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Title: An Interpretative Phenomenological Analysis Exploring Rural Nova Scotian Novel Physics Problem Solving

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Abstract

Rural Nova Scotians have a unique and heterogeneous cultural existence. This study explored how Nova Scotians make sense of their novel physics problem solving experience within a rural context, in an effort to draw out key aspects of experience warranting further investigation. Novel physics problems are structured to present an unfamiliar scenario, without the intent of eliciting a specific solution structure. The aim of novel physics problem solving is challenging the solver to apply their conceptual knowledge independently; it is a high level skill, with sharp contrast between experts and novices.

Novel physics problems were completed by the four rural Nova Scotian participants, followed by semi-structured interviews exploring each participant's experience of novel physics problem solving, and aspects of their rural lives and education that played a role in that experience. Using interpretative phenomenological analysis, narrative biographies were developed applying synchronic and diachronic narrative analysis to aid in engagement with the hermeneutic circle, consistently considering the data within a rural Nova Scotian context. Cross case analysis was carried out, and identified two major findings; relatedness to physics and problem solving appears to be stronger in people who identify as rural and demonstrate interest in typically rural pursuits, and experience of success from sources aside from formal novel problem solving may have similar effects to successful novel problem solving experience on competence.

Through exploration, this study identifies the need for further research into potential rural sources of physics relatedness and competence, to develop a clearer understanding of the relationship between rural life, physics engagement, and experience of success.

Declaration of Originality

This dissertation is the result of my own work and includes nothing which is the outcome of work done in collaboration except where specifically indicated in the text. This thesis does not exceed 20,000 words in length.

Signature ______________________

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Abbreviations

BSc	Bachelor of science
BERA	British Educational Research Association
CET	Cognitive evaluation theory
COVID-19	Novel corona virus disease 2019
CSAP	Conseil Scolaire Acadien provincial
DEECD	Department of education and Early childhood development
IPA	Interpretation phenomenological analysis
IT	Information technology
MPhil	Master of philosophy
NCTM	National council of teachers of mathematics
NSTU	Nova Scotia Teachers Union
PhD	Doctor of philosophy

Acknowledgements

I am grateful for the support of the Tri-County Regional Centre for Education Article 60 Committee, who granted me a year of educational leave to pursue this research programme, and the Nova Scotia Teachers Union who awarded me a full-time study grant to help towards studying in England. In addition to this generosity, my school community and students past and present have consistently encouraged my postgraduate study, and I hope to return to teaching with experiences and knowledge to benefit rural Nova Scotians.

My supervisor, Dr Steve Watson has consistently approached my research with an open mind, and curiosity. I appreciate his ability to suggest readings and theories that take me down beneficial rabbit holes. I will however, endeavour to continue providing evidence that Ricky and Bubbles are exceptional rather than typical Nova Scotians.

To my participants, thank you. I know it must have been weird to Zoom with your old teacher, but I am grateful for your willingness to participate, and your candour. Arthur Hatt, thanks for the proof-reading. I imagine some chocolate milk was needed to sustain you; consider me indebted.

To my family, thanks for putting up with the constant stream of messages from me when I was away, keeping me up to date on the gossip, and attempting to maintain interested expressions when I talked (possibly for too long) about my research.

Shawn Adams braved the confines of Westjet to get me settled in Cambridge, kept my cats alive, and routinely assured me that my research had value. I'll say thanks now, but I'm afraid you're not completely finished yet.

This dissertation is dedicated to my grandparents: Carroll and Helen Slauenwhite, who consider the idea that ability has limitations to be ridiculous (although I still can't swim).

1. Introduction

The goal of most; possibly all educational research, is to drive progress and improvement. But defining what progress is, and who will benefit from perceived improvement is fraught and value laden (Bogden & Biklen, 2007, p13; Johnson & Christensen, 2020, p53). When I initially sought to investigate physics problem solving, I intended to target a single aspect of problem solving in the hope of developing an intervention. But honing in on just one component of problem solving was problematic, particularly within a precise context: rural Nova Scotia, Canada. A need to understand; to build a picture of how rural Nova Scotians engage with unfamiliar physical situations emerged. As a result, how rural Nova Scotians make sense of the phenomenon of novel physics problem solving became the aim of this research.

1.1 Rationale

When I drive to work in the morning, I travel a half an hour along a highway that runs along a bay, in Nova Scotia, Canada. I see the same cars on the highway each day; people with schedules just like mine. When I arrive at school, I invariably run into the head custodian, who also invariably teases me about something. He puts up with me blowing up my sink (only a small chip out of the tap), dying my floor (and myself) green, and routinely stealing his nitrile gloves. I figure I can handle a bit of teasing in return. Students start arriving about forty five minutes later; they grab something from the breakfast program[1],

[1] In Nova Scotia, many schools have free breakfast programmes that supply all students with food.

socialise, then head to class. Our school is a community, and it is easily apparent when you are in the building.

Within a rural community, particular skillsets and experiences are highly valued, but are sometimes at odds with the values of formal education (Corbett, 2004). As a result, relevance is of key importance, and helps to bridge the divide (Hardre & Reeve, 2003). I have been teaching secondary science in primarily rural communities for ten years, and routinely notice that students are more content and academically focused when working towards something concrete, or directly relevant to their context. Abstraction, or learning something 'for the sake of it' is poorly tolerated, and often questioned.

Fortunately, physics is rife with everyday science; the issue is melding relevance, concept development, and skill development together to form a pedagogical practice that is effective, and accessible. There is no magic bullet, but one practice that I employ in my own physics classroom has shown itself to be academically valuable, without eliciting the "why do I have to learn this?" sort of question. This practice is novel physics problem solving, and by presenting students with unfamiliar physical situations, there is opportunity for them to experience the universality of physics.

1.2 Defining novel physics problem solving

Novel physics problems are physical problems situated in scenarios that have not yet been experienced by those attempting to solve them. In the simplest sense, physics problems are questions about situations that can be answered through the application of physics principles. Problems are not exercises, an exercise serves the purpose of eliciting a specific skill or algorithm; a problem is much more open ended and not aimed at a specific process. The aim of problem solving is to challenge the solver to apply conceptual knowledge independently, without relying on familiarity or procedural replication. The term ‘novel problem solving’ is used throughout this dissertation to heighten clarity of the somewhat ubiquitous and often misunderstood term *problem,* and ensure that there is no confusion as to the intent and structure of the problems discussed.

1.3 Research question

The root of this research is exploration, and the development of a ‘jumping off point’ for further research into the phenomenon of physics problem solving within a rural context. To address this, the following research question will inform the process and analysis of this study:

How do rural Nova Scotians make sense of their experiences with novel physics problem solving?

The question is simple, but that is by design; the intent is not to restrain results. Through exploratory research, elements of the phenomenon are free to emerge.

2. Theoretical framework

The development of this theoretical framework has been longitudinal and iterative in response to my developing understanding of the philosophical basis of social science research. This section will identify the ethical basis of the research, clarify my ontological and epistemological stance, and situate my philosophical perspective as an ongoing evolution running parallel to, and growing from the theoretical framework.

2.1 Personal philosophical permutation

I was recently struck by a quote from an essay written by George Orwell, in which he stated that, “Good prose is like a windowpane” (Orwell, 1946). I am not often found reading essays by George Orwell, rather, I read the quote in a biography of English physicist Paul Dirac (Farmelo, 2011). My immediate response was to respond in kind, that ‘good research is like a windowpane’. Hearing the words come from my mouth caused me to pause, and question why my research default seems to be positivism, as my comment had emerged from a perception of ‘good’ referring to hypothesis driven. My background is in the natural sciences; I have a BSc in biology, and a masters in physics. As a science teacher I spend countless hours contemplating science, developing experiments, and trying to think up impressive demonstrations. The control and ubiquitous principles provide comfort that the social sciences do not offer. Natural science in particular feels tidy and organised, research is impersonal and often data driven, there is (although possibly in error) little call for examining one’s own position in relation to the data; I have been happily indoctrinated into empiricism, and perhaps have even developed some naturalist leanings (Kim, 2001).

In contrast, my perception of the social sciences is one of disarray and inherent bias. Social science is messy, seemingly governed by the eb and flow of Western academic trends; in stark contrast to my perception of the hard sciences ‘chipping away at the coalface’ in an effort to extend universal, generalisable knowledge. Staid and trusted processes are reassuring; cobbling together methodologies to develop a basis of interpretation seems fraught with risk, with perpetual doubt of methodological quality. Add to that the qualitative nature of much social science research and its lack of generalisability, and I found myself questioning how knowledge could be pushed forward by isolated phenomena analysed subjectively. I needed a bridge between my narrow definition of valuable research, and the nature and construction of knowledge.

Again, my reading of Dirac's biography was useful, as a reference to the eminent physicist Niels Bohr's justification for having both a wave and particle picture of subatomic physics proved illuminating to me, "...in which truth cannot be pinned down using only one approach but needs complementary concepts; for example, a mixture of reason and feeling, analysis and intuition, innovation and tradition" (Farmelo, 2011, p128). Bohr felt so strongly about the complementary nature of the fundamental laws of physics that he designed his personal coat of arms around the concept, including the yin-yang symbol (Pais, 1993, p24) to represent the duality and complementarity of nature (see **Figure 1**).

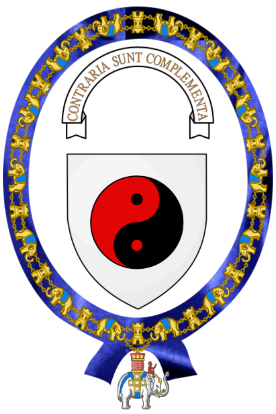

Figure 1: Coat of arms of Niels Bohr. Designed by Bohr himself upon being awarded the Danish *Order of the Elephant,* which required members to display their coat of arms at Frederiksborg Castle. GJo/Wikimedia commons/Public Domain

I was reminded that researchers are the vehicle of all research, and that social science is not separate from natural science, but complementary. I acknowledged a tendency to perceive scientific advancement as a linear, independent process, despite awareness of its collaborative and often heuristic nature. Years ago, Albert Einstein's five annus mirabilis (1905) papers (the 1965 English translations), particularly *Concerning an Heuristic Point of View Toward the Emission and Transformation of Light,* educated me on nonstandard approaches. In that paper, Einstein challenged the existing electromagnetic theory of light through wielding intuition as willingly as empirical data through a back-to-front heuristic. This encouraged me to open myself up to engaging in the 'messiness' of social science research.

Nevertheless, this new-found willingness to extend myself into unfamiliar methodologies and philosophical traditions did not resolve my concern about generalisation. Quantitative research plays an enormous role in the social sciences, but the questions emerging from my practice were not answerable through quantitative methods. Serendipitously, the source turned out to also be the salve, as reflection on my scepticism of classroom interventions revealed why externally developed interventions feel hollow; they fail to address my reality. I needed research that echoed the context of my practice, and there was precious little of it about. It then became clear that generalisation is not the litmus test for relevance; the individual matters. This realisation cracked my scientific pragmatism, allowing me to engage in open-ended qualitative research. My philosophical empiricism is still present, nudging me with reminders of comfortable objectivity as I struggle with philosophy that is unfamiliar and uncomfortable, but forward I go.

2.2 Ontology and epistemology

Nova Scotia is a geographically remote province; rural communities feel the impact acutely, in trivial ways such as waiting weeks for an Amazon[2] order, and in nontrivial ways such as lack of adequate healthcare (Health Assoc. Of Nova Scotia, 2013). Education in rural Nova Scotia likewise experiences adversity; the lack of internet coverage negatively affected access to course material during the COVID -19 lockdown. Three of the eight centres for education[3] reported that 13% of students had limited or no access to internet during the pandemic (McMillan, 2020). Nova Scotia has long had a delicate relationship with education, as the lure of employment traditionally pulled youth away from school (Corbett, 2007). To address these challenges, structuring the research within a critical framework seemed appropriate (Nielsen, 2019), influenced by the ethos of critical theory as emancipatory; "Its [critical theory] purpose is not merely to understand situations and phenomena but to change them. In particular it seeks to emancipate the disempowered, to redress inequality and to promote individual freedoms within a democratic society" (Cohen, Manion, & Morrison, 2007, p260).

For a few months, I maintained a critical philosophical perspective, but research is iterative, and I eventually acknowledged that while empowerment of rural youth through education spoke to me, rural emancipation did not. Certainly there are resource-based inequalities, but taking the position that rural education in Nova Scotia is uniformly marginalised was disingenuous. Further reflection yielded much in the way of positives; rural schools are often small, promoting community and connection, and strongly invest in

[2] Amazon is an e-commerce company
[3] Centres for educational hold regional control over the administration of schools

students as individuals (Cuervo, 2017, p33). Byun et al. (2012) found in their study on post-secondary completion that rural students actually had a “higher level of community social resources” than nonrural students, and within their sample, the benefit of these resources had a small positive effect on post-secondary attainment. I needed to find a framework that fit, rather than forcing a perspective that risked misrepresentation.

With a research question addressing sense making of novel physics problem solving experiences, the aim is necessarily to see through another’s eyes. Not a simple ambition, yet guidance can be taken from the German words *Verstehen* and *Deuten,* which translate, based on their use by sociologist Max Weber to; ‘to understand’ and ‘the interpretation of subjective states of mind’ (Roth & Wittich, 1978). The act of interpretation is inherent in both *Verstehen* and *Deuten,* linking the research question to an interpretivist theoretical perspective. I have not framed this research within interpretivism lightly; interpretivism is ubiquitous in qualitative literature, and I did not want to take ‘the well trodden road’, choosing a well-used safe ontology without justification (Freebody, 2003, p35). However, examination of the underlying assumptions uncovered a relativistic ontology, where “reality is constructed within the human mind, such that no one true reality exists; instead, reality is relative according to each individual who experiences it at a given time and place” (Moon & Blackman, 2014). This ontology ‘hit the nail on the head’ in terms of my perception of reality, so I conceded that an interpretive paradigm capably addressed the layering of sense making that emerges from the research question.

Assuming the position that reality is a relative product helped me pinpoint an epistemology in line with social constructionism, albeit in a limited way. The term social constructionism is eclectic in its usage, so I will define the meaning as: the construction of objects or referents of knowledge from linguistic, social, and historical contexts (Schwandt, 2015). I strongly object to the idea that all objects or referents of knowledge are social constructs, as this perspective dismisses any shared reality, and places the basis of fact on shaky ground. As a result, I must ascribe to a weak form of social constructionism, where the social character of knowledge is emphasised, but shared objective aspects of reality are present (Sayer, 2000, p90). It is my perception that individuals live a subjective existence imbedded in *real* conditions that situates my epistemological beliefs within a weak form of social constructivism. If nothing of reality was objective, then shared experience would be impossible; as I peer out the window, I see a woman walking her dog, and she looks back at me. It was the very real window that granted us a shared moment in time; a real occurrence experienced subjectively (Haraway, 1991).

There is potential to perceived a conflict between the relativistic ontology and weak social constructionist philosophical foundations of this research. I must argue however, that a relative construction of reality does not preclude the existence of the *real*, it simply means that the interpretation of objects and referents is relative, and individual reality is dependent upon unique perspective. Likewise, the linguistic, social, and historical contexts that emerge from a relative reality drive the construction of knowledge. What at first appears to be a controversial philosophical framework is actually a unified approach.

2.3 Ethics

As this research emerged from postgraduate work at an English institution, yet the crux of the research is firmly placed in Canada, it was imperative that I pay close attention to the ethical research standards of both countries. I established a clear understanding of the ethical research expectations of the British Educational Research Association (British Educational Research Association (BERA), 2018), and the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (Government of Canada, 2020), which is the Canadian equivalent of BERA's ethical guidelines. To address my professional ethical responsibilities, as a licenced teacher in Nova Scotia, I ensured that my behaviour and research methods adhered to the Nova Scotia Education Act (Education Act, 2018, Article 42), and the Nova Scotia Teachers Union Code of Ethics (NSTU Code of Ethics, 2016).

The BERA guidelines and Tri-Council policy statement overlap in their discussion of the ethical expectations of research; informed consent, the right to withdraw, avoidance of harmful practices, and anonymity and confidentiality. Each of these principles were followed throughout this research, however there were limitations to participant anonymity. Through the disclosure of my connection to the participants, and the biographical information included in the analysis, it is possible that interested parties could infer the identity of participants. It is also possible given the social closeness of rural neighbourhoods, that participants could disclose their research involvement (to family or friends), and have that information further disclosed throughout the community. Each participant was made aware of this, and reassured that all rough data would be held confidentially, accessed only by my supervisor and myself.

Consideration of participant rights, as well as full disclosure of challenges to protecting anonymity not only address BERA guidelines and Tri-Council policy, but complement the NSTU code of teacher ethics. Section I subsection (a) states, "The member regards as confidential, and does not divulge other than through professional channels any information of a personal or domestic nature, concerning either pupils or home, obtained through the course of professional duties" (NSTU Code of Ethics, 2020). Despite not currently teaching any of the participants, it was important to me to maintain my professional ethical standard. My position as their past teacher, although a positive association, could represent a position of power. For this reason, I was cognisant of reminding participants of their right to withdraw, and that the decision to participate was entirely their own.

Carrying out research in-line with ethical expectations of practice does not exhaust the responsibilities of a researcher. Given the aspiration of this research to understand how rural people make sense of novel physics problem solving, maintenance of participant voice was of utmost importance. The use of verbatim excerpts from interview transcripts honoured participant voice, while inviting participant feedback on data analysis throughout the process minimised any notion of researcher omniscience. There is honesty to this process, as Gilgun (2005) wrote, "...many contemporary researchers believe that the materials researchers generate are co-constructions, representations of interactive processes between researchers and researched" (p258). But this is not enough, the presentation and discussion of data must also maintain participant voice.

To meet the ethical challenge of preserving participant voice, I needed to beseech myself to step away from the practice of writing in the third person; a habit of decades, and instead record this dissertation in the first person. A first person narrative provides the opportunity to expose positionality and bias; avoiding the status of, "all knowing, yet separate researcher" (Chandler, Anstey, and Ross, 2015). The persistent presence of my own voice intermingled with participant voice aims to reinforce the collaborative nature of the research process, at once humanising it by acknowledging my personal context and capacity for reflexivity, and eschewing positivism by distancing myself from the disembodied 'other'.

3. Context

An emphasis on historical, cultural, and even geographical context may at first seem out of place in an investigation of novel physics problem solving. But the aim is a ‘zooming out’ of perspective, from the minutia of a participant’s individuality to the greater world that individual exists in, developed in, and is constantly influenced by. For this reason, this section will elucidate some components of the social structure of Nova Scotia; guiding the reader to some understanding of the Nova Scotian experience.

3.1 Nova Scotia: independent yet adhered

Canada is a geographically vast country, with an area of 9 984 670 km^2 (Geography of Canada, 2018). While Canada was confederated in 1867, only four of the current ten provinces predate confederation; one of those is Nova Scotia (Constitution Act, 1867). The unique position of a province predating its own country possibly speaks to the strength of provincial identity. In the 2019 Environics Institute survey: *Canada: Pulling Together or Drifting Apart,* 27% of surveyed maritimers[4] reported their provincial identity of higher personal relevance than their national identity, and 37% reported provincial and national identity to be of equal importance (Environics Institute, 2019). This builds upon the 2014 *Engage Nova Scotia Quality of Life Index,* as 73.8% of respondents reported a strong sense of belonging to community. Whilst these numbers emphasise Nova Scotian loyalty, sense of belonging and provincial pride is not an endowment; it is the result of a shared history of conflict and hardship (Elder & Conger, 2014).

[4] The term *maritimer* refers to citizens of Nova Scotia, New Brunswick, and Prince Edward Island; the *maritime* provinces.

Nova Scotia has a population of 971 395, with 43% of inhabitants living in rural areas (Statistics Canada, 2019). It is located in eastern Canada, and if you examine **Figure 2**, you will notice that Nova Scotia is a peninsula, almost entirely surrounded by the Atlantic ocean.

Figure 2: Nova Scotia's location in relation to the greater country (produced using smartdraw software)

This peninsular geography has a strong influence on daily life, as there is a well developed maritime culture, coupled with the independence typical of island cultures (Mackinnon and Mackinnon, 2015, p42). The unofficial provincial anthem; Barrett's Privateers by the folksinger Stan Rogers, typifies the essence of what it is to be a Nova Scotian, the song describes the lure of the sea felt by so many, and the subsequent sacrifice when the promise of prosperity is not realised.

God damn them all
I was told we'd cruise the seas for American gold
We'd fire no guns, shed no tears
Now I'm a broken man on a Halifax pier
The last of Barrett's Privateers (Rogers, 1977)

Fighting for prosperity and a 'fair shake' is a common theme running through our history; mining strikes beginning in the late-nineteenth century that continued for decades still produce ripples of hierarchical mistrust and industrial action into the twenty first century (Demont, J, 2000, p16). Fishermen and farmers vulnerable to the seasons, a sometimes fickle tourist trade; these are the mainstays of Nova Scotian economics, and formative influences on a culture marked by working class struggle (Candow, 2003). In 2002, then federal conservative party leader Stephen Harper (and subsequent Prime Minister) claimed that Atlantic Canada[5] suffers from a "culture of defeat", and would not succeed without conservative policy (CBC News, 2002). This perception of eastern Canada is common (Johnson, 2019), despite most traditional industries emerging from a colonial history, marked by poor conditions, physical toil, and competing cultures. Nova Scotia's heritage is a blend; the most recent census data (2016) reports 48 640 people of First Nation descent, 23 700 Acadian, and 21 915 of African descent; the remaining majority identify as European or recently immigrated (the total immigrant population in Nova Scotia was 55 680 in the 2016 census) (Statistics Canada, 2016). The tapestry of Nova Scotia is woven with many stories and cultures, and yet we are all Nova Scotians (Nova Scotia Archives, 2014).

3.2 Education system

Provincial governments are delegated power by the legislative branch of the Government of Canada based upon the Constitution Act of 1867 (Hogg, 2003, p. 686). One of the systems that fall under provincial power is education; Nova Scotian education is regulated by the Department of Education and Early Childhood Development (DEECD).

[5] Atlantic Canada refers to the following group of provinces on the Atlantic seaboard: Nova Scotia, Prince Edward Island, New Brunswick, and Newfoundland

Unlike many countries, and other Canadian provinces, Nova Scotia conducts standardised tests[6] primarily as a form of data collection and progress monitoring in mathematics and literacy (Education and Early Childhood Development, 2020).

This lack of high-stakes testing reveals an education system that values teacher autonomy, and recognises that a diverse population has diverse needs. The direct administration of schools is the responsibility of local *centres for education,* headed by a *Regional Executive Director* who oversees the implementation of programs, hiring, and professional development throughout the local area. There are seven such centres with local responsibilities, as well as the *Conseil Scolaire Acadien Provincial* (CSAP), which is responsible for French-language Acadian schools throughout the province (Our schools and regional centres for education, 2016). All centres for education teach from the same provincial curriculum documents, while the CSAP has curricula reflective of their French speaking programmes. This curriculum variance is consistent across Canada, Canadian cultural and geographic diversity is at the heart of why education is a provincial mandate.

The area of Nova Scotia is 52 942.27km^2, housing one city[7], and many rural communities. School aged children in rural communities attend schools of varying size; the range of which spans the hundreds. School size and staff expertise can impact equitable access to education, as small rural schools are sometimes unable to offer courses with low enrollment numbers or the requirement of specialised teaching skills. Physics is one such course that is often impacted by enrollment; at the secondary school I teach at, physics is

[6] Provincial assessments take place in grades 3, 6, 8, and 10 (years 4, 7, 9, and 11 of school enrolment), with results provided to schools and families to identify gaps and generally aid in progress (Education and Early Childhood Development, 2020). Only grade 10 exams contribute to summative assessment

[7] Halifax regional municipality (HRM), more commonly called ‘Halifax’

offered every second year, alternating with chemistry. Online offerings attempt to minimise inequity, but generally draw lower enrollment rates than their in-person counterparts. Poverty can also be a barrier to educational engagement in rural areas, as seasonal industries such as fishing, tourism, and agriculture are major employers. The current (July 2020) unemployment rates in Nova Scotia are shown in **Table 1**.

Table 1: Unemployment rate in Nova Scotia, as of July 2020. ***Source: Statistics Canada, Regional unemployment rates used by the Employment Insurance program.***

Region of Nova Scotia	Unemployment rate (%)	Primarily urban/rural
Eastern	18.5	Rural
Western	12.6	Rural
Halifax	11.8	Urban

Rural unemployment, particularly in the Eastern part of the province is high, and affects children. 2019 *Feed Nova Scotia* food bank use data states that 29.1 % of rural food bank users were children under 18 (Hunger Count, 2019). Going to school hungry is a reality for many Nova Scotian children, potentially exacerbated by the isolation of some rural communities.

3.3 Nova Scotia in a pandemic

In March 2020, Nova Scotia was impacted by the infectious virus known as COVID-19 (corona viral disease-2019). I returned to Nova Scotia from Cambridge on 14 March; the beginning of the Easter vacation, with the intent of completing data collection in Nova Scotia and returning to Cambridge in April. Unfortunately, the pandemic required the University to administer the Easter term remotely. While the changes impacted participant access as discussed in section 5.3.1, remaining in Nova Scotia enabled me to develop an insider perspective of Nova Scotian life through the pandemic.

On 17 March 2020, the provincial government announced that all schools would close, ultimately remaining closed until the end of the 2019/2020 school year. A move to remote schooling followed, as a provincial state of emergency was declared on March 22; allowing police to fine individuals and businesses not adhering to the province's social distancing regulations. As the number of infected individuals and deaths increased, Nova Scotians responded in ways very similar to people around the globe experiencing a 'new normal'. Some were fearful, and some made the best out of a bad situation.

Amidst the pandemic, a unified Nova Scotia was evident through the widespread reaction to an angry comment made by the Premier during one of his daily COVID -19 press conferences. Frustrated by Nova Scotians not social distancing, on 3 April 2020, Premier Stephen McNeil warned of the temptation to go out on the weekend, and the associated risk:

> The virus will find you. Then it finds your loved ones. Then it finds your neighbourhoods…then we have community spread. Then everyone is putting pressure on public health to solve it, and our health-care system to deal with it when all we have to do is *stay the blazes home* (McNeil, 2020).

The response was immediate, with Nova Scotian pride exploding over the Premier's very Nova Scotian, and presumably unplanned outburst of 'stay the blazes home'. In less than 24 hours there were memes, t-shirts, mugs, car decals (see **Figure 3**), and songs; even a new beer created in an effort to improve provincial morale; raising $90 000.00 for the provincial food bank in a span of two days (Mercer, 2020).

Figure 3: A Nova Scotia Strong vehicle decal. ***Source: Shawn Adams 2020***

Kitchen parties popped up on social media, with singers posting and writing songs to reflect the tone of the day; remembrance for those lost, celebration for few new cases. The Stanfields, a local band recorded a song titled *Stay the Blazes Home* which became a quarantine anthem; reminding people of the message, while adding a touch of normalcy through poking fun at the Premier in the following verse:

If you got the inkling you wanna go to town;
Remember there's a nasty bug going around;
This ain't no time wander;
This ain't no time to roam;
Listen up to Stevie-boy;
Stay the blazes home!
(The Stanfields, 2020)

The tone in Nova Scotia changed on 19 April from resilience to disbelief, when a spree shooter killed 22 people. The deaths touched families across the province, including my own, blanketing the province in grief. But Nova Scotians are not new to hardship; the population rallied in support of the victims' families, and the saying *Nova Scotia Strong* (**Figure 3**) soon became visible throughout the province, communicating the message that we can endure through adversity.

4. Literature review

The purpose of the literature review is to clarify terms related to the research question, particularly the often imprecisely defined term *rural* that is central to this research, place the research question into the elusive 'gap', and outline major theories connected to novel physics problem solving and rural education.

4.1 Scope and literature review methods

The initial literature review for this research was conducted prior to identifying a methodology, and included a broad examination of topics connected to physics problem solving and rural Nova Scotia (Nielsen, 2019). The huge range of phenomena related to problem solving actually obscured the aim, so I decided to pursue an exploratory phenomenological approach in the hope of uncovering aspects of physics problem solving particularly relevant to the rural Nova Scotian context. This meant I had to adopt a more fluid approach; identifying relevant theories as patterns emerged from data rather than collecting data with specific theories in mind (Chenail, Cooper & Desir, 2010).

Another challenge to this review was a lack of contextual exemplars, so rather than critically evaluating studies closely related to this research, I aimed to elucidate literature to define research parameters, and strengthen the analysis. What this means in application, is that much of the literature is peripheral, as many relevant theories have not been examined in a rural context.

4.1.1 Search methods

Literature was identified through the use of search terms. Terms were chosen for their relation to novel physics problem solving, rurality, or Nova Scotia. I used the search function in *idiscover*[8], as well as key word analysis and the thesaurus tools available in research databases to expand results through the use of synonyms. Searches were generally limited to educational and scientific databases (ERIC, British Education Index, Scopus, and Web of Science), though I used *Google Scholar*[9] when searching for Nova Scotian research due to its local search preferences. In addition to Google Scholar I searched the research interests of faculty at local universities to further uncover regional literature.

Literature discovered through this systematic process was collated based on connection to the context, topic, or theories with potential relevance to emergent themes in the data. No time bound was applied to the material that remained, as it was useful to track theory development over time.

4.2 Rural and rurality

To speak about rural life in a meaningful way, the term *rural* itself needs to be defined from a research perspective. According to the Canadian census, rural is defined as a measure of population density; an area of inhabited land with less than 400 people/km^2 (Statistics Canada, 2011). Within this defined parameter there is room for variation between rural communities; if the house I grew up in was placed at the center of a square kilometer, the area would have contained around 38 people. This represents a very different reality than had

[8] Idiscover is the University of Cambridge's library search engine
[9] Google Scholar is a free search engine for scholarly articles, owned by Google.

there been 380 people/km^2, so a quantitative definition lacks experiential representation. Access to amenities is often cited as a factor in defining rural; Lake (2008) describes rural places as those with limited access to social infrastructure such as healthcare, arts and culture, or adequate education. This definition fails to address what it is to be rural; focusing on what is missing from a rural place, rather than what is present.

It is clear that population density and remoteness are factors in defining *rural* (Oliver, 2007), but there is also an emergent cultural identity, *rurality*. Chigbu (2013) defines rurality as, "...a condition of place-based homeliness shared by people with common ancestry or heritage and who inhabit traditional, culturally defined areas or places statutorily recognised to be rural". I hesitate to fall into the trap of presenting a "nostalgic notion" (Karabanow, Naylor & Aube, 2014, p113) of rurality by emphasising Chigbu's claim of homeliness, but there is often a sense of 'rootedness'. I disagree with Chigbu's description of common ancestry or heritage being of crucial importance to rurality; instead taking a view that many rural Nova Scotian communities are heterogeneous in their ancestry and cultural heritage (Franklin & Glascock, 1998).

Just as rural populations are heterogeneous, so are the experiences that inform rural identity. Wainer and Chesters, (2000) note that some rural communities have a traditional masculine culture, which can make male mental health vulnerable to changes in accepted definitions of masculinity. Indigenous land rights, and widespread remnants of a colonial past can create discord; in Atlantic Canada disputes over First Nations fishing and hunting rights can turn violent, as in the Burnt Church Crisis, a conflict between Indigenous and non-Indigenous fishermen over lobster fishing rights (Obeidi, Hipel & Kilgour, 2006). In contrast, aspects of rural life such as small community size and access to nature can lead to stronger community connections, sense of inclusion, and position within society; all of which strengthen community and individual resilience (Wainer & Chester, 2000; Kirmayer et al., 2009). Rurality does not represent any one thing to any one person, and rural definitions span from the despotic to the idyllic.

The slipperiness of defining *rural* and *rurality* is illustrated in Oliver's (2007) description of rural schools, "We can know rural schools when we enter them, but it is not always easy to create a description of them that can be widely applied". Rural life leads to a cultural rurality that you 'know when you see it', typified by ubiquity despite heterogeneity. In practical terms, within this research the Canadian census definition of rural was used to class communities as rural, but how individuals construct rural identity could not be defined, instead I encouraged participants to define their own rurality.

4.3 Elements of physics problem solving experience

Problem solving is initiated by a problematic situation; response to a problematic situation is personal and unique, guided by individual characteristics, experience, and knowledge. Once engaged in the search for a solution, common components of the experience emerge: process, conceptual understanding, and behaviour (Muir, Beswick & Williamson, 2008). Each problem solving element is fragmentary, in that individuals construct them from disparate pieces, ultimately crafting a unique experience.

4.3.1 Conceptual understanding

Formally, conceptual understanding refers to the, "explicit or implicit understanding of domain principles and the interrelations between them" (Ruttle-Johnson & Alibali, 1999);

more often described as common sense, or the intuition associated with knowledge of physics (Hammer, 1994). When faced with a novel physics problem, novelty level is related to the solver's associated conceptual knowledge; there is a need to make sense of a problem prior to solving it, identify applicable conceptual elements, and determine how to apply them to the problem (Sabella & Reddish, 2007). There is some debate as to whether problem solving itself is a valid pedagogical tool in developing conceptual understanding (Gerace & Beatty, 2005), but it is widely accepted that conceptual understanding is a component of effective problem solving.

Describing conceptual knowledge as *intuitive* and *common sense* is contextual (Stitch, 2018). Intuition and common sense development is influenced by context, so it follows that conceptual knowledge follows a similar path. Piaget's theory of genetic epistemology describes children acquiring knowledge as a product of interacting with the surrounding world (Driscoll, 1994), and gave rise to cognitive constructivism; learning by connecting new information to pre-existing knowledge and assimilating it into an intellectual framework (Liu & Chen, 2010). Social constructivism, which is rooted in Vygotskian psychology characterises learning as a result of social interactions between individuals or cultural products, and considers the experience of learning to be as meaningful as the acquired knowledge (Sullivan Palincsar, 1998).

This sense of journey can be extended to problem solving as a whole, as the relationship between conceptual knowledge and problem solving is fluid; conceptual interpretation and integration is not fixed. May and Etkina (2002) compared student epistemological self-reflection and conceptual learning; finding a link between students who connected physics learning with formulas or authority to low conceptual gains. Perception of physics was found by Chu, Treagust, and Chandrasegran (2007) to have an impact on conceptual development, as they observed stagnation when students felt that physics was abstract and not connected to their lives, while those who related to physics progressed. Rural communities are rife with opportunity to connect to physics, from the accessibility of nature, to rural pursuits such as mechanics, fishing, and farming (Avery, 2013).

Moll et al. (1992) discussed the concept of funds of knowledge while investigating the relationship between classrooms and homes in Mexican working class communities in Arizona, United States. Funds of knowledge are, “historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being” (Greenberg 1989; Tapia, 1991, Velez-lbfaez, 1988; in Moll, Armanti, Neff & Gonzalez, 1992). They found that funds of knowledge are rich cultural and cognitive resources, which could be used to positive effect in classrooms, particularly in the area of student-centered teaching. They also observed that in the communities studied, knowledge is not imposed by adults, but obtained by children through interest. Moll et al. also note that this is in contrast to the view of working class homes in educational research literature as environments not conducive to knowledge acquisition.

Multiple studies have detected a disconnect between local and academic knowledge (Boyer, 2006), or even resistance to formal education in rural communities (Corbett, 2004). A lack of normalisation of higher education (Corbett, 2007) could impact the perception of physics as superfluous and of little value given the implied connection to higher education. One answer to this disconnect is honouring local and Indigenous ways of knowing, as they can impart scientific knowledge that is outside of or represented differently than curricular outcomes (Avery & Kassam, 2011). Wagner and Lunney-Borden (2010) identified traditional

Mi’kmaw practices that echoed mathematical principles taught in Atlantic Canadian schools. Linking traditional knowledge to academic work could encourage further conceptual development (Chu, Treagust & Chandrasegran, 2007).

4.3.2 Problem solving process

Just as conceptual understanding is entwined with place and identity, so is process. Problem solving process is defined as the strategy or steps used to solve a problem; a potentially expansive procedure (Gok, 2010). Process is not procedure in a purely operational sense, but the decisions and actions carried out in search of a solution. A constructivist model of problem solving sees process emerge from conceptual knowledge (Lavoie, 1995). Problem solving process can involve the application of a heuristic; a practical method used to solve a problem that provides structure, but is not a guarantee (Myers, 2010). The validity of teaching heuristic techniques is debated, however the absence of a structured approach, or supported decision making is detrimental to solution development (Schoenfeld, 1979; Johanssen, 2012), leading to the common belief that familiarity with a general heuristic is better than no heuristic at all. Studies exploring the difference between ‘expert’ and ‘novice’ problem solvers consistently observe experts utilising heuristics (Hensberry & Jacobbe, 2012), but acknowledge that a key factor in moving from novice to expert is experience (Polya, 1945; Lester, 1994).

Problem solving is not one-size fits all; experts have been found to aim for sense making, including it in their heuristics, drawing on metacognition, content knowledge and identifying patterns (Larkin & Reif, 1979; Schoenfeld, 1987; Wang & Chiew, 2010). Hedge and Meera (2012) found that novice problem solvers tend to see physics equations as sterile mathematical tools rather than illustrations of physical relationships. This argues for the development of conceptual knowledge prior to process development, but the data is not yet clear. In their examination of mathematical knowledge construction, Rittler-Johnson, Siegler, and Alibali (2001) argue that knowledge construction is iterative, with learners increasing their understanding of procedures through prior conceptual understanding, and vice versa. This is a somewhat contested account of knowledge construction, as conceptual learning followed by procedural learning is a more accepted sequence, actively encouraged by the National Council of Teachers of Mathematics, who explicitly state that procedural knowledge should not be pursued prior to significant time spent developing conceptual knowledge (NCTM, 2014).

Sabella and Redish (2007) draw attention to the neurocognitive basis of process, stating that neural networks are a key component of cognition, as associated neurons develop connections that can be strengthened through practice and experience. These networks are activated through recall or use of stored information; improving links between related concepts, and recruiting new connections. Neural networks organise information into cognitive units, or *schema* (Rumelhart, 2017). Access to the information within a schema is dependent upon information interpretation and schema flexibility; inflexibility can cause failure to recognise analogous patterns, integrate peripheral information, or connect novel presentations of information to familiar ones (see **Figure 4**).

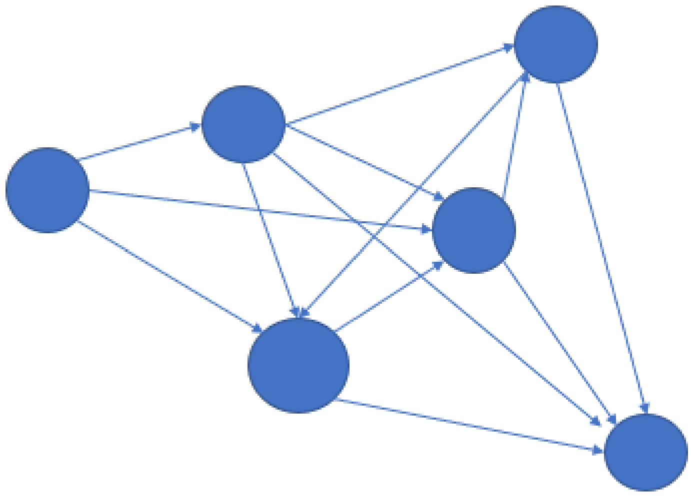

Figure 4: Model of schema illustrating differing access to conceptual knowledge and procedural processes, represented by the nodes. (Sabella & Reddish, 2007)

Encoding method also factors in to schema utilisation, contrasting the expert and novice problem solver; experts utilise multiple means of encoding, and draw connections between new and old knowledge, immediately strengthening neural networks, while novices sometimes experience schema inflexibility, failing to associate related knowledge (Sabella & Reddish, 2007).

Effective encoding for flexible schema is unique to individuals; there is no one-size-fits all approach to schematic development, and examining isolated effects tend to produce zero-friction studies that lack real-world translation. Greenfield and Bruner's (1966) paper, *Culture and Cognitive Growth* discusses how cultural and intellectual differences are connected, observing that "intelligence is to a great extent the internalisation of 'tools' provided by a given culture". This could be applied to the 'tools' of rurality, and extended to consider the influence of rural culture on cognitive processes. Although Greenfield and Bruner were focusing on the implications of language at the time, Bruner's (1967) theory of instruction was more general, composed of four components; curiosity and uncertainty, structure of knowledge, sequencing, and motivation. Applied to problem solving process, these constituents could contribute to effective neural network development.

Curiosity and uncertainty were important to Bruner, as discrepant events initiate desire in the learner to problem solve and look for alternative explanations and solutions (Lamnina & Chase, 2019). Bruner's theory of instruction is supported by structure and involves guidance, it is not purely independent learning. The second component; structure of knowledge, involves scaffolded learning through multiple representations. These representations are described as enactive (actions), iconic (images), and symbolic (symbols or abstract representations), and move the learner from easily understood concrete representations such as dropping a ball to demonstrate the action of gravity, to ultimately developing equations to illustrate gravitational relationships. The sequence of these events is what provides the scaffold, and avoids misconception or disparity between conceptual understanding and abstract processes (Bruner, 1961).

Progression through the sequence of representations is specific to the individual, but rushing to the symbolic without considering the enactive undermines the conceptual knowledge piece of problem solving, producing poorly considered process (Nardi & Steward, 2010). Addressing enactive and iconic modes of representation is a characteristic of expert problem solvers, as George Polya (1945) observed, expert problem solvers include a "look back" stage checking the accuracy of symbolic steps through referencing conceptual knowledge; arguably ensuring coherence between knowledge representations. Bruner's final principle is motivation, he particularly advocates the value of intrinsic motivation, with emphasis on interest guiding the development of intrinsic motivation as a problem solving behaviour.

4.3.3 Problem solving behaviours

Problem solving behaviour is characterised by three major components; motivation, belief, and the ability to exercise control over process (Muir, Beswick & Williamson, 2008). Motivation is present in all human behaviour, so it holds that it factors in physics problem solving (Deci, 1975). Theories of motivation are broken into two categories; content theories, and process theories. Content theories emphasise what causes motivation in individuals, while process theories examine the actual *process* of motivation itself. Effective problem solving requires an initial input of motivation, and the maintenance of motivation throughout.

McClelland's human motivation theory is a content theory that describes motivation as reliant upon how an individual perceives a stimulus, and their ability to adapt to it (McClelland, 2009). Cognitive dissonance theory describes motivation as driven by the level of discrepancy between perception and ability to adapt (Deci, 1975. p34). In novel physics problem solving this discrepancy could be caused by the novelty of the problem; a major gap between perceived capability and novelty, and avoidance behaviours occur; a manageable gap, and motivation aids in conceptual understanding and process development.
Self-determination theory (Ryan and Deci, 2017) examines the development of intrinsic motivation across multiple conditions; biological, social, and cultural. Intrinsic motivation is the act of engaging in an activity purely for inherent satisfaction (Ryan & Deci, 2000). Ryan

and Deci observe that although people are naturally inclined towards intrinsic motivation, many social and cultural contexts have the capacity to diminish it.

McClelland's (McClelland, 2009) discrepancy echoes Vygotsky's *zone of proximal development*; the space between what a learner can do without assistance, and what they cannot do at all. Inhabiting the zone of proximal development with scaffolding and social support can result in the learner expanding their independent ability (Calder, 2015). Completing a task that seemed out of reach increases sense of satisfaction and accomplishment, increasing intrinsic motivation. Intrinsic motivation is linked to willing progress in education, although extrinsic motivation (driven by recognition, competition, grades) can be a useful when a specific task does not engage intrinsic motivation (Lei, 2010). Ryan and Deci's (2000) Cognitive Evaluation Theory (CET) is a process theory that addresses the three psychological needs considered capable of inhibiting or facilitating intrinsic motivation; competence, autonomy, and relatedness (Riley, 2016).

Competence is built from successful experiences, and relates to the belief aspect of problem solving behaviour, which encompasses an individual's subjective knowledge about themself, their conceptual knowledge, and their process understanding. A link can also be drawn from competence and belief to self-efficacy. Self-efficacy is a component of Albert Bandura's social cognitive theory, and is a task-specific judgement of capability (Bandura, 1977). Sources of self-efficacy include emotional and physiological states, vicarious experience, experience of success, and social persuasion (Usher and Pajares, 2008). Parallel with competence, experience of success is considered a source of self-efficacy, yet it is important to point out that self-efficacy is not synonymous with academic self perception, academic self perception is often considered a product of social comparison, and linked to extrinsic motivation (Tian, Yu & Huebner, 2017). Competence alone will not maintain intrinsic motivation, autonomy and relatedness are also necessities. Autonomy is present in situations where there is choice, self-direction, and a learner's interests and feelings are considered (Riley, 2016). Loss of autonomy decreases intrinsic motivation, as there is loss of control in one's own learning, which fundamentally undermines learning for personal satisfaction.

Autonomy and relatedness are entwined, as relatedness refers to the relationship a learner has with their education, which could be determined by level of autonomy. Interest plays a role in how connected a learner feels to their education, and much of interest development is borne of culture and identity (Altugan, 2015). If competence, autonomy, or relatedness are lacking, intrinsic motivation declines, which can lead to a dismissive or negative task response (Deci et al., 1981). This can lead to spiralling of emotion that decreases engagement of neural networks, application of conceptual knowledge, or process development. To counter this, problem solvers can engage in self-regulated learning; a cognitive model where performance strategies and emotions are monitored, controlled, and reflected upon in the pursuit of self-identified goals (Tzohar-Rozen & Kramarski, 2014).

Zimmerman's (1990) three-dimensional model of self-regulated learning includes: metacognition, motivation, and behaviour. Metacognition occurs when cognitive processes are monitored, and choices are supported with justification (Flavell, 1979). Self-regulated learners share many characteristics with expert problem solvers; they are able to develop environments conducive to learning, make choices that increase self-efficacy, and employ metacognition and meta-affect (Corno, 1986; Ozcan, 2015). Meta-affect is the identification of negative emotions, and subsequent implementation of coping strategies. In 2000, Zimmerman introduced a triadic model of self regulation, that emphasised the interaction between a person, the environment, and their behaviour, describing the interplay between them as processes that are "proactively as well as reactively adapted for the attainment of personal goals" (Zimmerman, 2000, p15). Zimmerman argued that all people self-regulate in some manner, but there are effective and ineffective approaches connected to the "quality and quantity" of participation in self-regulatory processes. Zimmerman's process model described self-regulatory process as a cycle, involving forethought, self-reflection, and performance or volitional control; each process stage containing multiple subprocesses that contributed to an individual's self-regulation (see **Figure 5**).

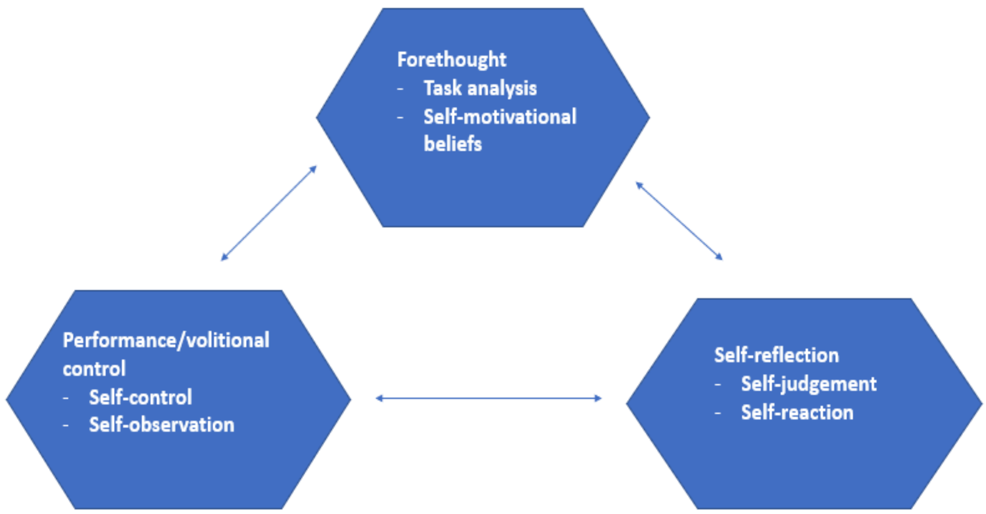

Figure 5: The phase structure and subprocesses of self-regulation (Zimmerman, 2000)

The research around identifying predictors and operationalising self-regulation is sparse, and without clear consensus (Duckworth, Akerman, MacGregor, Salter & Vorhaus, 2009). Yen et al. (2005) conducted a quantitative correlational study on Malaysian smart schools[10], determining predictors of self-regulation within smart schools to be: IT integration,

[10] Malaysian smart schools are schools designed to maximise engagement in technology

student-teacher interactions, motivational beliefs, and knowledge of self-regulation. Predictors of psychological or educational attainment are commonly variables such as age, socioeconomic status, or gender (Gill & Bell, 2013). Given this definition, Yen has identified educational interventions that impact self regulation, not predictors, as an intervention is defined as an intentional pedagogical or social strategy aimed at improving a specific target (Lestrud, 2013). One possible exception to this discrepancy is motivational beliefs, as the term 'belief' is a statement of individual values; clearly not an intervention, but likely not a predictor either. Motivation can be considered a precursor for behavioural development, but motivation also develops as a result of behavioural decisions (Pajares, 1996).

Self-regulation interventions are present in published literature (Dorrenbacher & Perels, 2016), although most successful interventions such as realistic and challenging tasks, and instructional variety (de Corte, Verschaffel & Op't Eynde, 2000, p690) are most effective during times of significant neural development (Blackmore & Frith, 2005). Difficulty adapting to progressive grade levels, and transitioning from primary to secondary education (Zimmerman & Martinez-Pons, 1990; Dorrenbacher & Perels, 2016) indicates that the structure of traditional schools may lack self-regulatory interventions. The potential implications of the absence of self-regulation skills are far reaching (Zimmerman, 2000). Accessing knowledge and understanding how to implement it is a characteristic of expert problem solvers, and can be described as effective metacognition (Tzohar-Rozen & Kramarski, 2014). When students fail to self-regulate, inactivation of knowledge and poor metacognitive skills can encourage negative emotions and anxiety (Shores & Shannon, 2007). Skills that assist in control and monitoring of emotions can mitigate feelings of frustration and despair, allowing problem solvers to productively engage in problem solving behaviours.

4.4 Conceptualising novel physics problem solving within a rural context

This research is positioned at the intersection of problem solving theory, and rural education. The majority of regionally relevant educational research in Nova Scotia is focused on the sociology of education and drawing local and traditional knowledge into mainstream education; it is this conversation that I am most mindful of, with an eye towards connecting rural context to the global discussion of problem solving.

As I am exploratory in my aim, theory development is a long-term goal. The purpose of this research is to draw out aspects of experience that are impactful to rural Nova Scotian novel physics problem solvers with the intent of further understanding connections between problem solving and environment. The conceptual framework is illustrated in figure 6; with the three aspects of problem solving, and environment perceived as interconnected.

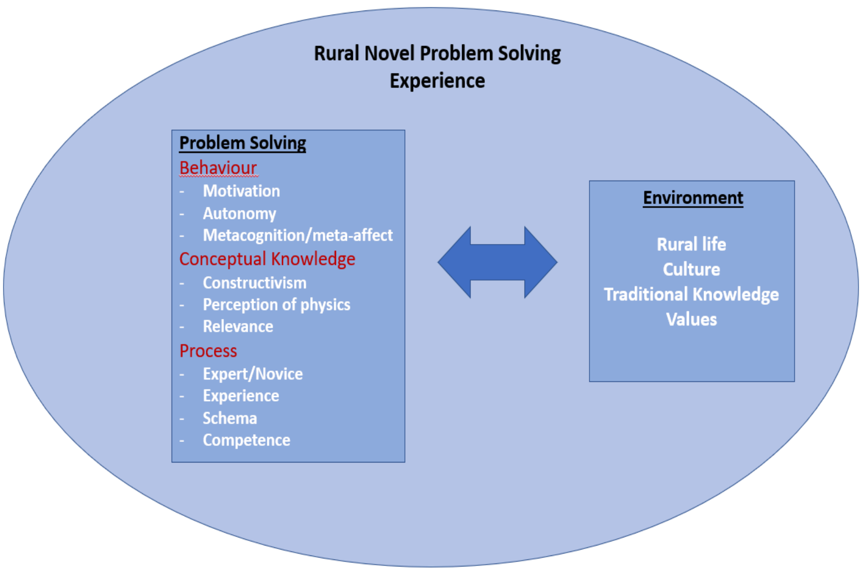

Figure 6: Conceptual framework of novel problem solving experience from a rural perspective.

As I move towards consideration of methodology and methods, the above conceptual framework will be a consistent theme in how I construct an interpretation of the emergent patterns.

5. Methodology and methods

The methodology of this research builds directly upon the ontological and epistemological foundation discussed in section 2, informing choice of methods. For clarity, methodology will be defined as, “a theory of how enquiry should proceed” (Schwandt, 2015, p194), which can be sharpened to, “the description, the explanation, and the justification - of methods, and not the methods themselves” (Kaplan, 1973, p18). Methods then, will be defined as the techniques used to collect and analyse data (Creswell & Poth, 2018), and will be explained with due consideration of the ethical practices they are embedded in.

5.1 In defense of the quantitative/qualitative divide

In reasoning a methodology, the novice researcher must be aware of the paradigmatic nature of social science research. The division of research into one of two traditional paradigms has a pragmatic purpose. The paradigms I speak of are qualitative and quantitative research, and will be defined as follows: quantitative research addresses social phenomena from an ‘outsider’ position typically with the aim of generalisation through the use of inferential statistics (Hampden-Thompson and Sundaram, 2013, p903), while qualitative research attempts to address social phenomena from an ‘insider’ position, with the aim of understanding the specific rather than the general (Schwandt, 1999, p451). Although the contrast between the two traditions is considered by some to be a false dichotomy (Walsh, 2012), the danger of severing the two is rooted in surreptitiously creating a divided research community. Avoidance of this is simple; methodology must follow logically from the research question.

Prior to fully developing the research question, I knew the specific case of physics education in rural Nova Scotia was more suited to a qualitative paradigm. I am careful to note that my *current* research is qualitative, as I have no interest in limiting the form of future research or pigeonholing myself into a single tradition. Just as my background in physical science informs my research interests, knowledge of quantitative methodologies enhances my ability to identify and fill research gaps in the future. Situating the research question within a tradition aided the development of a coherent research plan, as investigating the various qualitative methodologies helped guide method. This is certainly pragmatic; the MPhil programme is short, and priority of work tends towards topics that are directly relevant to the research.

5.2 Interpretative phenomenological analysis

Qualitative research methodologies are varied, yet none of the oft cited; narrative inquiry, phenomenology, grounded theory, ethnography, and case studies (Cohen, Manion, and Morrison 2017; Creswell and Poth, 2018; Somekh and Lewin, 2005) precisely suited the research question. Indeed, pieces of many methodologies seemed applicable, but I could not commit, and felt that 'cherry picking' pieces would fail to produce a cohesive methodology. Phenomenology immediately seemed suitable for examining the experience of novel physics problem solving, yet narrative inquiry also held appeal in building a story of experience, while incorporating biographical information and my relationship with participants into the analysis hermeneutically also held potential.

Fortuitously, I was introduced to a relatively modern methodology emerging from qualitative psychology; interpretative phenomenological analysis (IPA). IPA is beginning to gain traction in educational research, and auspiciously draws from phenomenology, hermeneutics, and idiography, pulling together relevant methodological strands into a single harmonious methodology targeted towards individuals making sense of their own experiences. IPA is described by Smith, Flowers, and Larkin as, "...committed to the detailed examination of the particular case. It wants to know in detail what the experience for this person is like, what sense this particular person is making of what is happening to them" (2012, p3).

IPA applies an idiographic approach to understanding how people determine the personal meaning of phenomena (Hermans, 1988, p786), subsequently orienting lived experience within layers of context to hermeneutically establish an intricate picture (Groenewald, 2004, p43). Hermeneutics originated as the practice of interpreting bible passages, considering narrative form and context. This was completely new to me; my gravitation towards hermeneutics actually came from the idea that scientific and mathematical concepts could be taught hermeneutically (Pelech, 2013). It seems a natural way to develop deep understanding, so the idea of hermeneutics had lingered in my mind prior to the consideration of a suitable research methodology.

Rural communities are heterogeneous; knowledge of one does not guarantee understanding of another (Oliver, 2007). To situate the examination of novel physics problem solving experience within a rural Nova Scotian context, I needed to examine both the narrow experience of problem solving, and the broader context each participant is embedded in to find links between the two. Application of the hermeneutic circle; or understanding how individual pieces are situated within a wider whole (Kezar, 2000, p387) is mirrored by the idiographic nature of IPA. IPA aims to determine personal meaning and sense making of experience (Smith, Flowers, and Larkin, 2012), while pure phenomenological research draws on common structures of experience; a contrast centered on IPA valuing the individual as well as shared and contrasting experiential elements across participants.The exploration of the phenomenon of rural novel physics problem solving will draw from individual, collective, and contextualised information to interpret experiential sense making.

5.3 Methods

The following justifies the methods used to collect and analyse the data (Creswell, 2018) within the framework of IPA. Focus initiates with the individual, collecting data to understand experience. Individual experience is then placed within context, and data is compared across participants.

5.3.1 Sampling and participants

Originally, purposeful sampling was the intended sampling method, rationalised by the necessity of extracting participants from a rural pool, with the analytical benefit of conducting interviews from the position of cultural insider. I planned to sample from the school I teach at, considering the connection to be beneficial to the research, as it allowed me to build on existing rapport, and collect comprehensive data. Prior to returning to Nova Scotia to begin data collection, I was granted research approval from the Centre for Education the school is located in, and received communication from the school principal welcoming my research. She also warned me that the recent outbreak of COVID -19 could impact access to students. This warning was timely, as days after my return to Nova Scotia, a state of emergency was declared and schools were closed.

This abrupt loss of access required an equally abrupt adjustment to convenience sampling. This deviation was not taken lightly; I considered requesting contact information from the school and approaching students individually. However, this plan was discarded after considering the ethical and collegial implications of requesting contact information for students; school administrators would need to discuss my access with guardians, and given the uncertain and fraught pandemic situation, I was not willing to make the request. Likewise, secondary students were adapting to lockdown and transitioning to online learning; I didn't feel I could reasonably add another potential stressor by requesting research participation.

Due to lockdown measures, students at Canadian universities had also returned to their homes to finish out the year online. In Canada, the university academic year ends mid-April, which meant that university students would complete their studies within my data collection window. With this in mind, I considered the sampling criteria necessary to meet my research goals; rurally educated, with experience in secondary physics. The convenience of the sample is apparent, as access and my knowledge of the criteria dictated potential candidates. I knew of a number of past students who met the criteria, so I contacted them through Facebook, introduced them to my research, and requested their participation.

The response to my research requests was overwhelmingly positive; all potential participants I contacted promptly agreed to take part. This was something of a surprise to me, as participant involvement in school-driven educational research in Nova Scotia is not common; research conducted by the DEEDC does not typically involve students or schools directly. I was concerned that past students would be hesitant to volunteer due to inexperience of first-hand research, but it turned out to be unfounded. An additional concern regarded research access when the intent was to study secondary students. Research approval depended on the local regional centre for education, and as DEEDC reports have been critical of regions in the past, I was concerned this might have incited mistrust in the research process (Njie, Sea & Williams, 2017). This concern also turned out to be unfounded, and research approval was granted easily, although ultimately the participants involved in the study were outside of the centre for education's purview.

5.3.2 Connection to the participants

Each participant was a previous student of mine, which was beneficial to the contextualisation of their responses, as I had observed their development throughout years of education. Anna, Dorothy, and Felix were in the same cohort in school, and I have known them since they were twelve, when I taught them science 7[11]. Kevin is a year older, I first taught Kevin science 10[12], although I taught him frequently, totaling 8 courses over his final three years of secondary school. Anna, Dorothy, and Felix all returned to my classroom for science 10, and remained with me for numerous classes afterwards; Anna took 9 courses with

[11] Science 7 is a required general science course taken in the eighth year of school
[12] Science 10 is a required general science course taken in the eleventh year of school

me, Dorothy 8, and Felix 7. The small size of the school necessitated that students pursuing science spend significant time in my class.

Despite their lack of teacher choice, each participant maintained a positive relationship with me, and throughout their school years I developed some understanding of their personalities and opinions (and presumably they have the same insight into me). That knowledge was useful, as I had a general idea of how each participant would respond to the interview format, as well as their comfort level when asked to reflect on their experiences. This allowed me to modify my questioning as needed, changing tact or phrasing to clarify or elicit a response.

The negative aspect of this convenience sample is precisely the same as the positive; the knowledge we have of one another. A general concern I have of being the primary science teacher in a small rural school is the potential for my students to adopt a similar lens to me from the lack of access to varied scientific perspectives. This influence could indicate that participants are aware of my thoughts around problem solving and physics, potentially unintentionally echoing my beliefs when questioned (Wentzel, 2010, p79). I am a strong proponent of problem solving, and can be critical of instructional methods that focus on product rather than process and relevance. However, I am cautiously optimistic that the idiographic nature of the interview questions encouraged each participant to think within their own context, and probing for justification extracted a level of specificity impossible if only relying on my past influence.

5.3.3 Data collection

Due to the crucial shift away from current physics students as participants, it was necessary to provide a problem solving experience; allowing for contemporary reflection on novel physics problem solving. During the first stage of data collection, participants were supplied with two mechanics problems (**Appendix A**) taken from *200 Puzzling Physics Problems,* written by Peter Gnadig, Gyula Honyek, and Ken Riley (2011). The decision to use mechanics problems stemmed from the emphasis on dynamics in the Nova Scotia physics curriculum (NS Physics, 2002). The problems themselves varied in form; one required the development of a formula for a general case, the other required application of physics concepts to reason through and explain a situation that did not require mathematics. The function of this variance was to challenge participants in multiple ways, producing a varied experience in the hope of eliciting rich data.

Participants were provided with the problems, and instructed to record their solutions, and notable aspects of the experience (Smith, Flowers & Larkin, 2012). From the responses, I identified comments or problem solving choices of interest, and developed personalised interview schedules. I chose to follow a semi-structured interview format rather than an unstructured format due to my novice interview skills (Cohen, Manion, & Morrison, 2017, p99). Relying on the structure of an interview schedule provided the assurance of a structured approach, but gave me the freedom to respond directly to comments and probe when necessary, to improve data quality.

All interview schedules contained biographical questions, and general questions that were identical across participants, as well as personalised questions based on problem solving responses. Interviews were carried out over Zoom[13], as it was free and readily available to all participants. The decision to conduct interviews remotely was a result of COVID -19 lockdown measures, although it is possible that remaining in their own environments reassured the participants, as being interviewed was a new experience. Each interview ranged from 0.75 to 1.25 hours, dependent primarily on how chatty the participants were, and how well I formulated follow-up questions that encouraged discussion.

I combed through each interview transcript to identify comments in need of clarification; a process similar to my evaluation of the problem solving data in preparation for the first interviews. Second interviews followed the first in technique, as they were again semi-structured, although interview schedules were entirely unique to each participant during the second round. Once all interviews were completed, I began formal data analysis (see 5.3.4), drawing out key aspects of each participant's experience.

5.3.4 Analysis

Informal data analysis was carried out throughout the data collection process (see 5.3.3). Interview audio files were uploaded to Otter.ai[14] for transcription, and the resultant transcript was proof-read and edited. The analytic intent was primarily identification of emergent themes, and development of narrative biographies, taking much guidance from the following sequence of analysis: reading and rereading, initial noting, developing emergent themes, searching for connections across themes, moving to the next case, and looking for patterns across cases (Smith, Flowers and Larkin, 2012, p82-101).

[13] Zoom is a free video-conferencing platform
[14] Otter.ai is a transcription website offering free transcription of audio files

Once I had read the transcripts multiple times, I moved on to initial noting and developing emergent themes. Originally, my plan involved using NVivo[15], but I felt it limited my autonomy. Clearly NVivo was not capable of interpreting data for me, but I felt as a small child would feel learning to tell the time on a digital rather than analog clock. I needed to develop my own processes, reason through analysis on my own, possibly clunky terms before utilising time-saving software. So, I bought a pack of markers, printed out the transcripts, and colour coded pieces of dialogue that linked to similar experiential themes, while noting my justification and observations. The themes were essentially sub-experiences of the broad experience of novel physics problem solving. Once this was complete, I developed a chart in Word[16], organising the overall themes and dialogue, then analysed intra-theme dialogue to draw out understanding. At this point in the analysis, I sent participants their data, to ensure that my representation of their experience reflected their sense making.

Moving to the next stage of analysis; searching for connections across themes, I drew on knowledge of the broader regional and cultural context of each participant, and filtered that through my own understanding of their secondary school development, utilising the hermeneutic circle to bring the data into an interpretative focus. I employed narrative analysis (Sayer, 2010, p176), building a story from the data that examined experience from a synchronic perspective, taking into account the single point in time of the interviews, as well as a diachronic perspective, where changes over time are considered (Stables, 2002). This was where my long-term knowledge of the participants was most effective, because I had

[15] Nvivo is qualitative analysis software, available free to University of Cambridge students
[16] Microsoft Word is a word processing software

memories of examples they referenced, and had observed in most cases (Kevin being the exception) six years of secondary school growth relative to their current state.

After completion of each participant's narrative biography I started looking for patterns across cases. This happened in two ways; reflection on each biography, searching for patterns consistent with other biographies, and a returned to the data tables; collating all main themes into one document and comparing them. While writing the biographies, I had carefully bracketed them from one another, and so needed to shift my thinking significantly. I also had to question the quality of that bracketing when I found similarities, and ensure that similarities and contrasts were valid and not a byproduct of a failure to adequately isolate each biography; allowing the narratives to blend together. When I was satisfied that the patterns identified across cases were well-founded, I moved forward.

Analysing emergent themes occurred in a similar fashion to the narrative biographies; I looked to contextualise and position aspects of experience and corresponding sense-making, simultaneously considering existing theory to justify connections. At this point I returned to the biographies, editing them to highlight similarities and contrasts across participants. As this research is exploratory, my aim was less to build theory, and more to identify areas of interest to inform future research, establishing links with current theoretical models that may provide insight.

6. Results and discussion

The results and discussion section sets the contextual scene through my anecdotal perspective as a cultural insider, introduces you to the participants and their experience through narrative biographies, and interprets emergent themes, locating the findings within current theory.

6.1 Setting the scene

Mustelidby is a small village settled in the 18th century, sitting astride a tidal river, comprising a rich culture of African Canadian, British, Acadian, and Mi'kmaw heritage. It has strong ties to the lumber and mink-ranching industries, and scattered around it are many rural communities. On the outskirts of Mustelidby is Scotia Secondary, the school that each research participant attended. I taught at Scotia Secondary for 7 years, and having spent 3 years at a town school previously, can attest that Scotia Secondary is solidly rural. After spending time in a town or city school, you can feel a tangible, yet evasive difference when you walk into a rural school, just as Oliver (2007) claimed. For me there is a pared back feeling that the people in the building do not maintain a facade. When I taught in town, I felt that my identity was separate from my job; I served an educational purpose. I put on my teacher persona in the morning, and took it off at 3:30pm. I was not equipped to penetrate staff or student social hierarchies; I have a rural background, and felt like an outsider, without the tools or shared values to find my place.

At Scotia Secondary, that is not the case. If you present a facade, the students will try to get under it to figure out who you are. Teachers present opportunity for students to develop relationships with adults who mesh with their values, but perhaps have different experiences of the world. Because teachers at Scotia Secondary are rarely from the immediate area (those who are have relatively seamless transitions to the role of teacher), we carry in experiences that are different from those of families who have lived in Mustelidby for generations. I live in a town about a half an hour away from Mustelidby, yet most of my students know where my house is. They know what I drive, where I grew up, how many cats I have, and where I went to university. Sometimes students show up on my doorstep, usually to deliver coffee. I assume that they are curious to see me in my natural habitat, but I am also suspicious that braving a knock on my door has become a grad class dare. There is no hiding, more than once students have observed my questionable driving skills and informed me of their opinion the next day at school. But the reverse also holds; I may just be the science teacher, but I need not hold back on voicing my thoughts on students' questionable decisions. I have doled out many lectures about smoking, drinking, stunt driving...you name it. Community acceptance grants candour, and often teachers hold influential roles far beyond their job description.

That is not to say that Scotia Secondary is idyllic. If you are branded an outsider, it is difficult to gain acceptance. And even if you are an insider, you will experience conflict. The social heterogeneity ensures this; there are matriarchal families, patriarchal families, people strongly attached to traditional male and female roles, intransigence, and escapism. Perception of education is conflicted; for some, school is an obstacle to overcome so you can get a job, for others it is a mark of status, for others still it is an escape route. Education is valued; practical knowledge is held in high esteem, and in many cases higher education is as well. But there is a disconnect, an assumption that higher education equates to leaving the community (Corbett, 2007). When I was accepted into Cambridge, my principal posted a notice on the school social media. The community responded strongly in support, but most people who spoke to me in person assumed I would not return. Even prior to that, students and parents regularly asked me why I remained in Mustelidby, assuming a masters degree in physics granted me bigger and better things. I have yet to identify what 'bigger and better' is, apart from a depiction of what happens when you surpass the level of education presumed viable in Mustelidby.

Physics in Scotia Secondary seems to hit a ‘sweet spot’ in terms of encouraging enrolment; practical enough to be held in rural esteem, and encouraging of higher education. Motivation for taking physics runs the gamut, from pure interest to practical skill development, sometimes fitting into a larger plan, and sometimes taken just to see what being a physics student is like. Persistence from physics 11 to physics 12 is varied, and most students who proceed to physics 12 are motivated by interest and/or potential post-secondary benefits, such as applied mathematical skills. Physics seems to bring to light how students and families see education, as often students fall into family conflict in connection to physics; one student loved physics, but wanted to take a trade. His mother so wanted him to study physics in university, but he did not see it as tangible. Another student was the opposite, his family could not fathom spending the money and leaving home to get a university degree when you could have a trade; he wanted to continue his science education. Value for different forms of knowledge, and the consequences of pursuing further education are prescient issues, and inform my perspective of rural physics students.

6.2 Relatedness and experience of success

Investigating the research question, ‘How do rural Nova Scotians make sense of their experiences with novel physics problem solving?’ uncovered different perceptions of, and associations with, rurality. As the literature poorly defines rural and rurality (Oliver, 2007), uncovering how participants defined rural life was important, and possibly linked to relatedness and the internalisation of physics concepts. According to Ryan and Deci (2017), relatedness is a key component of self-determination, and closely linked to competence. The evidence that follows provides some insight into how the development of relatedness and competence emerged as key features of problem solving experience.

Novel physics problem solving was considered by all participants to be a challenge for various reasons, but apart from individual difference, two conditions seemed strongly connected to feelings of competence in novel physics problem solving; relatedness, and experience of success. Relatedness seemed to show some connection to involvement in rural pursuits, as participants who mentioned enjoyment of building things, and the outdoors, more readily provided everyday examples of physics and described how physics and problem solving were connected to their lives. Relatedness, or perhaps the experiences that emerged from involvement in rural pursuits seemed to have some protective effect on feelings of competence, given minimal experience of success in school-based problem solving. The dominance of procedural, rather than problem solving experience in mathematics (which I have considered a cognate to physics, with justification in section 6.5) failed to supply experience of problem solving success prior to enrollment in physics, rather it supplied procedural success, which encouraged participants to find familiarity and comfort in formulaic solutions. The unstructured nature of novel problems, in contrast to the procedurally driven mathematics problems participants had experienced success with potentially encouraged a discrepancy between the perception of a problem's difficulty, and ability to adapt to it in some participants, further discouraging feelings of competence and self-efficacy (Deci, 1975, p34).

6.3 Narrative biographies

The following narrative biographies introduce each participant, placing them within context, and interpreting their novel physics problem solving experience. Each biography was constructed through the lens of physics teacher/researcher, incorporating my knowledge of the participants, as my students.

6.3.1 Kevin

Kevin was chatty and relaxed during the interviews, although he found it a bit ‘weird’ speaking to his old science teacher on Zoom. He is currently enrolled in a business programme at an urban university in Nova Scotia. Despite a long-term interest in business, he fought the idea of himself as a university student for months prior to secondary graduation; it was a waste of money, and he could earn a living without going. Apprehension at leaving home was a large piece of Kevin’s objection to university, transition to post-secondary school represented a drastic change in lifestyle and shift away from the security of Mustelidby. When I asked Kevin if he was a rural or urban person, he emphatically stated that he was rural, adding “I literally just got cleaned up from penning pigs, so (laughter) I prefer it out here”.

Kevin described rural life as a richer experience than urban, a place with challenges, where getting into sticky situations and figuring a way out is a fun time. By comparison, city life is boring, and lacks the opportunity for the experiential depth needed to build certain resiliencies, “...they've [urban people] never got a tractor stuck in a field. Right? They have not witnessed that. So, a lot of them are probably less resilient to shit hitting the fan”. In his estimation, if you live in a city you are less likely to be actively engaged in the tactile pieces of life, “ ...up in the city [...] a lot of people have never driven a tractor [...] or had to mow a lawn. They hire somebody to do that”. He presented urban life as hands-off, a ‘scrubbed’ kind of existence in comparison to messy, trial-and-error rural life, “myself and friends, we’ll just go do something. We don’t know how to do it, we’ll go try and teach ourselves how to do it”.

Ryan and Deci (2017, p567) point to culture as “perhaps the most pervasive influence on human behaviour”, as individuals internalise cultural values more readily when cultural aspects support autonomy, relatedness, and competence. Kevin attributed his willingness to attempt challenge in part to experience of varied situations, when I asked him how he learned this about himself, he replied “Just experience. I have ended up putting myself in a lot of situations where I needed to think things through. The other week, Tom and I almost killed each other because I got the tractor stuck”. The progressive accumulation of varied experiences is a form of scaffolding, which contributes to development of a sense of meaning and purpose. This may form a feedback loop, where meaning and purpose further encourage the active seeking out of new experiences, strengthening autonomy and competence. It is possible that Kevin’s cultural ‘tools’, as described by Greenfield and Bruner (1966) are sources of intrinsic motivation, with potential to generalise to novel physics problem solving.

When discussing novel physics problem solving, Kevin often used comparisons with everyday life to demonstrate its value. He related the reward of physics problem solving to raising pigs rather than cows, “ We have to tend the pigs all the time. So at the end of the season, you go like, ‘man, look, they’re so fat, we did that. But then the cow [which required less work] is like, whatever, we didn’t do anything [...] it’s a similar reward structure [to physics problem solving]”. Effortful reward speaks directly to rural values, but the reward of novel physics problem solving is further fortified by its application to daily life, and parallels to Kevin’s association of rural life’s ‘trial and error’ approach to experience, “I found that the more physics you learned the easier some jobs and tasks became. Same goes with work, the more tasks you complete, the easier relevant physics concepts became”.

Physics was relevant not only in its explanatory capabilities, but also in opportunity for skill building. I asked Kevin what it was that made him like physics, and he replied, “ It just made sense. Biology was all memorisation, I hate that. I’d rather learn a skill. Physics was more of a skill”. Moll’s concept of ‘funds of knowledge’ speaks of bodies of knowledge and skills that are historically and culturally accumulated. I would argue that for school-based knowledge to be personally relevant, it must connect in some way to an individual’s fund of knowledge. In this case, coming from a community with a resource-driven industrial history, physics-as-skill corresponded with Kevin’s fund of knowledge, encouraging him to rate physics as highly relevant, and easy to integrate into his life, “I found that physics would offer some value to my life”.

The study of secondary mathematics produced a contradictory experience for Kevin. In grade 12, Kevin became disenchanted with mathematics, finding it abstract and irrelevant. Cultural elements that are presented in ways that frustrate competency, autonomy, and relevance are less likely to encourage flourishing or integration (Ryan and Deci, 2017). A school, and the classes within a school are microcultures that can complement or clash with the broader culture (Berger & Ross, 2006). In this case, Kevin was unable to associate the mathematics he was learning within his life, or value system, which encouraged him to reject it. It is possible that the juxtaposition of physics and math exacerbated this discord, as Kevin was taking physics 11 when mathematics began to draw his ire, “I liked the fact that it [physics] was math, but it was math that you could understand. And it was useful. I didn’t like that about academic 12 [math]. You would do stuff, and it made sense. But you couldn’t apply it to anything. The questions were just out of this world”. This perception was not fixed, as later he took a course in university that used calculus in business applications, and expressed appreciation for the relevance of calculus within that setting.

Kevin acknowledged an awareness of process rigidity when it came to solving problems, and attributed that mainly to lack of exposure to problem solving prior to physics, and having a primarily procedural mathematics background. When I asked Kevin which he would find harder, a routine problem, or a novel problem, he replied, “[The novel problem is] a lot harder. [...] if you learn everything in similar situations, it’s that much harder to do a novel problem that requires problem solving [...] you want to apply what you already learned, in the same format”. There was no scaffolded transition from procedural learning to problem solving in physics class, I generally emphasise conceptual knowledge, try to give concrete referents through lab activities, and encourage discussion around problem solving. But I don’t ‘teach’ the students how to problem solve, which could have attributed to Kevin’s frustration. Kevin felt that he was prone to rigidity in his thinking, particularly when in a negative frame of mind, “I’ll get a plan in my head, and that’s what I’ll follow. I’ll be really rigid, I won’t stray away too far. [...] I think it’s going to work beautifully. Perfect, nothing’s going to go wrong. So then when something goes wrong, it’s like urgh!”

Kevin’s experience with frustration can be explained by McClelland’s human motivation theory, as procedural rigidity perhaps encourages a large discrepancy between perceived capability and ability to adapt (Deci, 1975). Kevin found ways to deal with this;

chunking solutions up into more manageable (less discrepant) pieces, and employing distraction to shift himself into a more positive frame of mind, "...if I'm having a bad day, I'll just go on the four wheeler and I will rant to myself, just in my head and then by the time I'm back, I am happy go lucky". His meta-affect was linked to increasing resilience, which he connected to experiencing varied situations. When I asked him why he thought he was more forward-thinking while in a good frame of mind, he responded, "...maybe it has to do with patience, where I'll take the time to sort of consider things. I'll have enough resilience to deal with problems or the stress of them". Willingness to deal with problems suggests an increase in competence, perhaps triggering meta-affect to adjust the circumstances to reduce frustration, consistent with the performance/volitional control of Zimmerman's process model of self-regulation (Zimmerman, 2000), and further ties to McClelland's human motivation theory, as Kevin showed ability to adapt to the problem (stimulus) and minimize discrepancy (McLelland, 2009).

6.3.2 Dorothy

Dorothy was calm and self assured during the interviews, although she appeared to show some discomfort when I probed for information; she is succinct in her expression and the pressure of follow-up questions seemed to put her at a loss for words at times. She is enrolled in a chemistry programme at a small urban university. Dorothy enrolled in physics 11 for the challenge, and remained in physics 12 as a result of the influence and encouragement of others. She studied introductory physics and calculus at university; so unlike the other participants in this study, Dorothy was a current physics student.

When asked if she thought of herself as rural or urban, Dorothy identified as both, although her association with rural and urban places seemed more statement of fact than formative aspect of her identity. She was raised in a rural environment; her family is involved in mink ranching. When I asked Dorothy why she was ‘a little bit of both’, she responded, “I grew up in the country so that always feels like home, but I really love living in the city at the same time”. Her love for the city did not diminish the appeal of rural life, but the convenience or urban ‘nearness’ was welcome, “In the city I really like being close to everything, that everything is within 20 minutes of us”. Dorothy’s distinction between urban and rural was physical and resource-based rather than social. *Rurality* did not seem to be a boone or a hindrance, there was no hint of her feeling that her rural background was a barrier to integrating into post-secondary education.

Byun, Meece, and Irvin (2012) argue that the tendency of researchers to assume a position of rural disadvantage has encouraged the assumption that rural society has a negative effect on further education. In contrast to this assumption, they found that rural community social resources had a “small but significant” positive effect on post-secondary completion. Dorothy’s university is within driving distance from her home, and she maintains close association with people from home, so it is possible that her maintenance of connection to social resources has proven a protective factor in the transition to post-secondary. This could explain why her description of the difference between urban and rural life was mostly physical; her rural social involvement was still intact.

Dorothy’s connection to physics was not grounded in rurality, when I asked her why she enrolled in physics, she was a bit hesitant in her response, “Um...I don’t know. I kind of like math and science. And I knew it was going to be a challenge. So that part was exciting”. There was no evidence that physics had direct relevance; problem solving fit within her academic goal structure, representing challenge and achievement but there was no suggestion that physics content was something embedded in the everyday, or referred to outside of academic situations. When I asked if physics problem solving had applications to things outside of physics, her reply was, "Good question...I don't know. I can't really think of any specific examples. But I mean, there definitely are real life scenarios where physics problem solving could come in handy". Dorothy's version of rurality did not emphasise the 'trial-and-error' messiness that Kevin's did. When I asked her what she liked about rural life, she described the country as, "...really quiet, relaxing, and you could roam around without meeting up with other people". It is difficult to draw a connection between this peaceful view of rural life and physics problem solving, potentially pointing to why relevance does not seem to be an aspect of Dorothy's relationship with physics.

Feelings of autonomy and competence were unclear, but it seemed that Dorothy did not feel that problem solving process was entirely within her control. She felt that her problem solving skills had not developed in a scaffolded manner (Ryan and Deci, 2017), when I asked Dorothy what tools she felt would have been beneficial going into physics, and she replied, "Just experience with harder questions, like in math. Being challenged more in my math courses would have prepared me a little more". There was an element of intimidation to Dorothy's relationship with physics, potentially brought on by a lack of experience of success and corresponding low self-efficacy, "...physics in general, I find pretty overwhelming. So I think it's just something I've had since the beginning [of the study of physics], that I find physics pretty scary and hard".

Feeling overwhelmed by physics problem solving could indicate the absence of self-regulation skills, particularly given Dorothy's assertion that she did not have much experience with challenging situations in school. However, Dorrenbacher and Perels (2016) cited weak self-regulation as a source of poor transitioning to post-secondary education, and Dorothy did not demonstrate this. Zimmerman's process-model of self-regulated learning (see **Figure 7**) refers to self-motivational beliefs as components of forethought, which is connected to performance and volitional control (Zimmerman, 2000). While Dorothy demonstrates outcome expectation and goal orientation, stating, "When I get stuck, I feel like I'm never going to be able to get to the end of the problem. And I get panicky because I freak out if I can't finish a problem because I'm obsessed with grades", there is a suggestion that a lack of successful problem solving experience has failed to provide for Dorothy's psychological need for autonomy and competence, possibly impeding her ability to maintain intrinsic motivation with respect to physics problem solving.

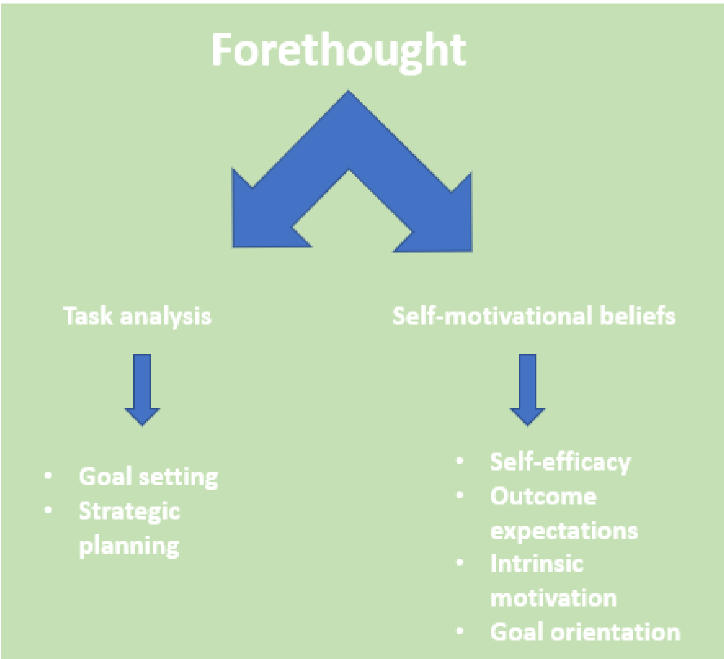

Figure 7: Subcomponents of forethought within self regulation (Zimmerman, 2000)

This does not mean that she is unable to progress; her 'obsession' with grades reflects motivation strengthened through strategic planning, " Being organised would help me through it, organising what I already know, what I need to find out, that definitely helps. [...] it's important to have your own strategy so that you don't get as overwhelmed or, I guess scared off by a question". There is awareness of emotional state, and applying process strategies in a cognisant way to maintain motivation indicates that Dorothy is self-observing; another piece of Zimmerman's process-model (see **Figure 5**), and closely related to metacognition. Awareness that problem solving draws on a different skillset than previously experienced is clear, as Dorothy states, "I think it's just having to think on your own. I mean, with something like math, you can just 'plug and chug' and you don't really have to think a lot about what you're doing. But [in] physics you have to really think about the problem and understand what's going on in order to get through it and that is intimidating". Dorothy's experience argues for a stronger, and more scaffolded (Bruner, 1961) approach to problem solving in schools.

6.3.3 Felix

Felix is a talkative person, who enjoys engaging in conversation and puzzling things out. He was not inhibited by Zoom, and seemed to derive entertainment from thinking about his experiences and providing interpretation. Felix attended elementary[17] school in suburban schools near Calgary, Alberta, Canada, and was home-schooled for half of grade 2. His family moved to rural Nova Scotia after he completed grade 6. When I asked him if he considered himself to be rural or urban, he replied that he considered himself to be rural. When I asked why, he referenced physical space and that rural areas suited his interests, "...I don't like being cooped up in blocks and stuff like that. I've always liked vehicles and stuff, and you can't have that in the city". Felix described rural community as cooperative, without

[17] In Canada, the first seven years of education are considered 'elementary' education

the social isolation that is possible within a city. He also linked a sense of community to the physical environment, “I'd say it's about the people and about geography, and how that works into people. I feel like if you're in a rural place, it's more of a... a good way to explain it may be down to earth”.

The relatedness of physics was easily apparent when I spoke with Felix, his interests easily connected to physics. The experiential and concrete applications of his hobbies and interests helped to decrease the novelty of physics problems; he could relate them to fixing vehicles, or video game scenarios and extend his intuition to understand underlying concepts constructively (Liu & Chen, 2010). His ability to trouble shoot in daily life carried over into his problem solving; he naturally searches out cause and effect. A downside to consistently relating physics problems to real life is over-complicating scenarios; recognising that often in school based problems you ignore variables (wind resistance for example). Despite the risk of not reaching a solution, Felix did not think complexity was a barrier to understanding physics, “...with [wheel] bearings I definitely overcomplicate things because I think of all the different ways that things will drag energy off an object if it's moving. Through bearings, through brakes, I'll always think of that. But it could lead to your answer. Or at least help you grasp what's going on”. There is a willingness to inhabit the zone of proximal development, referring to cultural products to assists in understanding (Sullivan Palincsar, 1998).

The fluidity with which Felix moved between speaking about life and physics was indicative of internalisation; concepts were not isolated in a ‘things I learned in school’ category, they were integrated into life, further illustrating a natural tendency towards constructivism. Problem solving was rarely a stress-inducing experience for Felix. He acknowledged desire to succeed, but marks were not prevalent in his mind; he was only lightly externally motivated by them. High self-efficacy supported him through frustrating situations, and he regulated his emotional response through metacognitive awareness that stress is discouraging, and not productive. Autonomy and competence were evident through the belief that he had the tools to problem solve, regardless of the discrepancy between novelty and ability to adapt, which helped move him forward (Deci, 1975), " I always know that somewhere in my mind there's some knowledge of this, especially when I was in physics class. If you're going to get this [problem], you have knowledge of it. You've been taught it". In instances where he could not find a solution, he did not "guilt trip" himself, because he saw no value in it, particularly if he felt he had applied his knowledge in the best way he knew how.

Felix had a unique relationship with mathematics, he declared an interest in it, but had a strained relationship with the mathematics of formal schooling, "I always liked math. I didn't like math as a class, because it was a lot of theory, [...] it just was so arbitrary that it really didn't make sense, and it annoyed me how many questions we were forced to do." Felix did not relate to the study of mathematics in the way he did to physics, it did not offer the same level of interest to him, despite the regular use of mathematics in physics, "Physics, I always thought was more how things worked. And I was interested in that, like vehicles and stuff. It's a lot more interesting mathematically to figure out why things are the way they are when you can actually understand how they work". Approaching mathematics through the vehicle of physics aligned with his cultural 'tools' (Greenfield & Bruner, 1966), and met his psychological needs of autonomy, competence, and relatedness. In contrast, the arbitrary presentation of mathematics in school transmitted values and regulations that inherently conflicted with his basic needs, resulting in reduced willingness to internalise rigid mathematical practices (Ryan & Deci, 2017, p565).

This conflict resulted in Felix changing mathematics classes; he switched from a university preparatory mathematics course to a vocational one. This had some effect on his physics problem solving, as sometimes he would come across techniques he was not familiar with. However, interest, through its effects on motivation, seemed to be a mitigating factor when Felix came upon problems that challenged his mathematical knowledge, "...with me being a person who has very limited further academic knowledge, the fact that I could still work through the math with the level that I have being interested in stuff; that, I thought was a driving force for me". The identification of interest being a driving force speaks directly to intrinsic motivation and Felix's sense of autonomy, which stemmed from science being a place to ask questions, make connections with everyday life, and the opportunity to apply mathematics in a sense-making way (Riley, 2016).

6.3.4 Anna

Anna is an introverted person; she can be apprehensive when the attention of others is entirely focused on her, which made her a bit uncomfortable being interviewed over Zoom. She is artistic; during her school years she often decorated her binders with drawings illustrating the course within, and took great pains to produce detailed creations for class projects. Anna is currently enrolled in a psychology programme at a small, urban, primarily undergraduate university. When I asked Anna if she considered herself urban or rural, her response was, "Rural definitely, since Mustelidby is extremely small. There's not many stores or anything there so it's definitely not close to being a city or even a suburb or anything". When I asked if size was a major factor in rural places, she responded, "Size and lack of...things for people in the community to do”. When I asked specifically if there is a rural culture, her response was, “um…” and the conversation moved again to population density and a lack of infrastructure.

Relatedness was not prevalent in Anna’s relationship with physics itself, her motivation for studying physics was mostly around skill building, applied mathematics, and prestige. When I asked her why study physics, she stated, “Honestly, because I thought it would look good on my transcript for university. And even if I didn’t understand it completely, I thought that I would learn techniques, and things that had to do with math that would help me with other courses”. Physics appeared to be cordoned off from Anna’s interests and everyday life, she knew it had relevance in the greater world, but her personal connection to it was primarily school-focused. I asked Anna if physics problems could be ‘not pencil and paper’, and she replied, “ Yeah [...] like that example you showed us in class with the bucket swinging with the water [...] that’s an example of a real-life situation”. I pushed a bit harder to see if she would make any observations of physics outside of school by asking if she had ever used her physics knowledge to solve ‘other’ (meaning non-school) problems, and she replied, “...I don’t know, maybe like a momentum related problem in real life or something like that. I probably have, but I can’t think of a specific situation”.

Anna’s struggle to think of applications of physics outside of school was indicative of her placement of physics outside of her everyday life. I wondered if autonomy and competency (Ryan and Deci, 2017) could be secured in the absence of relatedness. Anna showed evidence of metacognition and meta-affect, through the identification of useful problem solving thinking patterns and the realisation that feelings of defeat impeded progress, “I feel like it’s a big mind game. Like, you can’t let yourself feel defeated [...] you have to keep switching gears in order to look at it from different perspectives, because if you don't keep switching gears and thinking in different ways, then you won't progress". Her reference to problem solving being a "mind game" suggests a lack of assumed control in the process, and despite the presence of personal reflection, Anna struggled with the perception of her own competency (Zimmerman, 2000). When I asked her why she felt disappointment at not solving a problem, her response was, "...after I can't solve a problem, I always feel defeated. And I feel like it's like, I won't actively work towards problem solving since physics isn't a main part of my life". There is a sense of being deflated, an erosion of competency in the absence of autonomy.

This is not to say that Anna was easily defeated, she attributed frustration and slowed problem solving process to stagnation; when she has understood all that she can and is unsure of next steps, " I feel like if I actually understood 100% what was going on and still didn't get the answer, then I would be frustrated. I was still actively working at understanding the situation and the question [during data collection], so I feel like I was still in the mindset where I was working hard at trying to understand what was going on". She recognised that frame of mind was a factor in problem solving, and acknowledged that the lack of structure in novel problem solving was a source of discomfort, "I feel like it still goes back to the fact that I'm more comfortable just 'plugging and chugging'.[...] after none of the techniques that I remembered were helping me, then it became difficult because I didn't know what else to do".

Experience of success in such problems was limited in Anna's experience, as problem solving was the most challenging aspect to the study of physics for her, "...when I took physics, one of the main problems that I had was the thought process you have to have when you attempt physics problems as opposed to other kind of...math problems. Physics requires a different thought process in a way, because it's thinking more outside the box". It is possible that Ann was cognisant of the contrast between her previous experience and physics problem solving, as skill development was a factor in her choice of studying physics. She observed a more holistic approach to physics problems, requiring understanding of the situation as well as the constituent procedures, " I really struggled with that [thinking outside the box], because I'm used to just doing math that requires you to plug things into formulas, instead of actually thinking about what you're trying to figure out and what you're trying to solve in the first place". It is possible that similarly to Dorothy, Anna's education did not provide the scaffolded approach necessary to bridge her previous knowledge, and representations she was comfortable with, to novel problem solving, resulting in having to work to develop schema flexibility independently (Sabella & Reddish, 2007).

Interest could also have played a part in Anna's self-determination, as a compelling parallel was drawn between physics and Anna's chosen area of study, psychology. I asked her if she considered psychology as difficult as physics, and her immediate response was, "Nope (laughter). Probably because I'm interested in it and I actually enjoy it more than physics". In addition to teaching Anna physics, I was also her psychology teacher at Scotia Secondary. I can attest through that experience, that Anna's approach to psychology demonstrated self-determination; she was willing to engage in discussion, ask questions, and relate the material to herself. Her involvement with psychology was driven by interest and enjoyment, rather than the contrasting skill-development that motivated her study of physics. Anna's perception of physics itself implied a reliance on extrinsic motivation, to Anna physics carried a tone of exclusivity and competitiveness; she felt public perception of people who study physics is that they are “super smart”, which added external pressure to Anna’s problem solving process.

Anna felt that the physics class environment was competitive, as doing well in physics represented general success, and being recognized by others as being the ‘best of the brightest’. She did not feel that physicists cultivated this impression, rather the media perpetuates feelings of exclusivity in physics through the framing of discoveries to the public; reinforcing the notion that physics is not attainable for all. Anna’s feelings of exclusivity around physics caused anxiety and hyper-awareness of peer comparison, “Physics is like a competition since everybody sees it as difficult. [...] I always felt like it was a competition because you have to actually get what's going on [...] the people that don't get it are like, ‘Oh, I have to work harder’”. It is difficult to know if this perception of physics frustrated Anna’s self-efficacy, but it is possible that lacking comfort and feelings of inclusion could have impeded other sources of self-efficacy, such as emotional state, vicarious experience, and social persuasion (Usher & Pajares, 2008) in concert with physics not inciting interest.

6.4 “I found that physics would offer some value to my daily life”

Physics and novel problem solving were valued by all of the participants, but the source of value varied from person-to-person. Anna and Dorothy had similar feelings towards physics and problem solving, identifying them as intimidating, but capable of providing beneficial skill building opportunities. Kevin shared Dorothy and Anna’s view that building problem solving skill was an important facet of studying physics, but he also enjoyed its practicality and the relevant application of mathematics, “...with physics, you would be applying it to things that made sense. So how much force you had to use for brakes to stop, that makes sense because you drive vehicles every day". Felix's relationship to physics was predominantly interest based from the beginning, "I always thought I was good at physics and understood where things would go, especially with vehicles [...] my favourite part was to judge how the weight would carry something or how it would stop. It just interested me more than regular courses".

All of the participants were from rural backgrounds, and had spent all, or at least their teens (Felix moved to Mustelidby after elementary school) in Mustelidby, but overt connection to rurality was more prevalent in the conversations I had with Felix and Kevin. Most of the questions I asked were not specifically about rurality or rural places, but I did ask about rural identity very early on in the interviews; this could have primed the participants, increasing the likelihood that examples provided would have a rural tone. Nevertheless, this did not prompt Anna or Dorothy to reference rural life, their rural references were isolated to my questions about rural identity. This suggests that rurality is a more prevalent influence on Felix and Kevin; it is possible that discussion of physics and problem solving naturally connected to images of rurality for them.

It seemed that physics in general, and novel problem solving in specific blended well with Felix's fund of knowledge (Moll et al., 1992); enjoyment of vehicle mechanics and building things translated to interest in physics, "... I picked it up, I could understand a lot of the...I understood it well [...]. I just felt confident in it [physics]. And I thought it was kind of fun. It was fun to build crossbows". Phrases like "I picked it up" imply an ease of conceptual understanding, coupled with a sense of control and competence in the problem solving process, "...if I was doing a question and felt lost I never guilt tripped myself into feeling bad about not doing it. I would try my best and use the knowledge that I had and what I could think of to work through it". Felix's sense of autonomy and competence is linked to the relatedness of physics to his pervasive culture; the broader culture with which his experiences are embedded (Ryan and Deci, 2017, p562). Felix's description of rurality through cultural rather than solely physical associations is indicative of rurality's contribution to his pervasive culture, further embedding the relevance of physics within his rural identity.

Kevin's identification as a rural person was very direct; he described contrasts between urban and rural life that demonstrated preference for the latter, and stated that he was "Proud of being from a rural community". Kevin spoke of taking enjoyment from physics, and its availability, "...compared to other things, it's [physics] more readily available to use". Kevin found physics concepts easily relatable, "You can relate it to a lot of things, like driving. [...] I had to bring lawn chairs back from Heronville. And of course Dad was like, 'make sure you strap them down tight' and you're like, yes, I know. Because wind will take them and be gone! [...] So I value that [physics] more because it's a skill, it's going to be used". Usefulness was prevalent in Kevin's justification of why physics held relevance to his life, the example of knowing that chairs would be blown off a truck is demonstrative of tacit knowledge, but his assertion that physics skills are useful implies that relatedness is a critical piece of Kevin's enjoyment of physics.

Just as rural is a slippery term to define, so too are rural values, and the components of funds of knowledge that emerge from rural influence. Yet, components of rural life such as fixing vehicles, raising animals, and "just doing something and learning it" seemed to predispose Kevin and Felix to incorporate physics and problem solving into their everyday, bridging their fund of knowledge with physics (Moll et al., 1992). This provides some contradiction to claims of a disconnect between local and academic knowledge (Boyer, 2006), but that does not mean that a disconnect is completely unlikely; in this instance there was no resistance to formal education (Corbett, 2004), so no barrier to overcome in terms of acceptance of the validity of physics. The question that emerges from this observation, is where Anna and Dorothy's experience of rurality fits in; they struggled with relating to physics itself, both tending to focus on the benefits of problem solving skill development. They also defined rural identity in terms of physical space rather than culture or community. It is possible that their funds of knowledge were different from Felix and Kevin's; their experience of rurality one that did not immediately draw relevance from physics, limiting relatedness.

6.5 "It's more difficult since I'm used to the questions that allow you to plug numbers in and get the numerical answer"

Each participant found novel physics problems more challenging than "plug and chug" (procedurally based) problems. Novel problem solving was a new experience, and for some participants, was a source of stress far over and above learning physics concepts. Dorothy reflected on what represented difficulty in physics, "...the problem solving part for me. That's always what I found the hardest about physics, because I can learn a concept and think, yeah, that's okay. And I'm pretty good with math, but the problem solving [...] that's definitely the hardest part". Each participant referred to significant procedural experience in mathematics, but a lack of problem solving experience. Opinion on the effect of this varied; Kevin felt that procedural math was damaging to developing proficiency in problem solving, "...if you're doing the same one [question] over again, you're only going to know how to do that one. So it would hurt you because you would be programmed to solve that one problem".

In contrast, although Dorothy felt that more problem solving experience would have been beneficial, she did not see procedural math as a hindrance, "... math is procedural. But if you do enough math questions, then you probably develop your own way of looking at it and thinking about it. And I think that would help in physics". Dorothy's assertion echoes Rittler-Johnson, Sieglar, and Alibali's argument that knowledge construction is iterative, but it doesn't disqualify the importance of problem solving experience. Experience of success is a significant source of competence and self-efficacy (Riley, 2016; Bandura, 1977), and contributes to the maintenance of intrinsic motivation (Ryan and Deci, 2017). Dorothy and Anna did not demonstrate consistent self-belief; both were hesitant to identify themselves as 'good' problem solvers, and associated problem solving with words such as "intimidating" and "pressure" while Felix and Kevin had no such hesitation, and made no such references, apart from Kevin's acknowledgement that problem solving could be frustrating at times.

As discussed in section 6.3, Kevin and Felix both demonstrated signs of relatedness with physics; competence was also evident through comments referencing self-belief and feelings of confidence around problem solving. Felix's reference to completing ladder problems in physics demonstrates this, "...I just enjoyed, and was often pretty good at going at it and laying out where everything would have to go, and how things would work, and what would have to cause them to counteract that force, and what would have to happen. It seemed to go well, honestly". Kevin and Felix's self-belief developed in the absence of experience of success in mathematical problem solving. It is important to note that there are other potential sources of problem solving success with relevance to physics aside from mathematics, but the area of difficulty common to all participants was the applied mathematical problem solving component of novel physics problems. Since their first experience with physics was in physics 11, a comparatively advanced stage of their education, mathematical problem solving seemed the logical cognate for building problem solving efficacy, given that mathematics is studied throughout the elementary and secondary stages of education.

The observation that Kevin and Felix developed self-belief; competency, in the absence of successful cognate experience suggests there was something else contributing to the self-belief. It is possible to infer a connection between relatedness and competency, attributing experiences outside of formal education to strengthen self-belief. Section 6.3 related conceptual knowledge and fund of knowledge, their fund of knowledge could have included experiences that insulated them against the challenge of novel problem solving. Kevin referred to city-life as lacking resilience building activities, drawing a comparison to Wainer and Chester's (2000) claim that aspects of rural life can lead to individual resilience. This is a non-specific claim, as the self-efficacy building aspect of successful experience requires similarity, as self-efficacy is task specific and having it in one area (building a pig pen) does not necessarily equate to having it in another (completing a novel mechanics problem). It is possible that 'building' experiences, or 'figuring out' experiences contribute to novel physics problem solving competence and self-efficacy, as there are task similarities, but there is not sufficient evidence to make such a claim.

One possible explanation of a link between hands-on pursuits and competence is Bruner's (1967) structure of knowledge, which involved scaffolded learning through enactive, iconic, and symbolic representations. Pursuits such as fixing vehicles and raising animals could provide enactive and iconic representations that scaffold towards the symbolic representations applied in novel physics problem solving. Concrete experiences, particularly those involving manipulation and problem solving could provide experience of success, contributing to competence development. This does however beg the question as to whether rural life in particular is linked to physics competence, or if anyone with hands-on interests has access to experiences that provide scaffolded experience of success relevant to physics competence.

Dorothy and Anna's relationship with novel physics problem solving further draw the relationship between rurality and the self-belief necessary for competence into question, as they both grew up in a rural environment, and identified as rural (Dorothy identifying as rural and urban), yet did not seem to build relatedness or competence from rural experience. This does not completely undermine the potential for rurality to have a positive impact on novel physics problem solving competence, but it does highlight a need for further investigation to more thoroughly draw out patterns of rural experience and relatedness that potentially contribute to competence.

7. Conclusion

This section concludes the study, reflecting upon its strengths and weaknesses, and proposing a subsequent research direction in response to the results.

7.1 Evaluation of this research

The philosophical and methodological basis of this research project provided suitable grounding and structure for exploration. I found during the analysis in particular that an interpretivist ontology and weak constructionist epistemology were my natural disposition, and I rarely had to pull myself away from a positivist position; this was helped by the qualitative form of interview transcripts. Likewise interpretative phenomenological analysis drove data collection and analysis forward easily, the constant dipping into rural life and secondary school experiences was supported by IPA's consideration of hermeneutics, and led to what I feel is a well formed picture of the participants and their experiences.

The results as presented are tentative; the research was exploratory, and intended to uncover themes for further PhD level research. In this aim it was successful, however due to changes in participants as a result of COVID-19, it is possible that the results of this study will not be reproduced in secondary physics students. Of the four participants, one was a current physics student, and three had not taken physics for a few years. This could have caused a shift in perspective from when the participants were secondary physics students; Dorothy likely reflected somewhat on her university physics experience, and the other participants relied heavily on memories from a minimum of two years ago. While I supplied each participant with two novel physics problems, most reflected on broader experiences, drawing on secondary school experiences. The propensity for participants to think back to secondary physics experience could have functioned as a counter-balance to the limited problem solving experience that I supplied; it lacked the classroom environment, and the typical pressures that come with formal schooling and evaluation. As a result, drawing from secondary school experience could have improved the contextual value of the research, potentially increasing its relevance to secondary physics students (the original aim of the research).

Another potential weakness in data collection was the time lag between supplying the participants with problems, and conducting the interviews. This was partly by design; I used the solutions and comments as a source of questions for the first interview, so I needed time to read through the data and develop the interview schedule. There was also the practicality of scheduling convenient interview times for the participants; they had work schedules and other responsibilities to work around. However, the waiting period between completing the problems and reflecting on the experience during interviews could have diluted some aspects of experience that would have remained in the forefront of participants' minds had the interviews been conducted sooner. Looking forward, collecting data from multiple problem solving sessions may strengthen this aspect of the data; conducting an interview immediately after problem solving, and then reflecting upon the experience and transcript data to inform the next session would provide rich detail for analysis.

Moving to the rural aspect of the research, again the change in participants impacted data. Three of the participants were living in urban areas when I interviewed them. Despite all growing up in a rural area, the experience of living in a city may have affected their perception of rurality. As the majority of their physics education took place when they were living in the country, their retrospective experiences would have been from the eyes of someone still embedded in rural life, but current perspectives may have shifted their relationship with physics, and possibly rural life. In future this issue is easily remedied by ensuring that participants are living in rural areas; comparison of the two states could also prove informative, as rural location and rural identity are not the same thing, and changing one may or may not affect the other.

IPA research is generally small-scale, interested in the individual as well as the group. Lack of generalisability at this stage is not an issue; the research was exploratory, and uncovered patterns that validate further investigation.

7.2 Towards the future

Two apparent conditions emerged from the data in this study; relatedness to physics and problem solving appears to be stronger in people who identify as rural and demonstrate interest in typically rural pursuits, and experience of success from sources aside from formal novel problem solving may have similar effects to successful novel problem solving experience on competence. The potential implications of this research exist within practice and educational research, but significant further investigation is needed to examine the themes in a more focused and rigorous way.

In terms of practice, the results of this research will immediately inform my own teaching, as I will be more cognisant of drawing connections between areas of interest and physics concepts, and building a more scaffolded approach to problem solving in my courses. The potential for rural connection to be a positive factor in novel physics problem solving engagement speaks to the value of funds of knowledge (Moll et al., 1992), but drives the further question of why rurality alone does not necessarily provide relatedness.

Moving forward, drawing from a broader range of rural backgrounds within the participant sample, returning to secondary students and intensifying the examination of rurality and rural experience will help to clarify the position of rural life within novel physics problem solving engagement in secondary education. Proceeding with the intent of avoiding a position of rural disadvantage (Ryun, Meece & Irvin, 2012) will aid in my effort to improve the engagement of rural Nova Scotians in physics education through improved understanding of how rural life connects to relatedness, experience of success, and competence.

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Appendices

Appendix A: Novel physics problems

Instructions

Please complete, to the best of your ability, the physics problems listed below. As you work on each the problems, please record your work, your thought process about the problem, as well as any other related thoughts, emotions, or reactions you have to the problem or the experience in general. Please don't limit your response; the smallest comment could be important.

For ease of recording your information, please organize three pieces of paper as follows for each problem:

Problem solving work	Problem solving thoughts	Other thoughts, reactions, etc.

You may use a calculator, and the attached formula sheet to aid you in solving the problems. When you have completed your responses, please email copies to sdsn2@cam.ac.uk.

Physics Problems

1) In Victor Hugo's novel les Miserables, the main character Jean Valjean, an escaped prisoner, was noted for his ability to climb up the corner formed by the intersection of two vertical perpendicular walls. Find the minimum force with which he had to push on the walls whilst climbing. What is the minimum coefficient of static friction required for him to be able to perform such a feat?

2) A rocket is intended to leave the Earth's gravitational field. The fuel in its main engine is a little less than the amount that is necessary, and an auxiliary engine, only capable of operating for a short time, has to be used as well. When is it best to switch on the auxiliary engine: at take-off, or when the rocket has nearly stopped with respect to the Earth, or does it not matter?

Source: Gnädig Péter, Honyek, G., & Riley, K. F. (2009). *200 Puzzling physics problems:* Cambridge: Cambridge Univ. Press.

Appendix B: Interview schedule: Version 1 (all were personalised)

Research Question

How do rural Nova Scotian students make sense of their experiences with novel physics problem solving?

Biographical Questions:

1. What schools have you attended, for how long, and where were/are they located?
2. Would you consider yourself an urban, suburban, or rural person (or something else)? Why?
3. Why did you decide to enroll in physics?
4. Why did you decide to remain in physics through physics 11 and 12.
5. How long has it been since you studied physics, and what is your highest level of physics?
6. Do you consider problem solving to be a part of physics learning? Why or why not?

Stage 1 Reflection Questions:

1) Why did you feel frustrated when you saw that there were no numbers in the first question? Why are numbers important?
2) You said you liked the question about climbing the wall because it's interesting, but you also dislike it - can you explain what you mean, and why?
3) In the second question, you said you had an instant positive reaction to it because you had an answer - is there an association between easiness (or how fast you can get an answer) and a positive reaction? Why?
4) Were you surprised by any of your physics knowledge? (Did things come back, were you at a loss for things?)

Stage 1 General Questions:

1. What is noval physics problem solving like for you? Can you describe in detail what the experience of problem solving is like for you?
    a. Are emotions a factor?
    b. Do you have a structure you follow?
    c. What goes through your head?
    d. Is the experience valuable?

2. Can you describe a negative novel physics problem solving experience? What was that like for you?

    a. Why do you feel this experience was negative?
    b. Did this experience effect other aspects of your learning?

3. Can you describe a positive novel physics problem solving experience? What was that like for you?
    a. Why do you feel this experience was positive?
    b. Did this experience effect other aspects of your learning?

<u>Stage 2 Questions</u>

1. Can you describe for me what your ideal problem solving environment is?
    a. What is it about this environment that appeals to you?
    b. Why do you think this environment appeals to you?

2. Can you describe the sort of problem solving question you find valuable?
    a. What makes you value it?
    b. Why do you think these aspects are valuable to you?

3. Are you a good problem solver?
    a. Can you explain why?

4. You often brought up frustration in your response to problem solving. Why do you think problems can bring about frustration in you?
    a. Is frustration an acceptable part of problem solving?

5. You gave many references to real-life experiences (making a pig pen, driving a tractor) related to physics. Why do you think you did that?

6. In the first interview, you said that 'in the moment' you would choose an easy question, but in the long-term, and looking back, you would rather do a difficult question. Why do you think this is?

7. You said that you value difficulty in problem solving, why?

8. You said physics is more of a skill than other courses, what makes you think physics is a skill?

9. The problem solving skill you stated as number one for problem solving was breaking things up into smaller pieces. Why do you think this works for you?

10. What is more important to you - getting the correct answer, or understanding the correct process? Why?

Appendix C: Participant information and consent forms

University of Cambridge

Faculty of Education

184 Hills Rd, Cambridge CB2 8PQ
Tel: +44(0) 01223 767600
Graduate@educ.cam.ac.uk www.educ.cam.ac.uk

<u>Research Project</u>: Exploring the Experiences of Rural Nova Scotian Students Navigating Novel Physics Problem Solving Tasks

<u>Information for Student Participants</u>

My name is Sarah Nielsen and I am a research student at the Faculty of Education, University of Cambridge. I am writing to ask if I can carry out my research study in your school.

This project will involve the observation and video recording of you (a student participant) completing novel physics problems; in a classroom and/or individual setting. Following observation, semi-structured interviews focused on your experience of problem solving will be conducted and audio recorded, as well as discussions of biographical information. You will also be asked to complete a reflective written response to further examine your experience of novel physics problem solving.

The University of Cambridge has strict ethical procedures on conducting ethical research with teachers and young people, consistent with current British Educational Research Association guidelines: http://bit.ly/BERAethics2018. Before beginning the research, gatekeepers will be informed about the research and students, teachers, and gatekeepers will be offered the opportunity to refuse to participate. Throughout the research participants and gatekeepers will be able to refuse to participate or remove research access at any time.

Recordings are confidential, and participation is anonymous and voluntary. At any time, participants are free to change their mind or withdraw their consent. Recorded files will be archived and transcribed, and all data will be stored securely, with access limited to people directly involved in data analysis (Sarah Nielsen and Steve Watson). Data from participants who withdraw from the study will be destroyed.

This exercise does not involve any risks or discomfort for participants other than being video recorded completing physics problems and being audio-recorded in interviews.

With permission, I will use the recordings and the transcripts for training and research purposes, and possibly subsequent publications. The University of Cambridge is committed to the dissemination of its research for the benefit of society and the economy and, in support of this commitment, has established an online archive of research materials. This archive includes digital copies of dissertations successfully submitted as part of a University of Cambridge postgraduate degree program. Holding the archive online gives easy access for researchers to the full text of freely available dissertations, thereby increasing the likely impact and use of that research. If you agree to participate in this study, the research will be written up as a dissertation and made available to the public. Should you wish, you will be provided with a copy of the completed dissertation.

This study has been reviewed by the University of Cambridge Faculty of Education Research Ethnics Committee and has received ethics clearance.

If you have any further questions, please feel free to contact me (Sarah Nielsen) at sdsn2@cam.ac.uk or my supervisor, Dr Steve Watson at sw10014@cam.ac.uk .

Thank you for your time and attention. I look forward to hearing from you.

Yours sincerely,

Sarah Nielsen
MPhil Student
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UNIVERSITY OF CAMBRIDGE
Faculty of Education

Student Participant Consent Form

Project Title: Exploring the Experiences of Rural Nova Scotian Students Navigating Novel Physics Problem Solving Tasks

I, the undersigned, have read and understood the participant information sheet about the study and have had the opportunity to ask questions and get satisfactory answers about the study. I understand that I have the right to withdraw from the study without any consequences at any point of the research. I also understand who will have access to information provided and what will happen to the data at the end of the study. I am aware that this study has been reviewed by and received ethics clearance through the University of Cambridge Faculty of Education Research Ethics Committee. If need be, I can find out more about this research study by contacting the researcher Sarah Nielsen, sdsn2@cam.ac.uk or her supervisor at the department, Dr Steven Watson sw10014@cam.ac.uk

Fully informed of my rights, I agree to participate in the study, carried out by Sarah Nielsen a full-time MPhil student at the Faculty of Education, University of Cambridge.

Name of School Principal/ teacher: ________________________

Signature: ________________________

Date: ________________________

-- For Researcher's Use Only--

Name of researcher: ________________________

Signature: ________________________

Date: ________________________