time and night-time happen. Include these labels: *The Earth*, *The Sun*, *day-time*, *night-time***

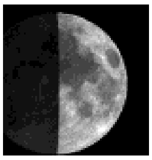
1b. **Write a few words to explain your picture.**

2a. **Imagine you are out in space looking down on the Earth, the Moon and the Sun. Draw a picture to show how they would move. - Show their orbits. - Label each thing**

2b. **Write a few words to explain your picture.**

3a. Sally looked for the Moon one week. Here is what she saw:

Use drawings in the space below to show why she saw the Moon these different shapes.

	Cloudy	Cloudy		Cloudy		Cloudy
Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

3b. Write a few words to explain your picture.

4. Draw pictures of the Earth and the Sun to show why Summer and Winter happen.

4b. Write a few words to explain your picture.

5. **As seen from your school, when will an upright flagpole cast *no shadow* because the Sun is directly above the flagpole?**

- ☐ Every day at noon.
- ☐ Only on the first day of summer.
- ☐ Only on the first day of winter.
- ☐ On two days between beginning of spring and beginning of fall.
- ☐ Never from my current location.

Please give the reason for your answer to this question?

____

____

____

____

6. **When the Moon appears to completely cover the Sun (an eclipse), the Moon must be at which phase?**

- ☐ Full
- ☐ At no particular phase
- ☐ First quarter
- ☐ New
- ☐ Last quarter

Please give the reason for your answer to this question?

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____

7. **Imagine that you are building a scale model of the Earth and the Moon. You are going to use a 30 cm basketball to represent the Earth and a 7 cm tennis ball to represent the Moon. To maintain the proper distance scale, about how far from the surface of the basketball should the tennis ball be placed?**

- ☐ 7 cm
- ☐ 15 cm
- ☐ 90 cm
- ☐ 9 m
- ☐ 90 m

Please give the reason for your answer to this question?

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8. Imagine that the Earth's orbit was changed to be a perfect circle about the Sun so that the distance to the Sun never changed. How would this affect the seasons?

- ☐ We would still experience seasons, but the difference would be much MORE noticeable.
- ☐ We would still experience seasons, but the difference would be much LESS noticeable.
- ☐ We would no longer experience a difference between the seasons.
- ☐ We would continue to experience seasons in the same way we do now.

Please give the reason for your answer to this question?

____

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____

9. On about September 22, the Sun sets directly to the west as shown on the diagram below. Where would the Sun appear to set two weeks later?

- ☐ Farther south
- ☐ In the same place
- ☐ Farther north

Please give the reason for your answer to this question?

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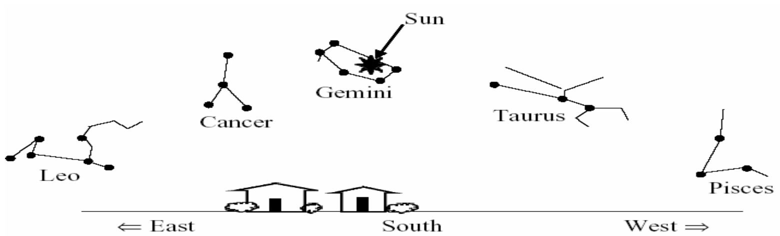
10. If you could see stars during the day, the diagram below shows what the sky would look like at noon on a given day. The Sun is near the stars of the constellation Gemini. Near which constellation would you expect the Sun to be located at sunset?

- ☐ Cancer
- ☐ Taurus
- ☐ Gemini
- ☐ Leo
- ☐ Pisces



Please give the reason for your answer to this question?

____

____

____

11. Which of the following lists is correctly arranged in order of closest-to-most-distant from the Earth?

☐ Moon, Sun, Pluto, stars

☐ Moon, Pluto, Sun, stars

☐ Moon, Sun, stars, Pluto

☐ Sun, Moon, Pluto, stars

☐ Stars, Moon, Sun, Pluto

Please give the reason for your answer to this question?

____

____

____

____

12. The hottest stars are what colour?

☐ Blue

☐ Red

☐ White

☐ Yellow

☐ Orange

Please give the reason for your answer to this question?

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13. **The diagram above shows the Earth and Sun as well as five different possible positions for the Moon. Which position of the Moon would cause it to appear like the picture below when viewed from Earth?**

☐ A

☐ B

☐ C

☐ D

☐ E

Please give the reason for your answer to this question?

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14. **You observe a full Moon rising in the east. How will it appear in six hours?**

☐ A

☐ B

☐ C

☐ D

Please give the reason for your answer to this question?

____

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15. Which statement explains why daylight and darkness occur on the Earth?

- ☐ The Earth rotates on its axis.
- ☐ The Sun rotates on its axis.
- ☐ The Earth's axis is tilted.
- ☐ The Earth revolves around the Sun.
- ☐ The Sun revolves around the Earth.

Please give the reason for your answer to this question?

16. In general, how confident are you that your answers to this survey are correct?

- ☐ Very confident
- ☐ Confident
- ☐ Not sure
- ☐ Not very confident
- ☐ Not at all confident (just guessing)

THANK YOU for your responses.

APPENDIX K

ASTRONOMY DIAGNOSTIC TEST
Russian Translation

1a) <u>С помощью рисунка объясните почему у нас есть день и ночь. Подпишите где на вашем рисунке изображение *Земли, Солнца, дня* и *ночи*.</u>
1b) Напишите объяснение к вашему рисунку.

2a) <u>Представьте, что вы смотрите на Землю, Луну и Солнце из космоса. Нарисуйте как они будут двигаться (нарисуйте их орбиты). Подпишите каждый объект.</u>
2b) Напишите объяснение к вашему рисунку.

3a) <u>На протяжении одной недели Салли наблюдала за Луной. Посмотрите, что она увидела. Нарисуйте схему, чтобы объяснить почему Салли увидела такие изменения Луны.</u>
3b) Напишите объяснение к вашему рисунку.

4a) <u>Объясните почему у нас есть лето и зима с помощью рисунка Солнца и Земли.</u>
4b) Напишите объяснение к вашему рисунку.

5a) <u>Если в вашей школе установить флагшток. При каких условиях он не будет отбрасывать тень под прямым воздействием солнца?</u>
1. Каждый день в обед.
2. Только в первый день лета.
3. Только в первый день зимы.
4. Только два дня; в начале весны и в начале осени.
5. Никогда

5b) Пожалуйста объясните свой ответ.

6a) <u>При какой фазе Луны мы можем наблюдать как Луна полностью закрывает Солнце (солнечное затмение)?</u>
1. Полнолуние.
2. Это не зависит от фазы луны.
3. Первая четверть луны.
4. Новолуние.
5. Последняя четверь луны.

6b) Пожалуйста объясните свой ответ.

7a) **<u>Представьте, что вам надо создать масштабную модель Земли и Луны. Вы используете баскетбольный мяч (30 см) как модель Земли и теннисный мяч (7 см) как модель Луны? Чтобы выдержать правильный масштаб (показать правильное расстояние), на каком расстоянии друг от друга должны быть мячи?</u>**

1. 7см.
2. 15 см.
3. 90 см.
4. 9 м.
5. 90 м.

7b) Пожалуйста объясните свой ответ.

8a) **<u>Представьте, что Земля вращается вокруг Солнца по идеальному кругу, так что Земля всегда будет находиться на одном и том же расстоянии от Солнца? Как это повлияет на времена года?</u>**

1. У нас будут времена года, но разница между временами года будет намного больше.
2. У нас будут времена года, но разница между временами года будет намного меньше.
3. Мы не будем замечать разницу между временами года.
4. У нас будут такие же времена года как сейчас.

8b) Пожалуйста объясните свой ответ.

9a) **<u>На рисунке показано, что 22 сентября Солнце садится прямо на западе. Где будет закат Солнца через две недели?</u>**

1. Дальше на юге.
2. В том же месте.
3. Дальше на севере

9b) Пожалуйста объясните свой ответ.

10a) **<u>На рисунке показано как бы выглядело звёздное небо в обед. Солнце находится рядом с созвездием Близнецов. Как вы думаете, рядом с каким созвездием будет находиться Солнце во время заката?</u>**

1. Рак.
2. Телец.
3. Близнецы.
4. Лев
5. Рыбы

10b) Пожалуйста объясните свой ответ.

11a) **<u>В каком ответе правильно перечислены объекты: от самого близкого до самого отдалённого по отношению к Земле?</u>**

1. Луна, Солнце, Плутон, звёзды.
2. Луна, Плутон, Солнце, звёзды.
3. Луна, Солнце, звёзды, Плутон.
4. Солнце, Луна, Плутон, звёзды.
5. Звёзды, Луна, Солнце, Плутон

11b) Пожалуйста объясните свой ответ.

12a) Какого цвета самые горячие звёзды?

1. Голубой.
2. Красный.
3. Белый.
4. Жёлтый.
5. Оранжевый.

12b) Пожалуйста объясните свой ответ.

13a) На рисунке показаны Земля, Солнце и пять возможных положений Луны? Где должна находится Луна, чтобы мы могли видеть её с Земли как на фотографии?

1. A.
2. B.
3. C.
4. D.
5. E.

13b) Пожалуйста объясните свой ответ.

14a) Вы наблюдаете полнолуние. Как будет выглядеть Луна через шесть часов?

1. A.
2. B.
3. C.
4. D.

14b) Пожалуйста объясните свой ответ.

15a) Какой ответ правильно объясняет почему на Земле есть день и ночь?

1. Земля вращается вокруг своей оси.
2. Солнце вращается вокруг своей оси.
3. Ось Земли находится под наклоном.
4. Земля вращается вокруг Солнца.
5. Солнце вращается вокруг Земли.

15b) Пожалуйста объясните свой ответ.

16a) Насколько вы уверенны в правильности своих ответов?

1. Абсолютно уверен\-на.
2. Уверен\-на.
3. Не очень уверен\-на.
4. Не уверен\-на.
5. Совсем не уверен\-на (я просто угадывал\-а).

APPENDIX L

STEM-A PILOT COURSE PROGRAM (English)

Astronomy course for children and teenagers

Secrets of the Stars

This is an engaging 9-day course that will help you to discover astronomy as an interesting scien subject and teach you to make videos about your own scientific enquiry.

Course duration: 9 days (Monday-Wednesday-Friday 16:00- 18:30)

Language of the course: English

(! To be enrolled in this course you need to have at least an intermediate level of English)

Methodology: interdisciplinary approach and interactive teaching strategy

Short description:

This is an innovative course based on the Australian science education standards. It includes the ba components of the popular Australian educational program called *Cultural Sky Stories* that has emphasis on scientific inquiry. During this course you will not only learn about space and things in Solar System, but also master video-making skills. The key goal of this course is to develop y scientific literacy and teach you to think as a scientist.

Course contents:

***Subject component**:* Solar System, Stars, Phases of the Moon, Night and Day, and Seasons

Science component: keeping a log book; making and testing hypotheses; making arguments, comparisons, analysis and conclusions

***ICT component**:* PowerPoint, video-editing software, *Stellarium*

Language component: listening, reading, writing, and speaking

***Cultural component**:* developing cultural awareness, learning about the astronomy knowledge of different peoples

Creative component: scriptwriting, storyboarding, making videos

Expected outcomes:

- broadening of awareness about science

- learning basic astronomy concepts

- uncovering creativity

- developing management and organisation skills

- using a target language in context

- creating a video from scratch

- engaging with learning astronomy, English and video-making

Program overview

Date	Session title	Goals	Activities
Day 1	Introduction **Science Inquiry**	• Gaining awareness about the plurality of the approaches to science • Making hypotheses and mastering argumentation • Collaboration • Work with a camera • Use of video-editing software • Developing interview questions	• Program overview • Astronomy diagnostic test • Teambuilding • Creating introductory videos • Next session preparation
Day 2	**Beliefs and Assumptions about Astronomy**	• Data search • Planning and organising • Data management • Video-editing	• Listening to the Australian Aboriginal story of creation • Learning the creation stories of other peoples • Script writing • Collecting and analysing information • Storyboarding • Taking footage • Video-editing • Discussion
Day 3	**The Solar System**	• Making scale models • Learning about the Solar System	• Investigating the structure of the Solar System • Building scale models of the Solar System • Making a video about the Solar System
Day 4	**Stars, colour, brightness, and life history**	• Stellarium software • Understanding the features of the stars • Making colour images of the stars	• Mapping constellations • Making colour images of the stars • Making a video guide to the use of the Stellarium software
Day 5	**How the constellation got its name?**	• Research skills • Presentation skills	• Finding a story behind the name of a constellation • Making a video about one of the constellations
Day 6	**Phases of the Moon**	• Understand the phases of the Moon • Practicing the use of scale models	• Completing the Moon phases observation log book

		• Keeping a log book of observations • Reporting the observations	• Making scale models of the Earth and the Moon • Making a video-report to explain the phases of the Moon
Day 7	**Day, Night and Seasons**	• Testing hypotheses • Comparing	• Exploring the reasons behind the night and day phenomenon • Exploring the reasons for the seasons • Making a video about night and day or seasons
Day 8	**What is an Ecotect?**	• Making predictions • Summarising	• Thinking about the possible high-demand jobs of the future
Day 9	**My Journey through Space and Time**	• Reflecting about the gained knowledge • Presentations and feedback	• Astronomy diagnostic test • Demonstration of the videos made during the course • Awarding Certificates of completion

APPENDIX M

STEM-A PILOT COURSE PROGRAM (Russian)

Astronomy course for children and teenagers

Secrets of the Stars

Спецкурс для детей (9-14 лет)

О чем молчат звезды

Курс состоит из 9 увлекательных занятий, которые помогут вашему ребенку открыть для себя астрономию и научиться снимать и редактировать видео в процессе проведения собственного научного исследования.

Продолжительность курса: 9 занятий (Понедельник-Среда-Пятница 16:00- 18:30)

Языки курса: английский и русский

(**!**Чтобы записаться на курс, необходимо владение английским языком на среднем уровне и выше)

Методика: междисциплинарный подход и интерактивное обучение

Краткое описание:

В основе курса лежит инновационная программа, базирующаяся на Австралийских стандартах преподавания точных наук. В курс включены основные компоненты широко известной в Австралии учебной программы *Cultural Sky Stories*, в которой особое внимание уделяется исследовательскому подходу. Кроме этого каждый ученик сможет не только познакомиться с космосом, но и овладеть мастерством режиссера. Цель курса – разбудить в ребенке исследователя и научить его мыслить логически.

Содержание курса:

Предметный компонент*:* Солнечная система, звезды, фазы Луны, смена дня и ночи, времена года.

Научный компонент: ведение журнала, построение гипотез, опровержение гипотез, аргументирование, сравнение, анализ, подведение итогов.

Технический компонент*:* освоение компьютерных програм *PowerPoint, программы видеоредакторы, Stellarium*

Языковой компонент: аудирование, чтение, письмо, свободная речь

Культурный компонент*:* расширение кругозора, знакомство с астрономией и представлением о ней в культурах разных народов

Творческий компонент: написание сценария, раскадровка, создание видео

Ожидаемые результаты:

- расширение кругозора

- знание основных астрономических концепций

- раскрытие творческого потенциала

- развитие самостоятельности

- практическое применение языковых навыков

- умение создавать тематическое видео с нуля

- интерес к дальнейшему изучению астрономии, английского языка и видеомонтажа

Программа курса

День	**Название**	**Цели**	**Задачи урока**
День 1	Введение **Научный подход**	• Понимание многообразия научных подходов • Выдвижение гипотез и освоение азов аргументирования • Работа в команде • Работа с камерой • Умение использовать программы-видеоредакторы • Составление вопросов и проведение интервью	• Знакомство с программой • Тестирование на знание астрономии • Создание команд • Создание видеовизиток для каждой команды • Подготовка к следующему занятию
День 2	**Теориии мироздания и астрономические знания разных народов мира**	• Поиск информации • Планирование • Сортировка данных • Освоение программ-видеоредакторов	• Знакомство с теорией мироздания первых народов Австралии и других народов • Написание сценария • Поиск информации • Раскадровка • Сбор видеоматериала • Редактирование видео • Обсуждение
День 3	**Солнечная система**	• Использование масштабов • Изучение структуры нашей солнечной системы	• Исследование структуры солнечной системы • Создание масштабной модели солнечной системы • Создание видео о солнечной системе
День 4	**Звезы: цвета, яркость и история**	• Знакомство с программой Stellarium	• Знакомство с картой звездного неба

		• Знакомство со свойствами звезд • Создание цветных фотографий звезд	• Создание цветных фотографий звезд • Создание видеогида об использовании программы Stellarium
День 5	**Как возникли названия созвездий?**	• Развитие исследовательских навыков • Навыки презентации	• Знакомство с историей возникновения названий различных созвездий • Создание видео об одном из созвездий
День 6	**Фазы Луны**	• Изучить фазы Луны • Использование масштабных моделей • Ведение исследовательского журнала • Фиксирование исследовательских данных	• Заполнение журнала наблюдений за фазами Луны • Создание моделей Луны и Земли • Создание видео-отчета о фазах Луны
День 7	**День, ночь и времена года**	• Тестирование гипотез • Сравнение	• Изучение причин смены дня и ночи • Изучение причин возникновения времен года • Создание видео о причинах смены дня и ночи или о причинах смены времен года
День 8	**Кто такой Экотек?**	• Размышление о будущем, прогнозирование • Подведение итогов	• Размышление о профессиях будущего
День 9	**Мое путешествие в пространстве и времени**	• Закрепление пройденного • Презентация и оценка достижений	• Тест по астрономии • Демонстрация созданных за время курса видеороликов • Подведение итогов и вручение сертификатов

APPENDIX N

STEM-A Course Program: Version 1 (English)

Astronomy course for children and teenagers

Secrets of the Stars

This is an engaging course that will help you to discover astronomy as an interesting science subject and teach you to make videos about your own scientific enquiry.

Course duration: 10 days (20 hours)

Language of instruction: English

(! To be enrolled in this course you need to have at least a pre-intermediate level of English)

Methodology: interdisciplinary approach and interactive teaching strategy

Course description:
This is an innovative course based on the Australian science education standards. It includes the basic components of the popular Australian educational program called *Cultural Sky Stories* that has an emphasis on scientific inquiry. During this course you will not only learn about space and things in our Solar System, but also master video-making skills. The key goal of this course is to develop your scientific literacy and teach you to think as a scientist.

Course content:

Subject component: Solar System, Phases of the Moon, Night and Day, and Seasons, and Stars

Science component: keeping a log book; making and testing hypotheses; making arguments, comparisons, analysis and conclusions

ICT component: video-editing software, *Stellarium*

***Language component*:** listening, reading, writing, and speaking

Cultural component: developing cultural awareness, learning about the astronomy knowledge of different peoples

***Creative component*:** scriptwriting, storyboarding, making videos

Expected outcomes:

- broadening of awareness about science
- learning basic astronomy concepts
- uncovering creativity
- developing management and organisation skills
- teambuilding skills

- using a target language in context

- creating a video from scratch

- engaging with learning astronomy, English and video-making

Program overview

	Session title	**Goals**	**Activities**
Day 1	Introduction **Science Inquiry**	• Gaining awareness about the plurality of the approaches to science • Making hypotheses and mastering argumentation	• Program overview • Astronomy diagnostic test
Day 2-4	**The Solar System**	• Making scale models • Learning about the Solar System • Planning and organising • Data management • Work with a camera • Video-editing	• Investigating the structure of the Solar System • Building scale models of the Solar System • Making a video about the Solar System • Script writing • Collecting and analysing information • Storyboarding • Taking footage • Video-editing • Discussion
Day 5-6	**Stars, colour, brightness, and life history**	• Stellarium software • Understanding the features of the stars • Making colour images of the stars • Research skills • Presentation skills	• Mapping constellations • Making colour images of the stars • Finding a story behind the name of a constellation • Making a video about one of the constellations
Day 7	**Phases of the Moon**	• Understand the phases of the Moon • Practicing the use of scale models • Keeping a log book of observations • Reporting the observations	• Completing the Moon phases observation log book • Making scale models of the Earth and the Moon • Making a video-report to explain the phases of the Moon
Day 8-9	**Day, Night and Seasons**	• Testing hypotheses • Comparing	• Exploring the reasons behind the night and day phenomenon

			• Exploring the reasons for the seasons • Making a video about night and day or seasons
Day 10	**My Journey through Space and Time**	• Reflecting about the gained knowledge • Presentations and feedback	• Astronomy diagnostic test • Demonstration of the videos made during the course

APPENDIX O

STEM-A Course Program: Version 1 (Russian)

Astronomy course for children and teenagers

Secrets of the Stars

Спецкурс для детей (9-15 лет)

О чем молчат звезды

Курс состоит из увлекательных занятий, которые помогут вашему ребенку открыть для себя астрономию и научиться снимать и редактировать видео в процессе проведения собственного научного исследования.

Продолжительность курса: 10 занятий (20 часов)

Языки курса: английский

(Чтобы записаться на курс, необходимо владение английским языком на среднем уровне и выше)

Методика: междисциплинарный подход и интерактивное обучение

Краткое описание:

В основе курса лежит инновационная программа, базирующаяся на Австралийских стандартах преподавания точных наук. В курс включены основные компоненты широко известной в Австралии учебной программы *Cultural Sky Stories*, в которой особое внимание уделяется исследовательскому подходу. Кроме этого каждый ученик сможет не только познакомиться с космосом, но и овладеть мастерством режиссера. Цель курса- разбудить в ребенке исследователя и научить его мыслить логически.

Содержание курса:

Предметный компонент: Солнечная система, фазы Луны, смена дня и ночи, времена года, звезды.

Научный компонент: ведение журнала, построение гипотез, опровержение гипотез, аргументирование, анализ, подведение итогов.

Технический компонент: *программы видеоредакторы и Stellarium*

Языковой компонент: аудирование, чтение, письмо, свободная речь

Культурный компонент: расширение кругозора, знакомство с астрономией и представлением о ней в культурах разных народов

Творческий компонент: написание сценария, раскадровка, создание видео

Ожидаемые результаты:

- расширение кругозора

- понимание основных астрономических концепций

- раскрытие творческого потенциала

- планирование

- командная работа

- практическое применение языковых навыков

- умение создавать тематическое видео с нуля

- интерес к дальнейшему изучению астрономии, английского языка и видеомонтажа

Программа курса:

	Название	**Цели**	**Задачи урока**
День 1	Введение **Научный подход**	• Понимание многообразия научных подходов • Выдвижение гипотез и освоение азов аргументирования	• Знакомство с программой • Тестирование на знание астрономии
День 2-4	**Солнечная система**	• Использование масштабов • Изучение структуры нашей солнечной системы • Поиск информации • Планирование • Сортировка данных • Работа с камерой • Освоение программ-видеоредакторов	• Исследование структуры солнечной системы • Создание масштабной модели солнечной системы • Написание сценария • Поиск информации • Раскадровка • Сбор видеоматериала • Редактирование видео • Обсуждение
День 5- 6	**Звезы: цвета, яркость и история Созвездия**	• Знакомство с программой Stellarium • Знакомство со свойствами звезд • Создание цвеных фотографий звезд • Развитие исследовательских навыков • Развитие навыков презентации	• Знакомство с картой звездного неба • Создание цвеных фотографий звезд • Знакомство с историей возникновения названий различных созвездий • Создание видео о созвездии
День 7	**Фазы Луны**	• Изучение Лунного цикла • Использование масштабных моделей • Ведение исследовательского журнала • Фиксирование исследовательских данных	• Заполнение журнала наблюдений за фазами Луны • Создание моделей Луны и Земли • Создание видео о фазах Луны

День 8-9	**День, ночь и времена года**	• Тестирование гипотез • Сравнение	• Изучение причин смены дня и ночи • Изучение причин возникновения времен года • Создание видео о причинах смены дня и ночи или о причинах смены времен года
День 10	**Мое путешествие в пространстве и времени**	• Закрепление пройденного • Презентация и оценка достижений	• Тестирование на знание астрономии • Демонстрация созданных за время курса видеороликов

APPENDIX P

STEM-A Program: Course Version 2 (English)

Astronomy course for children and teenagers

Secrets of the Stars

This is an engaging course that will help you to discover astronomy as an interesting science discipline and will teach you to make videos about your own scientific enquiry.

Course duration: 10 days (20 hours)

Language of instruction: English

(! To be enrolled in this course you need to have at least a pre-intermediate level of English)

Methodology: interdisciplinary approach and interactive teaching strategy

Course description:

This is an innovative course based on the Australian science education standards. It includes the basic components of the popular Australian educational program called *Cultural Sky Stories* that has an emphasis on scientific inquiry. During this course you will not only learn about space and things in our Solar System, but also master video-making skills. The key goal of this course is to develop your scientific literacy and teach you to think as a scientist.

Course content:

Subject component: Solar System, Phases of the Moon, Night and Day, and Seasons, and Stars

Science component: keeping a log book; making and testing hypotheses; making arguments, comparisons, analysis and conclusions

ICT component: video-editing software, *Stellarium*

***Language component*:** listening, reading, writing, and speaking

Cultural component: developing cultural awareness, learning about the astronomy knowledge of different peoples

***Creative component*:** scriptwriting, storyboarding, making videos

Expected outcomes:

- broadening of awareness about science
- learning basic astronomy concepts
- uncovering creativity
- developing management and organisation skills
- teambuilding skills

- using a target language in context

- creating a video from scratch

- engaging with learning astronomy, English and video-making

Program overview

	Session title	Goals	Activities
Day 1	Introduction **Science Inquiry**	• Gaining awareness about the plurality of the approaches to science • Making hypotheses and mastering argumentation	• Program overview • Astronomy diagnostic test
Day 2-3	**Phases of the Moon**	• Understand the phases of the Moon • Practicing the use of scale models • Keeping a log book of observations • Reporting the observations • Collaboration • Work with a camera • Use of video-editing software • Making a video-report to explain the phases of the Moon	• Completing the Moon phases observation log book • Making scale models of the Earth and the Moon • Script writing • Collecting and analysing information • Storyboarding • Taking footage • Video-editing • Discussion
Day 4-5	**Day, Night and Seasons**	• Testing hypotheses • Comparing • Research skills • Presentation skills	• Exploring the reasons behind the night and day phenomenon • Exploring the reasons for the seasons • Making a video about night and day or seasons
Day 6-8	**The Solar System**	• Making scale models • Learning about the Solar System	• Investigating the structure of the Solar System • Building scale models of the Solar System
Day 9	**Stars, colour, brightness, and life history**	• Stellarium software • Understanding the features of the stars • Making colour images of the stars	• Mapping constellations • Exploring constellation names • Astronomy diagnostic test
Day 10	**My Journey through Space and Time**	• Reflecting about the gained knowledge • Presentations and feedback • Making colour images of the stars	• Demonstration of the videos made during the course • Making colour images of the stars

APPENDIX Q

STEM-A Program: Course Version 2 (Russian)

Astronomy course for children and teenagers

Secrets of the Stars

Спецкурс для детей (9-15 лет)

О чем молчат звезды

Курс состоит из увлекательных занятий, которые помогут вашему ребенку открыть для себя астрономию и научиться снимать и редактировать видео в процессе проведения собственного научного исследования.

Продолжительность курса: 10 занятий (20 часов)

Языки курса: английский

(Чтобы записаться на курс, необходимо владение английским языком на среднем уровне и выше)

Методика: междисциплинарный подход и интерактивное обучение

Краткое описание:

В основе курса лежит инновационная программа, базирующаяся на Австралийских стандартах преподавания точных наук. В курс включены основные компоненты широко известной в Австралии учебной программы *Cultural Sky Stories*, в которой особое внимание уделяется исследовательскому подходу. Кроме этого каждый ученик сможет не только познакомиться с космосом, но и овладеть мастерством режиссера. Цель курса- разбудить в ребенке исследователя и научить его мыслить логически.

Содержание курса:

Предметный компонент: Солнечная система, фазы Луны, смена дня и ночи, времена года, звезды.

Научный компонент: ведение журнала, построение гипотез, опровержение гипотез, аргументирование, анализ, подведение итогов.

Технический компонент*: программы видеоредакторы и Stellarium*

Языковой компонент: аудирование, чтение, письмо, свободная речь

Культурный компонент: расширение кругозора, знакомство с астрономией и представлением о ней в культурах разных народов

Творческий компонент: написание сценария, раскадровка, создание видео

Ожидаемые результаты:

- расширение кругозора

- понимание основных астрономических концепций

- раскрытие творческого потенциала

- планирование

- командная работа

- практическое применение языковых навыков

- умение создавать тематическое видео с нуля

- интерес к дальнейшему изучению астрономии, английского языка и видеомонтажа

Программа курса

	Название	Цели	Задачи урока
День 1	Введение **Научный подход**	• Понимание многообразия научных подходов • Выдвижение гипотез и освоение азов аргументирования	• Знакомство с программой • Тестирование на знание астрономии
День 2-3	**Фазы Луны**	• Изучение Лунного цикла • Использование масштабных моделей • Ведение исследовательского журнала • Фиксирование исследовательских данных • Работа в команде • Работа с камерой • Умение использовать программы-видеоредакторы • Создание видео-отчета о фазах Луны	• Заполнение журнала наблюдений за фазами Луны • Создание моделей Луны и Земли • Написание сценария • Раскадровка • Сбор видеоматериала • Редактирование видео • Обсуждение
День 4-5	**День, ночь и времена года**	• Тестирование гипотез • Сравнение • Развитие исследовательских навыков • Развитие навыков презентации	• Изучение причин смены дня и ночи • Изучение причин возникновения времен года • Создание видео о причинах смены дня и ночи или о причинах смены времен года

День 6-8	**Солнечная система**	• Использование масштабов • Изучение структуры нашей солнечной системы	• Исследование структуры солнечной системы • Создание масштабной модели солнечной системы
День 9	**Звезы: цвета, яркость и история Созвездия**	• Знакомство с программой Stellarium • Знакомство со свойствами звезд • Создание цвеных фотографий звезд	• Знакомство с картой звездного неба • Знакомство с историей возникновения названий различных созвездий • Тест по астрономии
День 10	**Мое путешествие в пространстве и времени**	• Закрепление пройденного • Презентация и оценка достижений • Создание цветных фотографий звезд	• Демонстрация созданных за время курса видеороликов • Создание цветных фотографий звезд

APPENDIX R
Article 1

Issues in Educational Research, 2019, Vol 29(4), 1107-1130.
[Contents Vol 29] [IIER Home]

Engaging adolescent Kyrgyzstani EFL students in digital storytelling projects about astronomy

Nadezhda Chubko, Julia E. Morris, David H. McKinnon, Eileen V. Slater and Geoffrey W. Lummis
Edith Cowan University, Australia

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.
[PDF full text for this article]

APPENDIX S
Article 2

SOLO taxonomy as EFL students' disciplinary literacy evaluation tool in technology-enhanced integrated astronomy course

- Nadezhda Chubko,
- Julia E. Morris,
- David H. McKinnon,
- Eileen V. Slater &
- Geoffrey W. Lummis

Language Testing in Asia **volume 9**, Article number: 19 (2019)

Abstract

Whilst the role of disciplinary literacy in science, technology, engineering, and mathematics (STEM) education is becoming more prominent, there appears to be little adaptation or allowance made for English as a foreign or second language (EFL/ESL) students learning science in English, as well as no clear understanding of what comprises disciplinary literacy in science. In this article, we define the construct of disciplinary literacy in science education and justify the use of the *Structure of the Observed Learning Outcome* (SOLO) taxonomy (Biggs and Collis, *Teaching for quality learning at university* 1982) as a tool for measuring EFL students' disciplinary literacy development. This SOLO taxonomy was trialled in a STEM integrated astronomy course enhanced with a digital storytelling approach. Data were collected from adolescent EFL students' written responses in their pre- and post-Astronomy Diagnostic Test. The results show a positive change in participants' science disciplinary literacy development and contribute to the understanding of the EFL/ESL students' science disciplinary literacy development and assessment.

Full text for this article: https://link.springer.com/article/10.1186/s40468-019-0095-6#Abs1

APPENDIX T

Article 3 Proof of Submission

https://outlook.office.com/mail/search/id/AAQkAGM5Mzc1Y2FmLW...

Acknowledgement of Receipt of #ETRD-D-19-00498R2

[redacted]

on behalf of
Educational Technology Research & Development (ETRD) <em@editorialmanager.com>

Tue 4/14/2020 1:57 PM

To: Nadezhda CHUBKO <[redacted]

Dear Ms Chubko:

We acknowledge, with thanks, receipt of the revised version of your manuscript, "Digital Storytelling as a Disciplinary Literacy Enhancement Tool for EFL Students", submitted to Educational Technology Research and Development. The manuscript number is ETRD-D-19-00498R2.

You may check the status of your manuscript at any time by accessing the journal's Editorial Manager site.

Your username is: [redacted]
If you forgot your password, you can click the 'Send Login Details' link on the EM Login page at [redacted]

We will inform you of the Editor's decision as soon as possible.

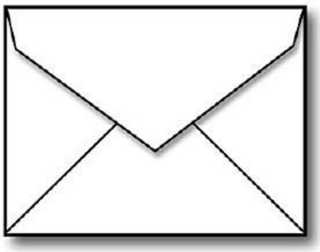
Best regards,
Springer Journals Editorial Office
Educational Technology Research and Development

APPENDIX U
Elephant puzzle and activity resources

Imagine that you are **scientists**.

Представьте, что вы **ученые**.

You need to investigate an object that is in the envelope.



Вам нужно исследовать объект, находящийся в конверте.

You need to write as many details about it is as you can.

Вам нужно написать как можно больше деталей

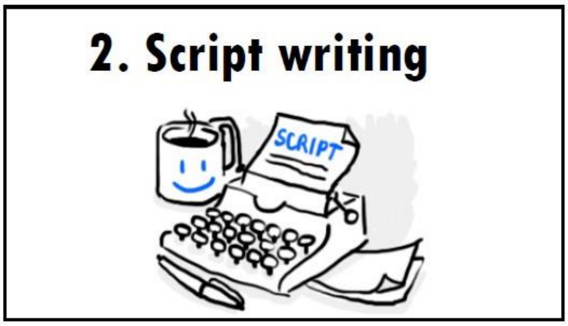
What was the purpose of this activity?

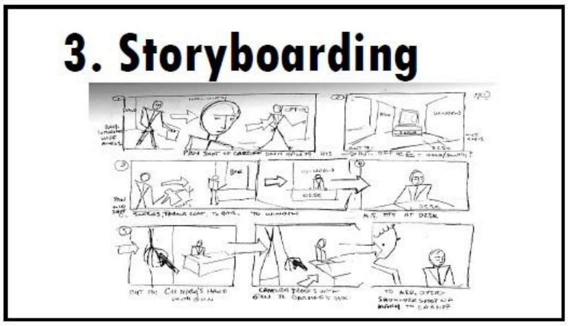
Какова была цель этого задания?

How is it related to science?

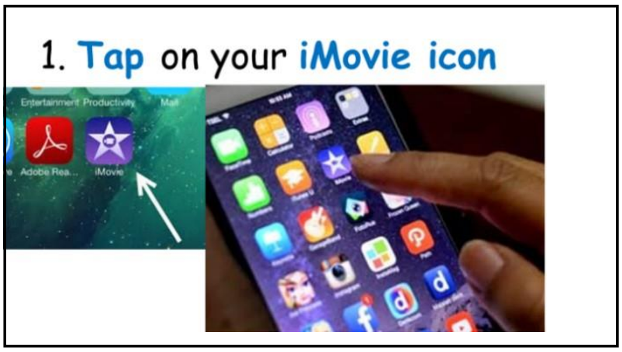
Как это связано с наукой?

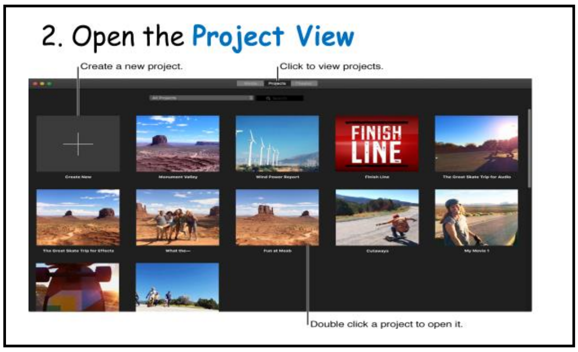
APPENDIX V
Steps to Video Making

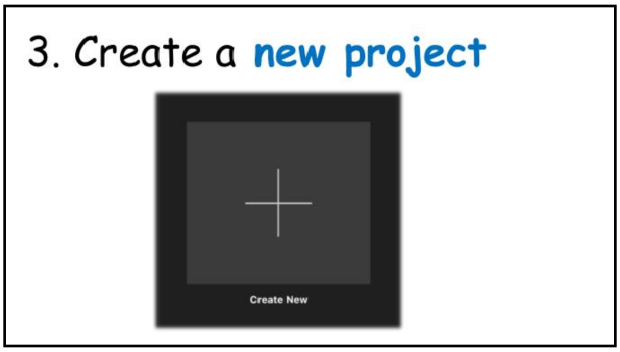


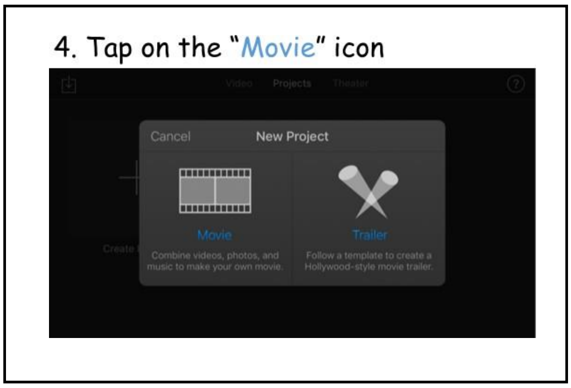


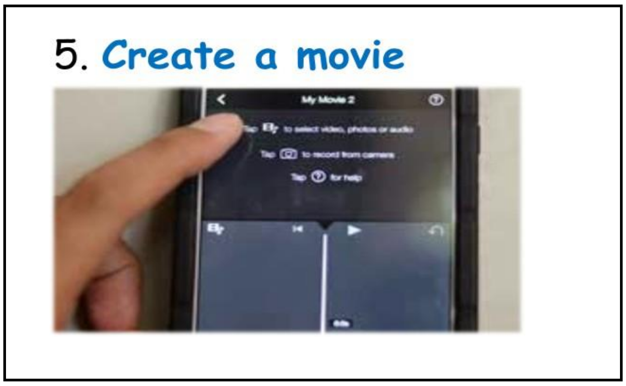
APPENDIX W
iMovie Guide











APPENDIX X
Example of students' storyboard