Integrating Virtual Field Experiences into Undergraduate Geoscience Education to Improve Student Learning

Henry Visneskie with supervisors John Johnston and Jen Parks

UNIVERSITY OF WATERLOO
FACULTY OF SCIENCE
Department of Earth and Environmental Sciences

Introduction

In late 2019, the University of Waterloo's (UW) Department of Earth and Environmental Sciences (EES) received funding through the Science Faculty's *Dean's Undergraduate Teaching Initiative* (DUTI) to implement Virtual Field Experiences into geoscience courses. The thesis author, Henry Visneskie, was hired as an Emerging Technology Research Assistant in Jan. 2020 as a co-op student to investigate educational VFEs and equipment and start designing VFEs for geoscience courses (Visneskie, Park, Johnston 2020 and Visneskie et al., 2020). This was to demonstrate a proof-of-concept application for the predicted benefits VFEs have for students to achieve course learning objectives and become more competent geoscientists.

Literature Summary

During his co-op work term from Jan. to Aug. 2020, Henry Visneskie conducted an extensive literature review, which provided a strong foundational understanding of VFEs. This understanding was further developed through a more thorough literature review conducted in the fall of 2020, the highlights of which are described below:

Geoscience-related skills developed using VFEs

- By creating a VFE that addresses learning at two levels (a basic knowledge level and a more critical, metacognitive level), student learning performance, achievement, motivation, self-efficacy, and problem solving are improved (Litherland & Stott, 2012; Meyer et al., 2019; Carbonell-Carrera & Saorín, 2017).

Tailoring VFEs to achieve learning outcomes

- VFEs can target learning outcomes in combination with lectures or assignments, to prepare for field work, or to review key information post-field work (Minocha et al., 2017; Dolphin et al. 2019; Kingston et al. 2012; Cliffe, 2017)
- When students are guided through a VFE by a teacher, they retain more information from the Tour than if they explore the Tour autonomously (Tutwiler et al., 2013). However, students are more engaged and excited about VFEs if they are able to guide themselves autonomously (Tutwiler et al., 2013). Therefore, the goal is to retain the engaging nature of virtual reality, while using strong educational design to facilitate learning (Parong & Mayer, 2018).

Hypothesis

Integrating VFEs into first- and second-year geoscience courses at UW-EES will help students better achieve course learning objectives and better develop student geoscience knowledge required for professional competency. Replacing a class fieldtrip and group assignment with a VFE will improve student performance on the respective assignment, due to the more guided nature of VFEs compared to student explorations while in the field.

Objectives

Earth 121: Introductory Earth Sciences - Students will view a VFE about salt, designed to help students think like geoscientists (a foundational course learning outcome). Students will report increases to their systems, spatial, temporal, and/or field thinking – ways of thinking used by geoscientists, as outlined in Earth 121: Introductory Earth sciences.

Earth 231: Mineralogy - Students will successfully complete a traditionally field-based geologic mapping and interpretation assignment using a VFE, designed to emulate a traditional field experience. This will also present a proof of concept of VFEs being used to convey specific field-based information, which was not feasible due to travel restrictions during a pandemic.

Methods

VFE implementation was different for the two courses, designed to specifically align with intended learning outcomes of each course. The design, assessment and data analysis (both quantitative and qualitative) are summarised in Figure 2.

Earth 121

VFE Design
VFE created by thesis author about salt, containing Scenes with 360-degree photospheres and POIs (text, 2D images). A VFE-based quiz was also created to evaluate students' knowledge and perception.

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Assessment
VFE-based quiz worth 3% of overall grade. Students were marked for the correctness of their knowledge-based question responses and for participation for the short answer questions.

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Data Analysis
Qualitative: data obtained from short answer quiz questions. Similar responses grouped to determine perceived types of learning the VFE facilitates. Distribution of responses by learning type shows for which types the VFE was successful.
Quantitative: data obtained from matching knowledge-based questions used to determine what information was effectively conveyed with the VFE. This was analysed to determine how many matches students made correctly

Earth 231

VFE Design
VFE created by Dr. J. Parks and TA Q. Worthington around HD panoramas of three Bancroft outcrops, containing markers and key text about outcrop information.

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Assessment
In groups of 4 or 5, students completed an assignment worth 25% of their final grade involving rock identification and outcrop interpretation using the VFE. Marks were assigned by Dr. Parks based on an existing rubric.

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Data Analysis
Quantitative: data obtained from students' grades in each section of the assignment rubric. Data used to determine student performance; compared to data from the assignment in previous terms to determine statistical impact of a VFE vs a field trip.

Figure 1: progression of methods including the design, assessment, and data analysis stages

Results and Discussion

Earth 121: Question 1 – Knowledge-based Matching (Quantitative)

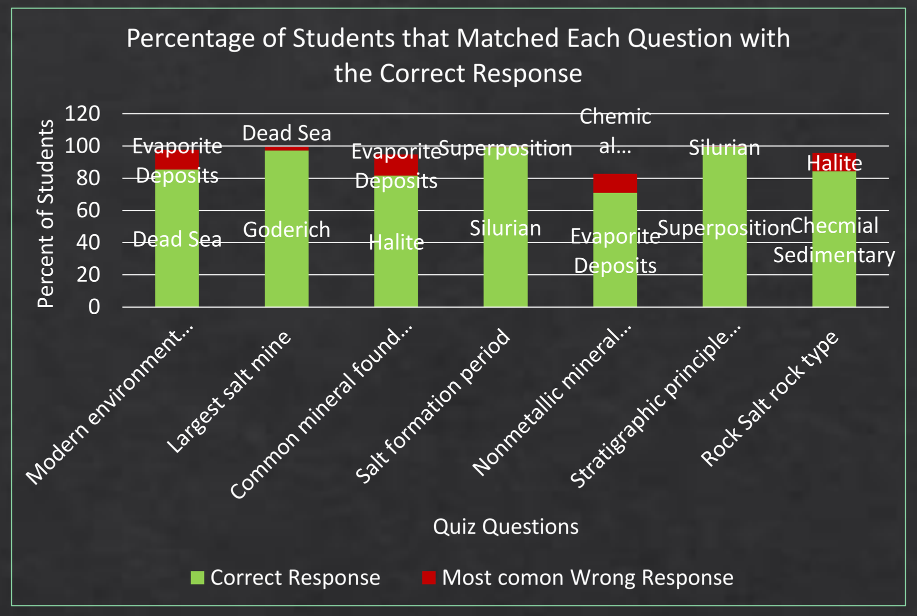

Figure 2: Proportion of students which correctly matched each term and corresponding response (in green or bottom boxes in each cumulative bar) as well as the most commonly selected incorrect match (in red or top boxes in each cumulative bar).

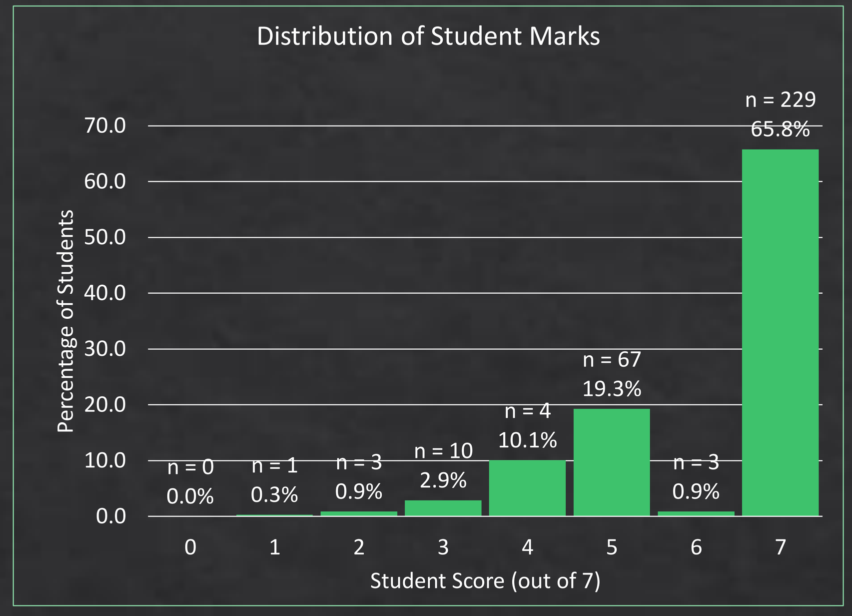

Figure 3: Number and percentage of students which achieved correct responses in a matching question related to the Salt VFE.

Figure 2 demonstrates that the definition "Stratigraphic principle used to determine relative age of salt layers" was matched most correctly, by 99.4% of students. Figure 2 also demonstrates that the least matched definition, "nonmetallic mineral resource", was matched correctly by 71% of students. Figure 3 shows that 65.8% (n = 229) of students correctly matched all seven responses, suggesting that most students achieved intended learning outcomes. Because definitions available to be matched were single-use and there was an equal number of definitions and terms to be matched, it is likely the success of students was favoured by the structure of the question (being easier to discern right and wrong matches as definitions were used)

Earth 231: Rubric Analysis (Quantitative)

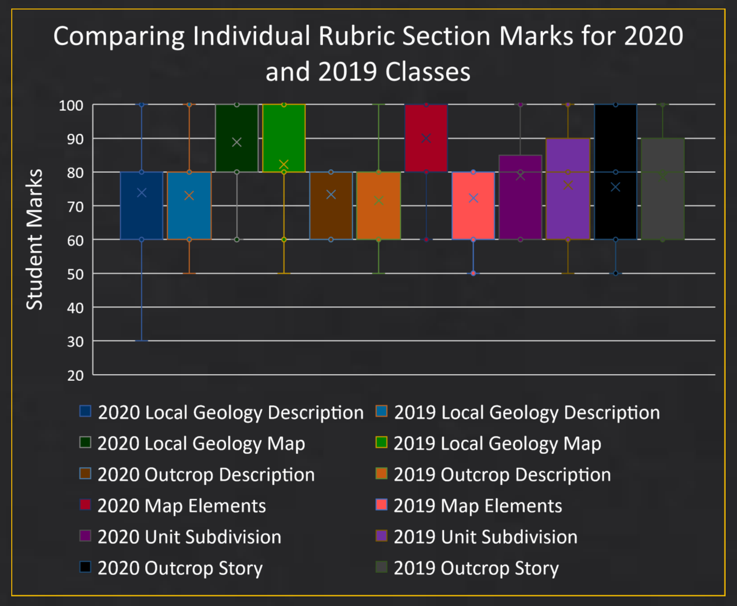

Figure 6: Boxplots representing overall student performance (no division based on outcrop) for 2019 and 2020, for each section of the rubric. Each of the seven sets of colours represents one section of the rubric.

	Local Geology Description		Local Geology Map		Outcrop Description		Map Elements		Unit Subdivision		Outcrop Story	
	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019
Mean	73.89	73.08	88.89	82.31	73.33	71.54	90.00	72.31	78.89	76.15	75.56	78.46
Variance	272.22	256.41	198.69	235.90	94.12	197.44	200.00	152.56	210.46	292.31	343.79	230.77
Observations	18.00	13.00	18.00	13.00	18.00	13.00	18.00	13.00	18.00	13.00	18.00	13.00
df	26.00		25.00		20.00		28.00		23.00		28.00	
t Stat	0.14		1.22		0.40		3.70		0.47		-0.48	
P(T<=t) one-tail	0.45		0.12		0.35		0.00		0.32		0.32	
t Critical one-tail	1.71		1.71		1.72		1.70		1.71		1.70	
P(T<=t) two-tail	0.89		0.23		0.70		0.00		0.64		0.64	
t Critical two-tail	2.06		2.06		2.09		2.05		2.07		2.05	

Figure 7: a chart comparing the quantitative information from each of the seven rubric categories. Each of the seven groups contains two mean, variance, and observation datasets (one for each year) and one set of test stats, P values, and t values.

Figures 6 and 7 collectively demonstrate that when comparing each section of the rubric between 2019 and 2020 classes, students achieved statistically different (greater) marks for their Map Elements. All other sections were statistically similar between years. This implies a specific influence contributed to students' improved abilities to create and format map elements (legends, symbols, scales).

Earth 121: Questions 3 and 4 – Short Answer (Qualitative)

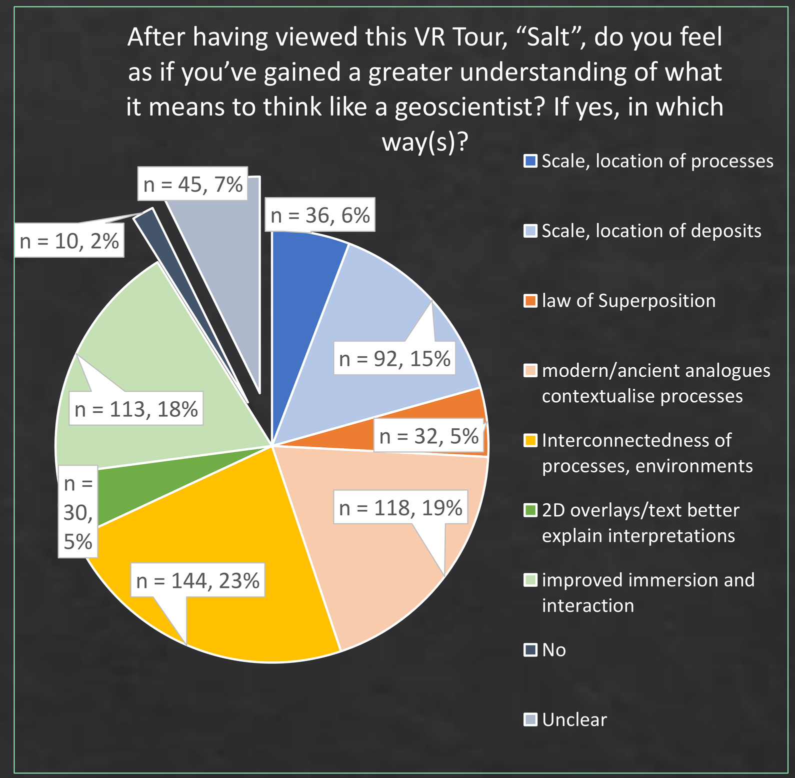

Figure 4: Pie graph demonstrating the relative proportion of student responses when asked if the Salt virtual Tour helped them think like a geoscientist

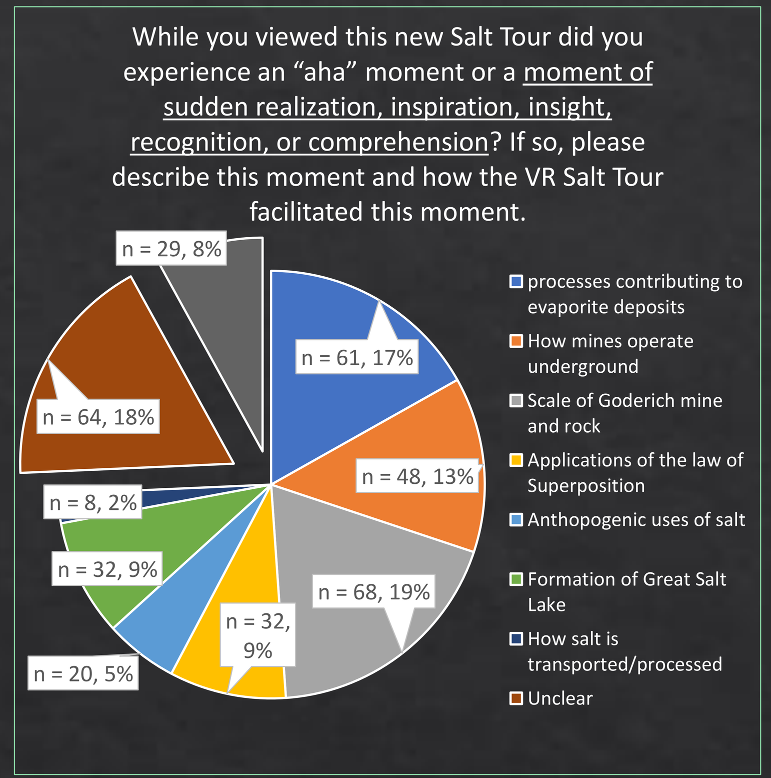

Figure 5: pie chart showing the proportion of students who responded to a question about experiencing a sudden moment of insight while viewing the Salt virtual Tour

Figure 4 shows that students perceived the VFE to strengthen to their ability to think like geoscientists. The four ways of thinking were reported in similar overall proportions (24% temporal, 23% systems, 23% field, 21% spatial). Therefore, the intentional design of the VFE was successful for facilitating all four ways of thinking. In Figure 5 the largest groups of students reported moments of insight related to salt formation processes (18%) and to the depth/scale of the Goderich Salt Mine (19%). 18% of students provided unclear responses.

Conclusions

- Students in Earth 121 successfully applied geoscience knowledge learnt from the Salt VFE, as shown from the quantitative matching question results. These results may have been influenced by the structure of the matching question and available responses. Students reported overwhelmingly being able to think like geoscientists, relatively evenly in each of the four ways of thinking, suggesting VFEs can be intentionally designed to facilitate specific and many ways of geoscience thinking. Students experienced moments of insight mostly related to locations or processes they would have otherwise not experienced in person (the Great Salt Lake and underground Goderich Mine).
- Students in Earth 231 earned similar overall grades between a field assignment in 2019 compared to a remote assignment in 2020 (due to the pandemic). Although this supports a good alternative when field work can't be completed, remote analysis does not replace the value of field work. Significantly higher marks were earned by students for one specific section of the assignment - the formatting and creation of their map elements (legend, symbols, scale). This may be related to an added lab exercise in 2020 where students were able to practise and receive feedback on creating map elements.
- VFEs are engaging and able to be designed to facilitate learning, when supported with good pedagogy. It is critical that VFEs are designed to integrate course learning objectives, to be effective.

References and Acknowledgements

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