Measuring, exploring and enhancing undergraduate students' emotional engagement with physics

A thesis submitted in fulfillment of the requirements for the degree of

Doctor of Philosophy

by

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Statement of Originality

To the best of my knowledge, this thesis contains no copy or paraphrasing of work published by another person, except where duly acknowledge in the text. This thesis contains no material which has been previously presented for a degree at The University of Sydney or any other university.

Aesha Bhansali

Statement of Contribution

The idea of investigating students emotions with 'colorful historical stories' was framed by me. All research, development and analysis has been undertaken by me, with advice from Professor Manjula Sharma and A/Prof Elizabeth Angstmann. The 'colorful historical stories' have been developed by me. Likewise, the survey and observation tools were developed by me with guidance from my supervisors. My peers in the Sydney University Physics Education (SUPER) group assisted by distribution/collecting the surveys and critiquing the stories as well as through broad discussions around my research, methods and findings. I have been provided statistical consulting by Sydney Informatics Hub for final checks on my results. Professor Brian McInnes and Ian Sefton have provided invaluable editorial assistance in writing the thesis. Throughout my research, the students, tutors and other staff, particularly the laboratory technical staff have assisted by consenting to participate and participating, as well as with logistics.

Aesha Bhansali

Included papers and attribution

The following reference list includes refereed papers and presentations that arose from this doctoral program and on which some of the chapters of this thesis are based. I am the lead and the corresponding author. I have designed the study, analysed the data, and wrote the drafts of the manuscript.

Aesha Bhansali

As supervisor for the candidature upon which this thesis is based, I can confirm that the authorship attribution statements above are correct.

Manjula Sharma

Refereed paper

Bhansali, A., & Sharma, M. D. (2019). The Achievement Emotions Questionnaire: Validation and implementation for undergraduate physics practicals. International Journal of Innovation in Science and Mathematics Education, 27 (9), 34-46. http://dx.doi.org/10.30722/IJISME.27.09.003

Conference paper (refereed)

Bhansali, A., Angstmann, E. & Sharma, M. D. (2020) AEQ-PHYSICS: A Valid and Reliable Tool To Measure Emotions in Physics, Proceedings of the Australian Conference on Science and Mathematics Education (ACSME), 93-98. https://openjournals.library.sydney.edu.au/index.php/IISME/article/viewFile/14640/13105

Conference presentations

Bhansali, A., Angstmann, E., and Sharma, M. D. (30 September - 2 October 2020). Impact of COVID-19: Students' Emotional Engagement With Face-To-Face Labs Transiting To Online Mode [Paper presentation]. Australian Conference on Science and Mathematics Education (ACSME). http://www.acds-tlcc.edu.au/events/acsme-2/acsme-2020-program/

Bhansali, A., Angstmann, E., and Sharma, M. D. (30 September - 2 October, 2020). AEQ-Physics: A valid and reliable tool to measure emotions in physics [Poster presentation]. Australian Conference on Science and Mathematics Education (ACSME).

Bhansali, A., Angstmann, E., and Sharma, M. D. (23-26 June, 2020). AEQ-PhysicsLec: Measuring first year students' emotions with Physics Lectures [Paper Presentation]. Australasian Science Education Research Association (ASERA), 15. https://eprints.qut.edu.au/207502/1/ASERA2020_Book_of_Abstracts_1_.pdf

Bhansali, and Sharma, M. D. (23-26 June, 2020). Students' emotions in first year Physics practicals [Paper Presentation]. Australasian Science Education Research Association (ASERA), 16.
https://eprints.qut.edu.au/207502/1/ASERA2020_Book_of_Abstracts_1_.pdf

Bhansali, A., and Sharma, M. D. (3-6 January, 2020). Measuring students' emotional engagement in Physics : AEQ-PhysicsPrac [Poster Presentation]. Proceedings of the Eighth International Conference to Review Research in Science, Technology and Mathematics Education, Homi Bhabha Centre for Science Education, India, 7.
https://episteme8.hbcse.tifr.res.in/docs/Conference_Schedule.pdf

Bhansali, A., Angstmann, E., and Sharma, M. D. (3-6 December 2019). Measuring Students' Emotional Engagement with Physics Lectures [Poster Presentation].

Australian Institute of Physics. Royal Melbourne Institute of Technology (RMIT) University, Melbourne, Australia.

Bhansali, A., Angstmann, E., and Sharma, M. D. (2-4 October, 2019) The AEQ - PhysPrac: a tool to measure students' emotional engagement with physics practicals [Poster Presention]. The Australian Conference on Science and Mathematics Education (ACSME). The University of Sydney, Sydney, Australia.

Bhansali, A., and Sharma, M. D. (24-25 July, 2019). First year students' emotional engagement with Physics [Poster Presention]. Physics Education Research Conference (PERC). Provo, Utah.

Bhansali, A., and Sharma, M. D. (20-24 July, 2019) Measuring Students' Emotional Engagement with Physics Experiments [Paper Presention]. American Association of Physics Teachers Summer Meeting (AAPT). Provo, Utah.

Bhansali, A., and Sharma, M. D. (9 - 13 December 2018). Using colour and history to engage students with a thermal experiment [Paper Presention]. 23rd Australian Institute of Physics Congress (AIP). University of Western Australia, Perth, Australia.

Bhansali, A., and Sharma, M. D. (2-6 December, 2018). Students' emotional engagement with physics experiments: role of colour and the inclusion of a history of science context in experiment notes [Paper Presention]. Australian Association for Research in Education (AARE). The University of Sydney, Sydney, Australia.

Bhansali, A., and Sharma, M. D. (1-5 October 2018). What Does Emotional Engagement of Undergraduate Students With Experiments Depend On? [Poster Presention]. International Conference of Physics Education (ICPE). University of the Witwatersrand, Johannesburg, South Africa.

Bhansali, A., and Sharma, M. D. (26-28 September, 2018). Feeling The Heat: Exploring Emotional Engagement of Students With Experiments. The Australian Conference on Science and Mathematics Education (ACSME). Flinders University, South Australia.

Abstract

Physics is a discipline associated with diverse emotions; some students enjoy it, others don't. Yet students' emotional engagement, which is important for their continued interest in the subject, is under researched. My thesis rests on two pillars; measuring emotions and creating research-based 'colorful historical stories' in order to encourage emotional engagement.

For the first pillar of my thesis, I have adapted the Achievement Emotions Questionnaire (AEQ) to measure the emotions of students undertaking first year physics studies. The measured emotions are pride, enjoyment, anger, anxiety, hopelessness, and boredom. I adapted the AEQ to measure emotions in the laboratories. I validated the new tool called AEQ-PhysicsPrac, using SPSS software, by conducting exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). Later, similar adaptation and validation process followed for the tool to measure emotions for the whole course, AEQ-Physics.

For the second pillar of my thesis, I have carefully created interesting stories with historical anecdotes and real life applications of physics; colorful pictures accompany the stories. 'Colorful historical stories' were crafted for both the laboratory and the lecture components of the Teaching Course, with somewhat different styles being used. In both environments, laboratories and lectures, the stories were 'presented' without intruding into the content being taught.

For the laboratories, I used the 'colorful historical stories' in an intervention-control style study. I demonstrated that the use of the stories influences students' emotional engagement. Furthermore, I inserted the stories in a series of four experiments on electricity in two courses and showed that 'latch and hold interest' plays a role in emotional engagement in the laboratories.

For the lectures too, I used the ’colorful historical stories’ in an intervention-control style study. The stories were briefly displayed but were not discussed. There was no difference found between the emotions in the intervention and control, probably because they had a lot of common engagement elements like interactive question-answer session and demonstrations.

This work began and was in operation before the COVID-19 pandemic and continued into the time of pandemic; this meant that face-to-face, blended and entirely online delivery modes were used and the effect of these different teaching modes could be investigated. However, I was not able to incorporate ‘colorful historical stories’ into the online teaching materials. I found that students engaged more positively in face-to-face mode of teaching than in blended and online mode during the pandemic. During the pandemic students’ positive emotions about the course were reduced. Results indicated that female students experienced less positive and more negative emotions compared to male students irrespective of the scenarios such as the COVID-19 pandemic.

The study shows the utility of the adapted AEQ in physics, where it can be used to differentiate emotion profiles for different factors including introductory story context, different courses and mode of studies. It also shows that colorful stories, containing historical anecdotes, engage students emotionally while stimulating their interest and so can be inserted in students’ learning materials to influence their emotional engagement.

I suggest that the AEQ-Physics can be used in other contexts providing academics with a measure of emotional engagement in their courses. Now that emotions can be measured and stories can be inserted, future studies can probe their influence on students’ achievements.

Acknowledgements

Without my family by my side, I would not have been able to commence this journey. I will take this opportunity to show my warm gratitude to my grandparents, Babiben & Mafatlal Bhansali and Sharda & Suryakant Parikh, who instilled sincerity and eagerness in me to know more about the universe. A big thanks to my parents, Bina & Piyush Bhansali, who support all my endeavors, and to my siblings, Puja & Raj, who shower unconditional love on me. Thank you to all my extended family members for motivating and supporting me to pursue my dreams. Special mention to Rajni & Jyotsana Bhansali, Asha Adani, Bhavik Parikh, and Bhavin & Purvi Parikh for being there.

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This isn't just a degree for me, it is a quantum leap personally and professionally. I would like to thank all the people involved in this life-changing journey. I am short of words to thank my supervisor Manjula Sharma, who trusted my ideas and provided me undying guidance and support throughout the degree. If it was not for her dedication, support, and skills, I would not have been able to pursue Ph.D. smoothly. She is not only the most wonderful guide but also one who wishes for the holistic development of her students. She has inspired me to develop skills such as emotion management, resilience, work ethics, and teamwork. I have learned a lot from her, and I wish I can work as sincerely and be as giving as her in my professional life ahead.

I am very grateful to Ian Sefton and Brian McInnes for the gracious help and diligent feedback that they provided for my entire thesis. My sincere thanks to my co-supervisor, Elizabeth Angstmann, for her guidance and expertise. A warm thanks to Derek Muller, as through his YouTube channel ‘Veritasium’, I got to know about the Sydney University Physics Education Research (SUPER) group. Lots of love to my colleagues Vicky Tzoumis, Arunee Eambaipreuk, Petr Lebedev, SriVidya Kota, Tom Gordon, Gabriel Nguyen, and Jules Rankin for always being there to share my problems, achievements, and hot chocolates with. Thank you, Ian Johnston, Helen Georgiou, and Alexander Samarian for helping and providing expert feedback to my research work. I would like to acknowledge Christine Lindstrom and others from the PERfect research group. Thank you, Aditya Vaishya, Simon Crook, and Matthew Hill for the research collaboration. Thanks to all the tutors and students who volunteered to participate in the research.

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This experience has reformed and refined me, which would not have been possible without all of you!

Upwards and onwards,
Aesha

Contents

List of Figures

List of Tables

CHAPTER 1

Introduction

I propose that science be taught at whatever level, from the lowest to the highest, in the humanistic way. It should be taught with a certain historical understanding, with a certain philosophical understanding, with a social understanding and a human understanding in the sense of the biography, the nature of the people who made this construction, the triumphs, the trials, the tribulations. - I.I. Rabi
(Pell, 2020)

FIGURE 1.1. The 'Ice Stupa' designed by Sonam Wangchuk, as presented in Strochlic (2021), are used to conserve water and use it for farming in the Himalayas

This quote from Rabi, recipient of the 1944 Nobel Prize in Physics, appearing on the first page of the Harvard Project Physics textbook crystallises the central tenet of those who advocate for physics to be relevant to learners as individuals within society.

The quote by Rabi also resonates with my ideas and the research I am sharing in my thesis. For example, a humanistic historical story relevant to me is the one shared by Sonam Wangchuk, an Indian engineer and educator. His story amalgamates science in a colorful way with its social relevance to counter climate change. In figure 1.1, the water that would otherwise flow away in streams/rivers in winter is captured/conserved in the form of Stupas. In spring the Stupa slowly melts releasing water for farming (Strochlic, 2021).

During my academic journey through physics education, I have found that many of the students around me have been intimidated by physics. I believe that if those students were given an interesting humane context within their studies, they would likely find physics more appealing. This is what inspired me to pursue research in the field of physics education. My research on students' emotional engagement with physics tries to fill some gaps and can help students connect with their physics studies. In time, I hope that work such as this can help broaden participation in physics.

The four largest aspects of my thesis are:

(1) Designing research-based stories containing color and historical anecdotes, for laboratories and lectures, and describing a process others can implement to do the same. *This is addressed in Chapter 3.*
(2) Adapting a survey called Achievement Emotion Questionnaire (AEQ) (Pekrun et al, 2005b) for physics practicals and lecture courses. *This is addressed in Chapter 5 and 7.*
(3) Implementing the adapted AEQ in physics practicals to investigate the effect of the inclusion of 'colorful historical stories' on the emotional engagement of students studying in different cohorts. *This is addressed in Chapters 5 and 6.*

(4) Implementing the adapted AEQ in whole physics courses to investigate the effect of factors such as the inclusion of 'colorful historical stories' and mode of study on students' emotional engagement. *This is addressed in Chapter 7.*

In Chapter 2, I introduce the literature supporting my research. Firstly, I present earlier studies on students' engagement indicating the necessity to investigate emotions. Secondly, I describe the control-value theory (Pekrun, 2006), the conceptual basis, for measuring the emotions. I then present the rationale for enhancing students' emotional engagement by using historical and colorful stories. I also discuss the process followed to develop these stories. The rapid transfer to online studies as a consequence of the COVID-19 pandemic did not allow me to insert the 'colorful historical stories' in the online learning materials and thus I could not investigate the impact of stories on students' emotional engagement. However the pandemic gave me an opportunity to measure students' emotions in online mode of study. Thus lastly, I present the literature on students' engagement with a focus on different modes of studies.

In Chapter 3, I showcase the 'colorful historical stories' that I created for physics laboratories and lectures. The Chapter dives into the guidelines provided by earlier studies and in-depth methods to develop engaging stories containing colorful pictures and historical aspects. I also present a description of how the stories were created and presented for each topic in the laboratories and lectures.

In Chapter 4, I elaborate on the research methodology used in the thesis. I present the process and criteria followed for the validation of the adapted AEQ to measure students' emotions. I also discuss the theoretical basis and the process of qualitative and quantitative analyses conducted.

In Chapter 5, I present the adaptation and validation of the adapted AEQ for physics practicals. I explore the utility of the newly developed tool, called AEQ-PhysicsPrac, for two practicals; one with the 'colorful historical story' and the other without. The Chapter showcases the effect of stories as well as the AEQ-PhysicsPrac as a tool capable of discerning differences in emotions and evaluating learning resources.

In Chapter 6, I explore the emotional engagement of students who are interested in technological fields and are more likely to major in physics as well as the emotional engagement of students who are pursuing environmental and health disciplines and are unlikely to major in physics. I also investigate and compare the influence of the stories on students' emotions for both types of cohort.

In Chapter 7, I present the validation of the adaptation of the AEQ for a whole physics course. The utility of AEQ-Physics is demonstrated through my use of the tool to compare the emotional engagement of students in lecture streams with and without colorful historic stories. I further explore the effect of different modes of study on emotional engagement. As the COVID-19 pandemic struck during this part of my study and there was a rapid shift to entirely online learning, I was not able to implement the 'colorful historical stories'. Instead, I compare students' emotions in face-to-face mode, blended mode and online COVID-19 mode.

In Chapter 8, I conclude the thesis by presenting a discussion on the results and the implications of my study in physics education. I also discuss how this study can be useful for future research and education practice, along with representing the constraints to the scopes of this study.

In summary, through this thesis I set forth the case that the use of 'colorful historical stories' can add value to physics teaching and learning, without impacting the content coverage.

CHAPTER 2

Literature review

2.1 Introduction

In this Chapter, I present the literature supporting the approach I follow in my research. In the first two sections I consider studies of student engagement leading to the necessity to focus on emotional engagement. I describe the control-value theory that forms the conceptual basis for the measurements underpinning my research. I then present the rationale for and process followed to develop the colorful historical stories, a term developed by my supervisors and me. These stories form the interventions for my research. The rapid transfer to online studies as a consequence of the COVID-19 pandemic allowed measurement of emotional engagement in online modes to be included in my research. The final sections of this Chapter include pertinent literature on online learning. Figure 2.1 presents section-wise flow of ideas covered in this Chapter.

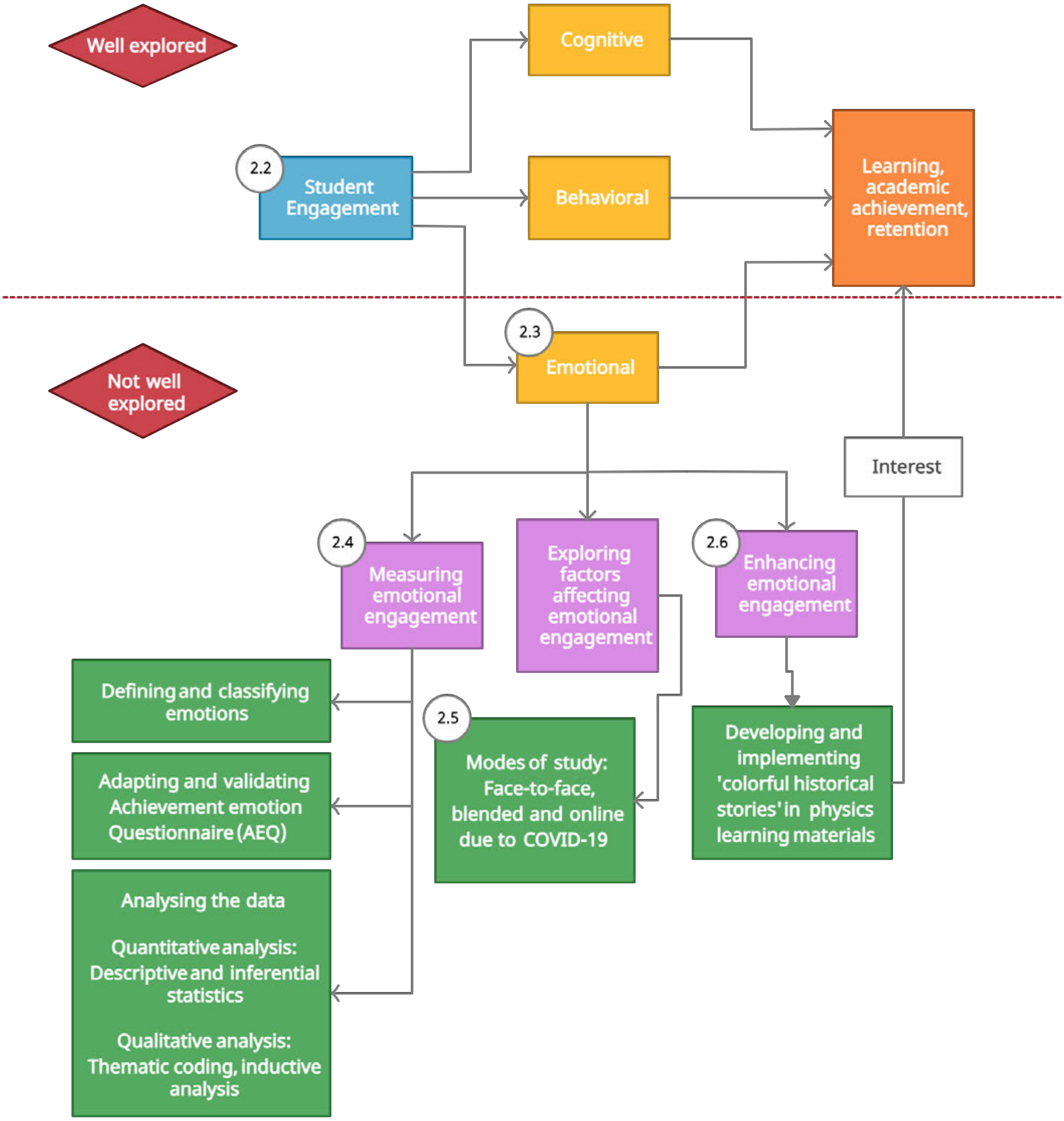


FIGURE 2.1. Section-wise flow of ideas in Chapter 2

2.2 Student engagement

Engagement, described as the ‘holy grail of learning’, has been linked to positive learning outcomes and has a role in persistence in STEM subjects (Sinatra et al, 2015). But what is student engagement? How is engagement manifested? What does it mean to engage students in their learning? A useful stance is to consider the components of student engagement during a learning task or activity (See for example Fredricks et al (2004)):

- Cognitive engagement in which students are mentally intent and engrossed.
- Behavioural engagement where students are actively participating.
- Emotional engagement in which students’ feelings and moods are evoked.

While the engagements can be theorized and developed as separate elements, they are intimately connected to each other. Student engagement results in increased motivation and achievement in the domain of science learning (Sinatra et al, 2015). Researchers such as Fredricks et al (2004) have referred to student engagement as a resource that ‘once established, builds on itself, thereby contributing to increased improvements in more distal outcomes of interest’. In other words, student engagement contributes to interest, and once interest is aroused, attitudes and motivation can be influenced (Renninger and Hidi, 2015).

The Oxford Learner’s Dictionary (2022) defines interest as “interest (in somebody/something) the feeling that you have when you want to know or learn more about someone or something”. Interest is also recognised to have an influence on academic achievement and learning (Krapp, 1999).

Interest is an important feature that directs academic and career paths while engaging students (Renninger and Hidi, 2015). Interest latches onto and holds a student’s attention so that they continue with the academic subject (González and Paoloni, 2015; Renninger and Hidi, 2015). It knits affective reactions, perceived value, and cognitive functioning together, and makes learning feel effortless (Dewey, 1913; Ainley, 2006; Hidi, 2006). It relates to self-regulation, task engagement, and persistence while improving performance in the task at hand (Hidi and Harackiewicz, 2000; Thoman et al, 2011). In summary, interest in a subject is associated with students' emotional engagement (Ainley, 2006).

Student engagement has been at the forefront in various strategies which have been trialed and advocated in physics. For example, the use of context has been investigated (McCullough, 2004), as has assessment (Wilson, 2009). In parallel, active learning as a pedagogy has been extensively explored (Michael, 2006; Drew and Mackie, 2011; Sharma et al, 2013; Koretsky et al, 2018). Mentoring, networking, and belonging have also received attention as has meta-cognition (Ivie et al, 2016; Binning et al, 2020). In engaging students, these strategies range from cognitive, social, behavioural to meta-cognitive (Sinatra et al, 2015). While these all impinge on emotional engagement, what has not received much attention in mainstream undergraduate physics education are strategies specifically designed to evoke emotional engagement. The question then arises: how can emotional engagement elements be infused in physics education?

2.3 Emotional engagement

As argued above, a student's emotional engagement is required for continued interest and achievement in a subject. It has been shown that emotions influence students' learning, motivation, and achievement outcomes (Pekrun, 2006; Kuh et al, 2008; Robinson et al, 2008; Svanum and Bigatti, 2009; Weiner, 2010). For the majority of students, positive emotions can be beneficial and negative emotions detrimental for academic learning (Pekrun et al, 2011). Subjects such as physics are often associated with particularly diverse emotions and can be difficult for students to find interesting (Pekrun et al, 2002; Williams et al, 2003), so how can positive emotions be evoked for such subjects?

2.3.1 Defining emotions

The word 'emotion' is used widely in everyday discourse. The Oxford Learner's Dictionaries (2022) defines it as, "a strong feeling such as love, fear or anger; the part of a person's character that consists of feelings". The Encyclopedia Britannica (Solomon, 2019) defines emotion as "a complex experience of consciousness, bodily sensation, and behaviour that reflects the personal significance of a thing, an event, or a state of affairs". In his elaboration, Solomon (2019) cites Aristotle (384–322 BCE) as follows: "Emotions are all those feelings that so change people as to affect their judgements, and that are also attended by pain or pleasure. Such are anger, pity, fear and the like, with their opposites". In everyday life, emotion is intertwined with feeling, mood, temperament, personality, disposition, creativity and motivation (Ekman and Davidson, 1994; Damasio, 1998; Averill, 1999; Cabanac, 2002; Panksepp, 2005; Cherry, 2020). Putting all of these together, in an everyday sense, emotion is coupled with behaviour, motivation, attitudes and moods. While some argue that selected/underpinning emotions are universal, others argue that they are nuanced by context (Kuang et al, 2019), the emotions investigated in this thesis are commonly referenced to on popular culture.

The *Handbook of Emotions* (Lewis and Haviland-Jones, 2000) claims that "the idea that emotion is as such more primitive, less intelligent, more bestial, less dependable, and more dangerous than reason, and thus needs to be controlled by reason". Perhaps this is why emotion is approached tentatively in education, as education tries to focus on reason. Tyng et al (2017) provide a counter argument for the effect of emotion on reasoning and other cognitive processes. Their study proposes: "Emotion has a substantial influence on the cognitive processes in humans, including perception, attention, learning, memory, reasoning, and problem solving". Cavanagh (2016) argues for harnessing emotion to aid college education while elaborating on how emotions help to craft students' first impressions, mobilize their efforts, and prolong their persistence.

Gendron and Barrett (2009) present three eras in the research of emotions: "golden years" with research like that of Darwin (1872) and James (1884), "dark ages" with limited work, and "renaissance" with the revival of efforts such as those by Arnold (1960a) and Arnold (1960b).

My research is based on Arnold's work which is described as the "appraisal model" of emotion. The appraisal model assumes that "emotions are not merely triggered by objects in a reflexive or habitual way but arise from a meaningful interpretation of an object by an individual" (Gendron and Barrett, 2009). “Input some event with its particular meaning; out comes an emotion of a particular kind” (Frijda, 1988). My research draws on this notion of appraisals acting as special cognitive mechanisms associated with emotions, making emotions pivotal for education. The basic premise of appraisal theories is that emotions are caused and differentiated by evaluations and interpretations of events and experiences, these will be affected by how a student perceives the goal relevance of the activity as well as their control, and agency.

2.3.2 Types of emotions

Enjoyment and pride are positive emotions. Anger, anxiety, hopelessness, and boredom are negative emotions. Are they distinct? Do they differ? To elaborate I draw on ‘emotion wheels’ such as the Junto Emotion Wheel *(2020)* and the *Geneva Emotion Wheel* (Scherer et al, 2013). Junto Emotion Wheel *(2020)* has been used to identify words related to a specific emotion and the *Geneva Emotion Wheel* (Scherer et al, 2013) is used as a theoretical structure. Figure 2.2A shows a schematic of the Junto Emotion Wheel and Figure 2.2B shows a schematic of the Geneva Emotion Wheel.

The Junto Emotion Wheel *(2020)* is a useful tool for naming and labelling emotional awareness as well as grouping words used for similar emotions. It helps recognize emotions, moods, and related thoughts and behaviour. It helps label the feelings with a construct of six wedges representing core human emotions, with two additional layers in each wedge identifying more specific feelings.

The *Geneva Emotion Wheel* (Scherer et al, 2013) can be used for constructing a self-reporting tool for measuring emotions. In the middle of the wheel there is either no emotion or a different emotion being reported. Bubbles’ sizes increase towards the circumference to represent increase in particular emotions labelled on the circumference. One half of the wheel represents positive emotions and the other half negative emotions. Together with the *Geneva Emotion Wheel*, Scherer (2005) has also developed guidelines to measure discrete emotions in an organized and easy way. These guidelines include the use of terms so that the emotions seem close to everyday language of the reader and dimensions for expressing positive/negative emotions and the control the learner has.

2.3.3 Framework for measuring emotions: The control-value theory of achievement emotions

The control-value theory of achievement emotions (Pekrun, 2006) is possibly the most widely accepted framework for emotional engagement. It is in line with the theoretical structure of the Geneva Emotion Wheel (Scherer et al, 2013). Pekrun (2006) pointed out that the control-value theory of achievement emotions provides "an integrative framework for analyzing the antecedents and effects of emotions experienced in achievement and academic contexts". Figure 2.3A presents a simplified version of the model underpinning the control-value theory (adapted from Pekrun et al (2017)).

Pekrun (2006) conceptualizes that some emotions are associated with a sense of achievement with the activity or a sense of achievement with the outcomes. Hence, they are considered as 'achievement emotions', which are interrelated psychological processes. The control-value theory acknowledges that feelings in activities such as class attendance, learning, and taking tests are associated with achievement during a process in an activity or achievement of an outcome.

Pekrun (2006) classifies achievement emotions according to three dimensions: valence (positive vs negative), activity level (activating vs deactivating), and object focus (activity vs outcome). Valence is simply whether the emotions are positive or negative and object focus is whether the student is focusing on the process or the outcome. Activity level is whether the emotion is activating or deactivating. Pekrun noted that not all positive emotions lead to attention, so he proposed the distinction between activating and deactivating emotions. Figure 2.3A shows emotions in four quadrants classifying them as:

- Positive activating emotions such as enjoyment, hope and pride
- Positive deactivating emotion such as relief
- Negative activating emotions such as anger, anxiety and shame

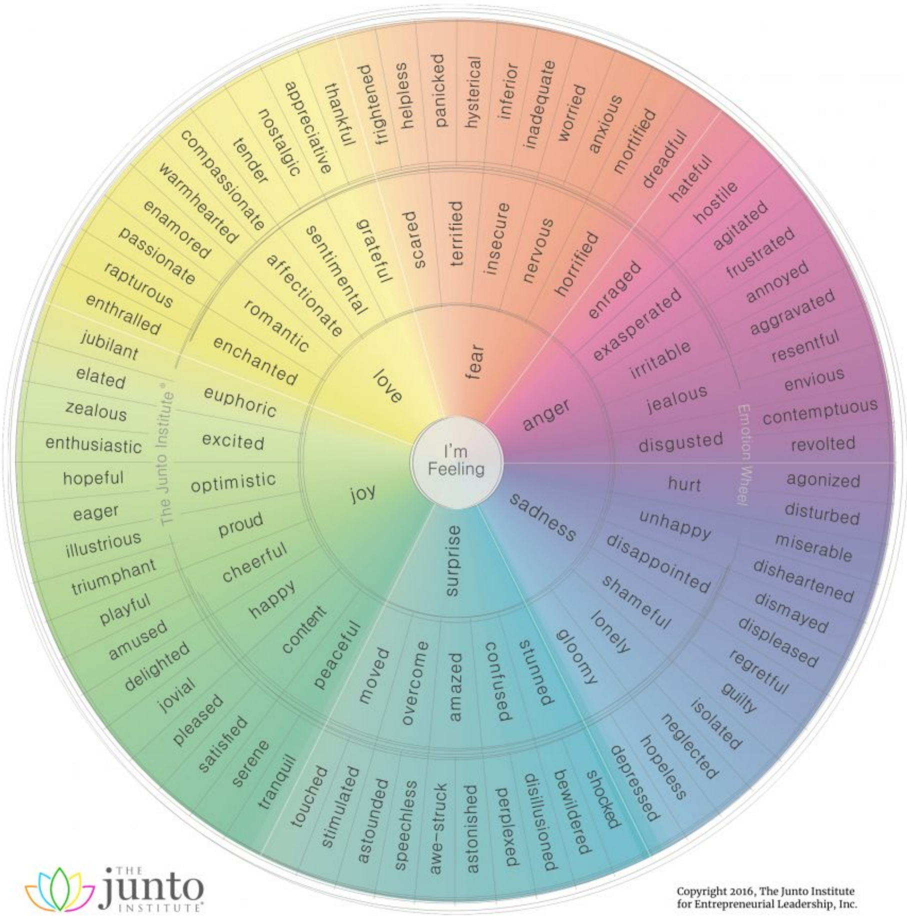
- Negative deactivating emotions such as hopelessness and boredom

Furthermore, the control - value theory identifies two groups of appraisals as being relevant for achievement emotions. Appraisal was mentioned earlier (Arnold, 1960a; Arnold, 1960b; Frijda, 1988; Gendron and Barrett, 2009) as a reflex or habit arising from a meaningful engagement triggering cognitive mechanisms associated with emotions. Appraisals, not dissimilar to Scherer's 2005 are:

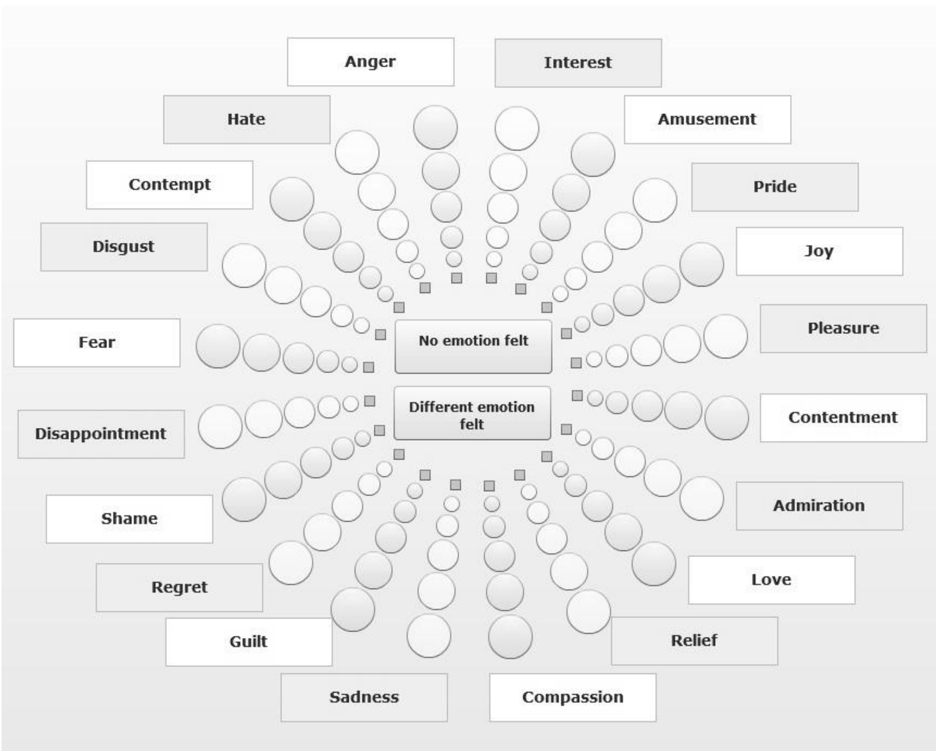
- Control over achievement activities and their outcomes, i.e. hold over actions and outcomes (Skinner, 1996). For example the expectation that persistence leads to success.
- Perceived values of these achievement activities and outcomes. For example, the perceived importance of success.

The theory asserts that appraisals of control and values are fundamental in describing the stimulation of emotions, separated into two valences, positive and negative. Hope, pride, enjoyment, and relief have positive valence whereas anger, anxiety, shame, hopelessness, and boredom have negative valence.

Figure 2.3B summarises a cognitive-motivational model of emotion effects which can be described as either "activating" or "de-activating" (Pekrun et al, 2017). The effects of emotions on the cognitive and motivational factors result in students' learning achievement which in turn influence students' emotions in an iterative manner. Activating emotions lead to attention, focus, and engagement, while deactivating emotions result in attention going astray, a loss of focus, and disengagement. Positive activating emotions lead to attention, while positive deactivating emotions lead to a loss of attention, hence disengagement. Negative activating emotions can lead to attention while negative deactivating emotions generally lead to disengagement. For the majority of students, positive activating emotions can be beneficial and negative deactivating emotions can be detrimental. Positive deactivating and negative activating emotions are more complex, mostly affecting achievement performance negatively.

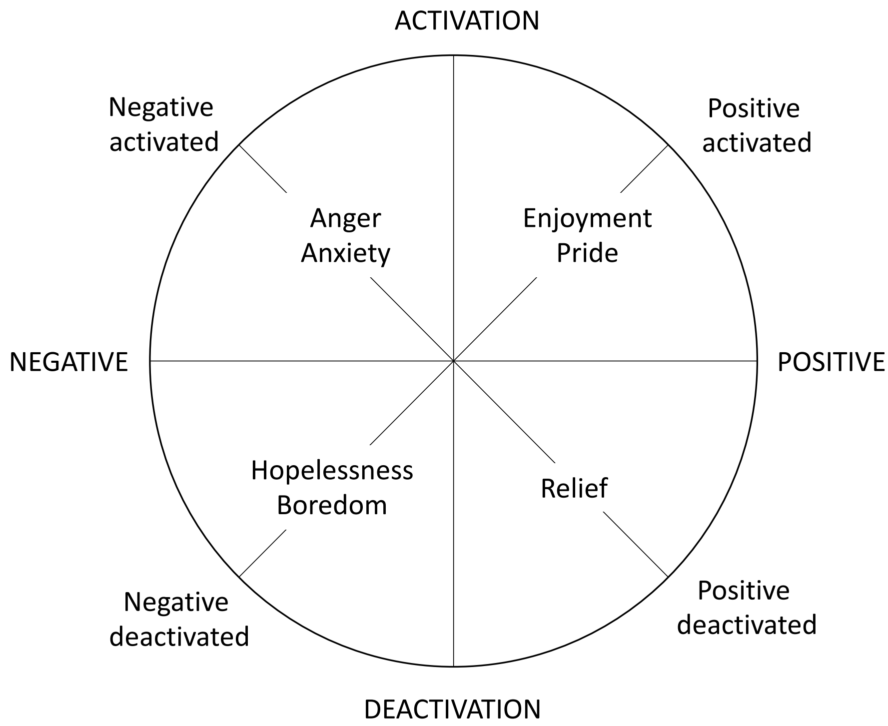


(A) *Junto Emotion Wheel* (2020)

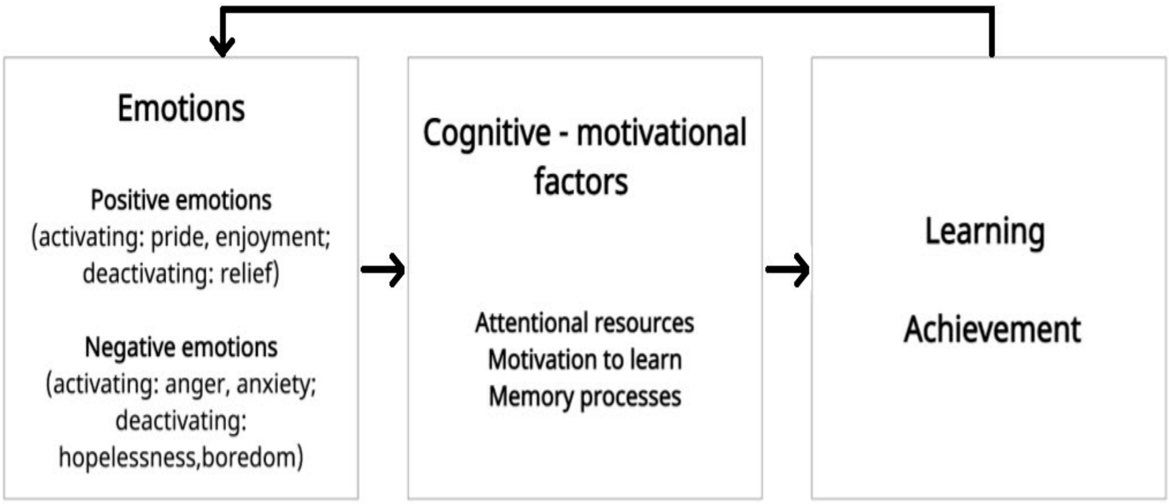


(B) Geneva Emotion Wheel (Scherer et al, 2013)

FIGURE 2.2. Emotion wheels



(A) Affective circumplex model adapted from Pekrun et al (2017)



(B) Cognitive- motivational model of emotion effects adapted from Pekrun et al (2017)

FIGURE 2.3. Models adapted from Control-value theory

2.4 Instruments for measuring student emotions during learning

In physics education, the domain of this study, the research on students learning ranges from metacognition (Kung and Linder, 2007) to perceptions of learning experiences (Barrie et al, 2015). Furthermore, several instruments are available for measuring other affective and attitudinal aspects of studying physics, for example, Physics Self-Efficacy Questionnaire (Lindstrøm and Sharma, 2011), Physics Goal Orientation survey (Lindstrøm and Sharma, 2010) and the Maryland Physics Expectations (MPEX) Survey (Redish et al, 1998). Of note is work done three decades ago by Watson et al (1988) developing and validating the Positive Affect and Negative Affect Schedule (PANAS). More recently, in a qualitative study involving 19 first-year physics students, Kahu (2014) found that students' emotions are important for explaining the links between their interest and their engagement with physics. Lehtamo et al (2018) in researching situational emotions with 36 school students found that reduced stress is a significant predictor for retaining students in physics. Test anxiety has also received some attention; for example see Weiner (2010). A Physics Anxiety Rating Scale (PARS) has been developed for both school and university students by Sahin et al (2015). Emotions as a field of research is largely fragmented, with a few emotions like anxiety researched whereas many others have not yet been researched (Pekrun, 2006). A holistic emotion measurement tool for physics learning is yet lacking. The research on achievement emotions in physics studies is limited as well.

While the measurement and interpretation of emotions continue to be deliberated (Scherer, 2005; Linnenbrink-Garcia and Pekrun, 2011), Pekrun has developed and validated the Achievement Emotions Questionnaire (AEQ) (Pekrun et al, 2005b) to 'quantify' emotions. The AEQ aligns with Scherer's model (2009) of emotions and the Geneva Emotion Wheel (GEW) (Scherer et al, 2013) discussed above. The AEQ not only assesses individual emotions but provides an organized and hierarchical structure for correlating emotions. It enables us to measure emotions in a systematic manner.

The AEQ has been used in multiple languages such as German (Molfenter, 1999; Titz, 2001), Chinese and English (Pekrun et al, 2005b). The AEQ also has been used in a variety of contexts including middle and high school students' emotions experienced in mathematics and language-related subjects (Pekrun et al, 2005b). Lichtenfeld et al (2012) constructed the AEQ—Elementary School which assesses three emotions, namely, enjoyment, anxiety and boredom. For pre-adolescents Pekrun et al (2005a) developed the AEQ— Mathematics (AEQ-M) which measures seven emotions, namely enjoyment, pride, anger, anxiety, shame, hopelessness, boredom. AEQ-M is available in English, German and Chinese languages.

The AEQ is relevant for my research purposes as it was initially developed for college students (Pekrun et al, 2005b) and has been tested by sufficient studies to suggest that it is robust for investigating achievement emotions.

AEQ is a self-report tool. Self-report is a primary method to assess emotions in education research (Pekrun, 2016). Pekrun (2016) discusses advantages and problems of self-report. "Self-report can be used to assess all of the affective, cognitive, physiological, and behavioral processes that are part of self-regulated learning – all of these processes can be represented in the human mind and can be reported accordingly. Though, self-report is limited to the assessment of processes that are accessible to consciousness" (Pekrun, 2020).

2.5 Students' emotional engagement in different modes of teaching and learning

Several studies have shown that there is no significant difference in course performance between students studying face-to-face and online (Ni, 2013; Szeto, 2014; Paul and Jefferson, 2019). Kemp and Grieve (2014) conducted a study on 67 psychology undergraduates at an Australian university while comparing their preference and performance on class material and assessment in face-to-face and online modes. The results indicate that while students appreciate the flexibility of online classes, they still prefer face-to-face classes, finding it easier to engage with the course when given the opportunity to have discussions with the peers and get immediate feedback.

With the advent of electronic media, blended learning has been found to be effective (Kintu et al, 2017). Bazelais and Doleck (2018) asserted that a blended mode of teaching leads to more conceptual change, acquisition of more skills, and higher performance. Numerous studies have been conducted to develop effective online learning resources and investigate students' experiences and learning outcomes with the developed material (Hill et al, 2015; Pape-Lindstrom et al, 2018; Gamage et al, 2019; Scagnoli et al, 2019).

Hill et al (2015) developed, implemented and evaluated research-based online learning resources for 400 first year physics students at The University of Sydney. This study indicated that carefully designed online resources used for pre-instruction can make a difference in students' conceptual understanding and representational fluency in physics, as well as make them more aware of their learning processes.

Scagnoli et al (2019) investigated college students' experiences with online video lectures (VL) regarding their usefulness, satisfaction and perception of learning. Findings showed that students' satisfaction with VL has a strong relationship with positive overall learning experience. In addition, careful planning and balanced integration of VL with other course materials enhanced students' feelings of engagement with the content. Gamage et al (2019) ascertained the effectiveness of online quizzes to assess and improve students' learning in a civil engineering course at an Australian university. Their study involving 169 students showed that the multimodal quizzes containing questions with embedded text, images, audio and video were effective in teaching and assessing students' knowledge levels.

Kintu et al (2017) investigated the significance of the relationship between students' characteristics and backgrounds, alongside design features as predictors for their learning outcomes in blended learning. Though students' emotions are an important, possibly crucial, component for their learning and motivation, a specific study on students' discrete emotions defined as per Pekrun (2006) while studying in different modes has not been undertaken for physics.

2.5.1 Online mode of teaching in 2020: Impact of COVID

The year 2020 has been exceptional, as the effects of the COVID-19 pandemic go beyond the physical illness it causes. Its emotional, behavioural and psychological impact has resulted in a rise of mental stress (Pedrosa et al, 2020). Studies have explored the impact of COVID-19 on mental health of university students (Kecojevic et al, 2020; Khan et al, 2020). Li and Lalani (2020) presents the impact of the pandemic on the economic front. Across the world many resources have been utilized for rapid transition to online teaching. Due to COVID-19, there has been a significant surge in the usage of online learning tools like language apps, virtual tutoring, video conferencing tools, or online learning software. Online education is a big market and is projected to reach $350 Billion by 2025.

A number of studies have explored students' experiences during the COVID-19 pandemic as teaching and learning transitioned to an entirely online mode (Agarwal and Kaushik, 2020; Shetty et al, 2020). Shetty et al (2020) conducted an observational study on 170 third year Bachelor of Medicine and a Bachelor of Surgery (M.B.B.S.) undergraduate students at an Indian institute. The study found that students favoured online over face-to-face learning to sustain their academic interest and development but felt a lack of face-to-face interactions which in turn affected their learning.

Although COVID-19 pandemic scenario isn't readily translatable, it provides a natural setting to study students' emotions and the factors affecting them. My study sheds light on students' emotional engagement during the COVID-19 pandemic when teaching was rapidly moved entirely online.

2.6 Theoretical basis of the intervention: Colorful historical stories

My research focuses on enhancing emotional engagement through enhancing physics learning materials as these materials generally lack contexts (Stinner, 1995) and overwhelm students with a highly rational portrayal of science (Martin and Brouwer, 1991). My work attends to the development of a strategy to be used as part of an initial presentation of content with the specific intention of engaging students and capturing their interest. I have developed ‘colorful historical stories’ that are grounded in literature. The word ‘colorful’ here refers not only to the optical spectrum but also to the light-hearted nature of the historical anecdotes, which include novel and surprising elements (Goethe, 1810; Stinner, 1995). The word ‘historical’ refers to a time span capturing the human pursuit of science (Matthews, 1994). In my study, the depth of the history is limited following scholars such as Arons (1989), who recommended infusing history in introductory physics courses without seriously affecting the amount of physics covered. The word ‘stories’ refers to science stories crafted with some creative license (Stinner, 1995).

The stories relate to human aspiration, thoughts, and processes behind particular discoveries which result in the advancement of scientific knowledge. Höttecke (2012), and Monk and Osborne (1997) have shown that such science stories can lead to the development of scientific thinking skills. Stinner (1995) also mentions that appropriately designed stories appeal to students, motivating them to learn science. In addition to science stories, color has been associated with emotion. Notably the artist and poet Goethe (1810) argued that color does not simply encompass the wavelength of light representing a scientific measurement, but is also a subjective experience linked with various emotions. This arguement was further developed by Goldstein (1942) as well as by (Elliot, 2015) leading to the framing of the idea that physiological reactions are produced by colors. While the use of colors (Goethe, 1810) and historical anecdotes (Stinner, 1995) separately have been shown to enhance students’ emotional engagement, the combination is still under-researched. I integrate these elements to create my ‘colorful historical stories’. The next few paragraphs elaborate on what the literature says about color, history, and stories pertinent to my thesis.

2.6.1 Color

‘Color’ has been associated with feelings, mood, or ambiance with the capacity to generate emotional engagement (Goethe, 1810). Goethe’s early works in 1810 attributed ‘plus’ and ‘minus’ to colors. The colors on the plus side span yellow, orange to cinnabar, while the colors on the minus side span blue to purple. Goethe (1810) places green in between plus and

Plus.	*Minus.*
Yellow.	Blue.
Action.	Negation.
Light.	Shadow.
Brightness.	Darkness.
Force.	Weakness.
Warmth.	Coldness.
Proximity.	Distance.
Repulsion.	Attraction.
Affinity with acids.	Affinity with alkalis.

FIGURE 2.4. Plus and minus colors generating different emotions/moods as presented in Goethe (1810)

minus. He notes that the brightness of the color also plays a role in generating feelings. The colors on the plus side are associated with quickness, liveliness, and aspirations, while those on the minus side are associated with restlessness, vulnerability, and anxiety. Figure 2.4 illustrates the feelings, mood, or ambiance that Goethe associated with the plus and minus sides. Hence, it is safe to say that Goethe (1810) linked color perception to emotional experience. Gremillion (2020) has categorized colors in six groups according to the feelings that they generate: warm, cool, happy, sad, energizing, and calming. Stone and English (1998) have found further evidence of a link between color and mood. Their study involved a sample of 112 students; the students performed either a high or low demand task in a red or blue workspace. It was found that perceived task demands were marginally related to workplace colors and that shorter wavelengths facilitate performance on complex tasks, whereas longer wavelengths facilitate performance on simple tasks. Elliot (2015) and other researchers (Nakshian, 1964; Crowley, 1993) have supported that conclusion, further affirming that colors are related to emotional experience, focus, and behaviour.

The research supporting colorful material compared to black and white material suggests that although color is helpful, it should be limited and allow for a clear discernment of objects with minimum background details (Muller and Sharma, 2005). Goethe (1810) has eluded on tones and colors that generate strong negative feelings when discussing brightness. Historically, color has been found to play a role in learning. However, my extensive review of the literature about color reveals that despite the switch from black and white printed materials to the ubiquity of color in both print and online material in the last thirty years, the role that color plays in science learning through emotional engagement is under-researched.

2.6.2 History

When one thinks about including history in physics education, a range of scenarios emerges. The history could consist of brief interludes with some relevance to the physics being learnt, the history can be meaningfully integrated into the physics curriculum itself or it could be used in a way that distracts from the physics being taught. Allchin (1992) points out that ‘we cannot merely import historical material without attending to its new functional context”. His argument is that the historical material needs to be relevant and should aid or complement the content being taught, i.e. it should be meaningfully integrated. The ideas of striving for a functional use of history in an educational context is supported by researchers such as Clough (2010) and James (1907).

Matthews (1994) has commented in favour of presenting examples from the history of science that provide an authentic picture of how science has been done. Milne (1998) has identified four distinct categories of science stories presented in science textbooks, namely:

- heroic story
- discovery story
- declarative story
- politically correct story

Here, I provide examples for the different types of stories from Milne (1998), Gujarat Board textbook Gajjar et al (2012), and the National Council of Educational Research and Training Physics Textbook (Uppal, 2006b).

In heroic science stories, the focus is on a solo hero who plays a key role in the growth of science, for example, the manner in which Newton is presented in mechanics and Einstein in quantum in most physics text books. Figure 2.5A - 2.5B shows examples of Joule's heroic contribution to heat and thermodynamics, and Galileo's heroic contributions to mechanics as presented in Milne (1998).

In discovery science stories, scientific knowledge is represented as being constructed accidentally, e.g. the discovery of penicillin by Alexander Fleming. Figure 2.5C shows an example of Archimedes' accidental discovery of a way to measure the volume of an irregular solid leading to the law of buoyancy as presented in the National Council of Educational Research and Training (NCERT) Physics Textbook (Uppal, 2006a).

In declarative science stories, processes or scientific concepts become objects and are represented as open to observation in nature by anyone, for example, Thomas Young experimentally confirming the intuitive ideas of Huygens regarding the wave nature of light. This example is presented in Figure 2.5D.

Politically correct science stories include 'fair representation of the different cultures, genders, religions, and countries in the development of science' (Milne, 1998) and look into the interaction between science and society. Figure 2.5E shows an example of models of light by scientists from different countries, Newton's recognition over Descartes for the corpuscular model of light and non-acceptance of Huygen's wave model of light.

Nielsen and Thomsen (1990) articulate four purposes for the inclusion of history:

- To present physics as a human activity
- To observe the cultural connection
- For positive change of students' attitudes

James Joule (1818-1889) was an unusual scientist because he was only an amateur. Science was his hobby. James was the son of a brewer, and could therefore afford to focus on his strong interest in heat. He had a reputation of being a fanatic as far as measurements were concerned. He even spent his honeymoon measuring the difference in temperature between the water at the top of the waterfall and the water at the bottom! At first his results were not taken seriously, but after Lord Kelvin supported him, he became famous and the unit of energy was named after him.

(Lofts, Living with science and technology, Book 1, 1991, p.93)

(A) Heroic science story (1) from Milne (1998)

At that time [17th century], scientists began to realise that all physical events follow understandable laws. One of the first scientists to understand this was Galileo Galilei (1564-1642). While still attending the university, he challenged so called knowledge that was based on little, if any, observation or experimentation. He questioned the belief that the earth is the centre of the universe. . . . Galileo was dismissed from the university before he could complete his studies. However, he did not change his ideas. He knew that he could answer his critics only by showing them proof that could not be denied. To do this, he developed a systematic method of observation and analysis. . . . Galileo also found that all motion follows a simple set of laws. . . . He observed the heavens with a telescope. He confirmed the theory of Copernicus that the earth travels around the sun while spinning on its axis. This discovery did not agree with the religious belief of that day. As a result, Galileo was brought before the Inquisition. He was kept a prisoner for the rest of his life.

(Murphy & Smoot, 1982, p. 19-20)

(B) Heroic science story (2) from Milne (1998)

Archimedes (287-212 B.C.)

Archimedes was a Greek philosopher, mathematician, scientist and engineer. He invented the catapult and devised a system of pulleys and levers to handle heavy loads. The king of his native city Syracuse, Hiero II, asked him to determine if his gold crown was alloyed with some cheaper metal, such as silver without damaging the crown. The partial loss of weight he experienced while lying in his bathtub suggested a solution to him. According to legend, he ran naked through the streets of Syracuse, exclaiming "Eureka, eureka!", which means "I have found it, I have found it!"

(C) Discovery science story from the National Council of Educational Research and Training (NCERT) Physics Textbook (Uppal, 2006a)

4.1 Introduction

We have noted in the previous semester in the chapter 'Ray Optics' that various theories have been put forward to understand the nature of light. Ray optics or geometric optics has limitations in explaining certain optical phenomena such as interference, diffraction, polarization, transmission, holography, etc. In 1678, Huygen proposed a wave theory of light. According to this theory, light energy is supposed to be transferred from one point to another in the form of waves. He, based on his wave theory, could explain the laws of reflection and refraction. Later, in 1801, Thomas Young could explain the phenomenon of interference of light. Augustin Fresnel in 1815 had developed the wave theory to explain rectilinear propagation of light. The polarization phenomenon, as discovered by Malus in 1808, remained an unsolved problem to Huygen's wave theory. Huygen's wave theory assumes light waves as longitudinal, while the polarization effect can be observed only for transverse waves. As longitudinal waves always require elastic medium for propagation, Young and Fresnel assumed presence of luminiferous ether in entire universe.

Later Young realized that light is transverse waves, though he was still believing in the presence of omnipresent ether. It was Faraday who showed that the polarization of light was affected by a strong magnetic field. This was the first hint about electromagnetic nature of light. Clerk Maxwell unified the empirical laws of electricity and magnetism into a coherent theory of electromagnetism. As studied in the previous chapter, Maxwell made the prediction that light is a high frequency electromagnetic waves. Theoretical prediction of Maxwell was confirmed by Hertz by producing and detecting electromagnetic waves. In 1887, Michelson-Morely performed the famous ether-drift experiment, and concluded that ether does not exist. Hence, light waves are high frequency non-mechanical transverse electromagnetic waves, comprising of oscillating electric and magnetic field vectors.

(D) Declarative science story from the Gujarat Board Physics Textbook (Gajjar et al, 2012, Gajjar et al, 2012)

10.1 INTRODUCTION

In 1637 Descartes gave the corpuscular model of light and derived Snell's law. It explained the laws of reflection and refraction of light at an interface. The corpuscular model predicted that if the ray of light (on refraction) bends towards the normal then the speed of light would be greater in the second medium. This corpuscular model of light was further developed by Isaac Newton in his famous book entitled *OPTICKS* and because of the tremendous popularity of this book, the corpuscular model is very often attributed to Newton.

In 1678, the Dutch physicist Christiaan Huygens put forward the wave theory of light – it is this wave model of light that we will discuss in this chapter. As we will see, the wave model could satisfactorily explain the phenomena of reflection and refraction; however, it predicted that on refraction if the wave bends towards the normal then the speed of light would be less in the second medium. This is in contradiction to the prediction made by using the corpuscular model of light. It was much later confirmed by experiments where it was shown that the speed of light in water is less than the speed in air confirming the prediction of the wave model; Foucault carried out this experiment in 1850.

The wave theory was not readily accepted primarily because of Newton's authority and also because light could travel through vacuum

(E) Politically correct science story from the National Council of Educational Research and Training Physics Textbook (Uppal, 2006b)

FIGURE 2.5. Example of types of stories as classified by Milne (1998)

- For better understanding of the fundamental concepts.

Höttecke et al (2010) have reported that students find the inclusion of understanding the processes of doing science through historical stories very attractive.

Matthews (1994) presents the following four arguments in support of the role of historical stories or anecdotes in science education. Phrases in bold will be used when the stories are described later in Chapter 3.:

- Helping students **see connections between 'isolated facts',**
- Acting as a '**vehicle for conceptual change**' utilizing the parallels between the development of an understanding of subject matter by students and historical development of the subject matter,
- Developing students' **critical thinking skills** and so stimulating their imagination,
- Emphasizing **science as a human pursuit** (Martin and Brouwer, 1991).

An overarching aspect is that the inclusion of history humanizes science for the students, while helping them with conceptual understanding and other skills. In my inclusion of history, I display science as being built by a community of scientists with converging and often contradictory ideas that advance disciplinary knowledge, where failure often adds to positive outcomes. This will be apparent when the stories are presented in Chapter 3.

2.6.3 Stories

Researchers have time and again shown the benefits of using a story line to draw students to science (Arons, 1988; Strube, 1989; Stinner, 1995). Corni (2014) asserts that stories and physics are not dissociated.

Stinner (1995) upholds the argument that 'science stories' motivate learning by making the science curriculum more human, more socially relevant and exciting by presenting discoveries and their applications.

Stinner (1995) presents a set of guidelines to create stories as listed below. Phrases in bold will be used when the stories are described later in Chapter 3.

(1) **Mapping out a context based on a unifying idea** to capture students' imaginations.
(2) **Providing experiences related to the everyday world that are scientifically explainable** at a level likely to make sense to students.
(3) **Inventing a dramatic "storyline"** highlighting the main idea.

Stinner (1995) presents Egan's argument that the story approach is important for "constructivist nature of human sense making" and students' induction into "full membership of their culture" (Egan, 1986; Egan, 1988). Approaches can include important events associated with a person, conflicts with other characters and scientific debates.

(4) Ensuring that selected **ideas, concepts, or problems emerge naturally from the storyline.**
(5) Progressing the storyline from **romance to precision to generalization** as described by Whitehead (1929). This is best accomplished by using contexts that are intrinsically interesting, connecting diverse concepts in various settings including present-day science and technology, and providing room for individual extensions.

It is worth taking a deeper look at the way that Stinner drew heavily on a model of educational progress proposed by the philosopher Whitehead (1929). Whitehead (1929) expressed the need to look at the "rhythm of mental growth" which goes through repeated cycles with subtle and clear stages which he called: "romance, precision, generalisation". It takes a learner on a journey from "ferment, acquirement of precision, to fruition". He postulated that giving due consideration to the rhythm can support effective "intellectual progress" amongst learners.

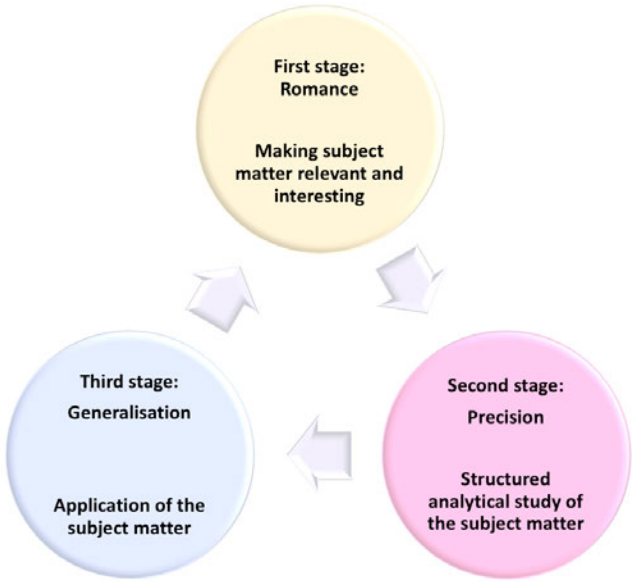


FIGURE 2.6. Iterative cycles of intellectual progress as described by Whitehead (1929)

Whitehead envisioned education as a process building on what already exists in the learners' mind, stating that "you cannot educate a mind in *vaccou*". He refers to the first stage of the process as **romance**; here the first connections are made and an impression left. This stage represents the emotion related to the realization that unconnected observations can lead to interrelated concepts. It introduces the concepts with the possibilities of applications making the subject matter relevant and interesting. The **romance** stage involves emotional engagement which can lead to further systematic procedures for understanding the knowledge.

Precision, the next stage, takes the unconnected observations and unpacks them, systematically examining and relating concepts and providing structures in order to improve accuracy and comprehension of the knowledge. Without a context of **romance**, learners can still learn subject matter, but as a mere list of statements, often perceived as unconnected and disjointed - one might say 'irrelevant'. **Precision** provides a closure to **romance** with systematic analyses and synthesis of the introduced subject matter.

Generalisation, the final stage, involves applying the newly-gained subject matter knowledge to relevant problems. This stage is a transition from the systematic structures of **precision** back to a more unstructured zone, one of exploration, making new connections and drawing on intuitions. This stage along with **romance** provides the freedom and possibilities of generating new knowledge, creativity. Thus, one can achieve one of the goals of education, use of ‘precise training’, to generate new knowledge.

While Whitehead associated **romance** with primary education, **precision** with predominantly secondary education and **generalisation** with university, he made the case for repetitive cycles of all three in each topic and educational activity. Subtle incorporation of the "rhythm of mental growth" through repeated cycles can satisfy students’ "rhythmic cravings". Hence, selected lectures and laboratories could involve all three learning stages, by taking learners on a journey from "ferment, acquirement of precision, to fruition", and supporting "intellectual progress" amongst learners.

In my inclusion of stories, I have incorporated iterative cycles of romance, precision, and generalisation stages of "intellectual progress" in the sub-stories for each practical. This will be elaborated in Chapter 3.

2.6.4 Implementing the ‘stories’

Although the inclusion of such stories develops a positive attitude and conceptual understanding (Nielsen and Thomsen, 1990; Stinner, 1995), Höttecke and Silva (2011) noted that the deficiency of such contexts in formal physics education is because of four major hurdles:

- A culture of teaching physics that is different from other subjects and is more content-driven,
- A requirement for different skills amongst curriculum designers to add context, not aligning with traditional epistemological beliefs,
- A hesitancy within the curriculum design to include such contexts,
- A lack of adequate contexts appropriate to the level of physics.

Overcoming such hurdles to include stories is not trivial and can be time consuming. In my research I have attempted to address these hurdles. This has been attempted multiple times by different groups. Projects such as *Science in social context (SISCON)* (1983), and one by Solomon (1991) have failed. A few including those reported by Klopfer (1969) and Nielsen and Thomsen (1990) have marginally succeeded. Even fewer projects have succeeded; in particular, the Project Physics Course (Rutherford et al, 1970) and History and Philosophy in Science Teaching, HIPST, 2008-2010 have tasted success (Höttecke, 2012).

Project Physics Course was a project initiated by the National Science Foundation with the aim of providing a course in physics that engaged students and inclined them towards science. It was a humanistic and historically oriented school course that regarded physics as a 'coherent story of the result of the thoughts and work of living beings' (Holton, 2003). Under this project a six unit physics book consisting of the history of science along with illustrations, and the applications of the content was developed. For each unit a book of readings was provided, content included history, applications, and poems referring to the science content. Interconnections were established between physics and different sciences, history, cultural context and applications. Additionally, films, instructional booklets, teachers' handbooks and teacher training courses were provided (Holton, 2003). In an extensive evaluation of Project Physics, Welch (1973) stated that "Perhaps the more important implication is that the attitudinal goals of the course were achieved without a resulting loss in physics achievement. … the goals of the Project Physics authors were to reduce the difficulty stigma attached to physics, reduce the mathematical orientation, and to show physics as an intellectual endeavor rather than as applied technology."

History and Philosophy in Science Teaching (HIPST) was a large scale project, with 10 partners from 8 European countries, focusing on effective strategies for development and implementation of contexts and stories (Höttecke, 2012). The HIPST model shifts the focus of learning from knowledge acquisition to understanding the processes of doing science while insisting that science should be portrayed as a human and social endeavor in a historical context. HIPST regards science 'in the making', not as a linear process, characterized by a false dichotomy of success or failure, but as an endeavor characterized by detours and mistakes balanced by creative solutions and a self-correcting nature. Such a broad scope on science is realized within a narrative approach focusing on a storyline along one central idea as suggested by Stinner (1995). It focuses on a multiplicity of perspectives: the researchers' (science, history and philosophy), the teachers' (content to be covered, manageable instructional models) and the students' (interests, prior beliefs and ideas). The results revealed that students were attracted to such a perspective at university as well as school level.

HIPST takes four central points into account during the development process: gathering options and restrictions; exploration, immersion, and storyline; discussion and didactical structuring; teachers' professional development. In Chapter 3 I shall discuss how I used these points in my creation of the stories. In particular Seroglou et al (2011) report that, "… when science is taught or presented in the context of HIPST, …, then an overall picture of science is provided to pupils, students and/or teachers and truly appreciated by them. This overall picture of science includes the nature of science content and contexts, the synthetic and evolutionary character of science, the nature of the methodologies of science, the nature of the interrelations between science and society, the nature of values and attitudes fostered by science."

Figure 2.7 describes the HIPST model of educational reconstruction which involves three interrelated processes as well as my adaptation of the model. The first process is designing the instructional model. The HIPST model used creative writing, role-play, and experimenting with replicas of historical scientific instruments, while I created colorful, historical stories. The second process involves investigating students' perspectives on the subject matter being taught. The HIPST model considered students' interests, prior ideas and beliefs, while I connected stories with what students were learning and what could interest them. The third process involves classification and analysis of science content. The HIPST model used 'nature of science' aspects and history of science, while I used scientific discoveries, events associated with people, conflicts and debates for the stories.

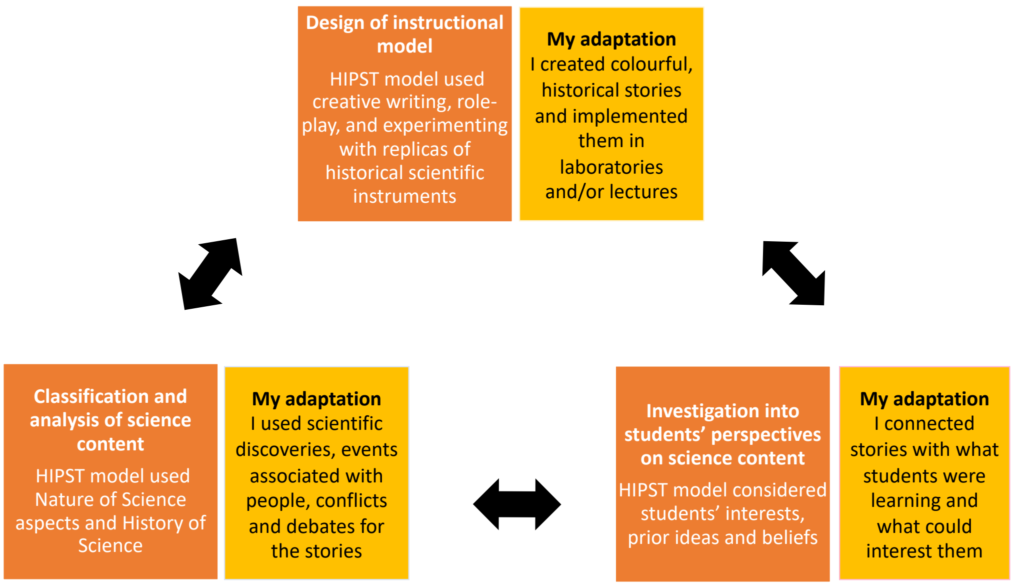


FIGURE 2.7. My adaptation of the HIPST model of educational reconstruction as defined by Höttecke (2012)

2.7 Summary

Students often have strong feelings about physics, while some students like or love it, others dislike or detest it. Despite the benefits of students experiencing positive emotional engagement, students' emotional engagement in physics is under researched. My study fills a gap in investigating emotional engagement for students' who are inclined to physics and those who are not.

My research identifies the Achievement Emotion Questionnaire (AEQ) as a suitable tool to measure students' emotions in physics. It is based on control-value theory (Pekrun, 2006), as described in section 2.4. My study adapts and validates the survey in physics context. The survey helps assess students' emotional engagement in different teaching and learning environments while comparing their respective emotion profiles. A strategy that I suggest to enhance students' emotional engagement is to provide a context to students' learning using 'colorful historical stories', which involves creatively combining colors, history and stories. The earlier literature on the use of color, history and stories to enhance students' engagement and process adapted for the development of 'colorful historical stories' are described in section 2.6. Using AEQ, my research shows how the newly developed strategy is able to engage students emotionally, generates interest and helps their learning.

In addition, I compared students' emotions for different cohorts. During 2020, COVID-19 pandemic happened and I stepped into exploring students' emotional experiences and the effect of sudden transition of teaching and learning to online mode, section 2.5 presents the earlier findings on students' experiences in face-to-face, online and blended mode of teaching.

Combining all that I mentioned above, this is a timely and novel study focusing on measuring, understanding and enhancing students' emotional engagement with the potential to broaden participation in physics.

CHAPTER 3

Colorful historical stories

3.1 Introduction

In this Chapter, I discuss the process I followed to develop the ‘colorful historical stories’. I also present the ‘colorful historical stories’ I crafted for my study. In the first section I describe the theoretical underpinning of the process. In the next two sections, I provide details of the stories incorporated into laboratory exercises and those incorporated into a lecture series.

3.2 Who are the stories for?

My study is conducted at two of Australia’s leading research intensive universities, The University of Sydney and the University of New South Wales. Both the universities are consistently amongst the highest ranked universities in Australia and globally (Lane, 2021; Sydney, 2021a; Sydney, 2021b), entrance to which is competitive. The stories are crafted for first-year undergraduate students, mostly directly coming from high schools in Australia and other parts of the world. The students I sampled, are enrolled in engineering, physics majors or other degrees. Around 250 to 800 students are enrolled in these courses.

3.3 The process for developing the stories

My process for developing the stories followed the History and Philosophy in Science Teaching (HIPST) model (Höttecke et al, 2010) presented briefly in Chapter 2 and in more detail below. In the process of preparing the stories, obstacles identified by Höttecke were considered and addressed. These are articulated in my description below.

- **Gathering options and restrictions**: Based on the general topic being taught but restricted by the concepts, I scoped a broad idea and gathered possible options from colleagues in physics education research. Firstly, I placed the topics of the laboratories/lectures as boundaries, within which I jotted down all the possible options: most attractive characters, facts, quotes and history. These were discussed in my research group meetings, some were found to be more appropriate than others, and some more options were revealed through discussions. While scoping the broad ideas, I addressed the obstacle identified by Höttecke (2010) relating to a hesitancy within the curriculum design team to include stories such as those developed in my research. In my case, generally the need for a story wasn't recognized by the group and there was a level of skepticism towards the inclusion of the stories. My supervisor worked closely with the teaching team, clearly communicating the benefits and made the case for a trial with one new experiment. With positive student and tutor feedback, eventually over the two years, stories were inserted into all the newly developed laboratory notes for the practicals.
- **Exploration, immersion, and story line**: With a few selected story lines and the broad idea, I immersed myself in detailed research to find authentic history in the research literature as well as famous stories from the public domain. Web and literature searches were conducted, seeking rich contextual anecdotes intentionally pursuing emergent stories and their trails. Once ideas from the searches were identified, they were specifically investigated and verified through science communications, outreach and creative writing sources. Three to four stories, with one picture and three dot points for each, were selected and linked together creating a story line with interrelated important milestones. This was repeated, producing a story for each practical. For the lectures, relatively short stories were prepared, with one picture and a tagline placed on a single slide. These were presented for about a minute as a break within the lecture.

While exploring and selecting story lines, I addressed the obstacle identified by Höttecke relating to a lack of adequate contexts appropriate to the level of physics. Though there have been a few instances of use of contexts in the materials for undergraduate physics, I had to methodically and systematically develop and craft the 'colorful historical stories' as such contexts have not been created before.

- **Discussion and didactical structuring**: Once the first drafts of the stories were created, they went through iterative rounds; gathering feedback, and prompting me to make changes and refine them. The first round was with my research team. The printed copies of the laboratory notes were discussed as I elaborated the rationale behind the stories. The team assessed whether the stories were coming across as intended, whether the quotations selected were appropriate, and most importantly, whether the stories were serving the purpose of student engagement in a consistent manner for the credibility of the research. For the stories in the practicals, in the second round of development, together with gathering feedback from the research team, the laboratory supervisor and his team were briefed and their input sought. In these discussion sessions I addressed the obstacle identified by Höttecke relating to a requirement for developing different skills amongst curriculum designers to add context. Though the curriculum designers have adequate skills to design physics content; most of the time, being from a physics background, they need support to understand the need for stories and to develop contexts such as stories. For the stories in the lectures, my co-supervisor was the lecturer, so her outlook on the stories was used in the second round and as the final filter.
- **Teacher's professional development**: For the practicals, a workshop was conducted for the tutors, in which they were briefed about the background and foundations of the research and purpose of the stories. The stories were discussed together with the practicals. Tutors were requested to introduce the practicals in their natural way, incorporating a mention of the story and my research according to human ethics protocols. In these professional development sessions, I addressed the obstacle identified by Höttecke (2010) relating to the culture of teaching physics that is more content-driven. The laboratory supervisor and tutors had reservations about

stories being inserted in the laboratory notes. They doubted if stories were appropriate to engage students with a subject like physics, and whether stories would help students learn. They also raised concerns regarding stories taking up students' time, hampering the physics content coverage. We spent time collectively brainstorming, discussing these concerns with the tutors and supervisors. Finally, we converged, agreeing to 'give the stories a go'. For the lectures, the lecturer, knowing the purpose of the research, made sure to pause on the story slide for a minute or two in the lectures. The lecturer just mentioned that the students could have a read, at times talking them through the stories.

3.3.1 Creating and crafting the stories

In section 2.6, I have presented the underlying literature for the 'colorful historical stories'. Some of the phrases from the literature were presented in bold fonts, I am going to refer to the literature here while presenting the phrases in bold fonts again. In creating my stories, I have used Matthew's (1994) concept of **representing science as a human pursuit** in the form of a time travel, by which I mean presenting relevant anecdotes from different points in history, in various formats. The development process for the stories follows Stinner's (1995) and Whitehead's (1929) guidelines whereas its refining and incorporation into curriculum material drew upon on the HIPST project (Höttecke, 2012).

While crafting the content for the stories, I aimed to use the most effective amount of history and color. Each story is presented with colorful pictures to evoke positive emotions (Gremillion, 2020). I have not changed what the students do/study in the laboratory/lecture. I have tried to showcase the representation and contribution of both men and women, while ensuring that the story flows naturally through different scientists. I was not able to develop a suitable story with 'balanced' representation of men and women in topics such as mechanics, whereas in topics such as waves I was able to showcase more 'gender-balanced' representations. It needs to be emphasized that the main purpose of creating these stories was to create a hook to engage students in a limited amount of time, providing them with something that might stay with them. With this purpose in mind famous philosophers, scientists, and their quotes were utilized. The stories were unique in utilizing conflicting and contrasting characters who influenced the applications of the research along with characters who constructively contributed to the scientific discoveries.

In the following sections, I provide an in-depth explanation of the rationale for inclusion of specific features of the stories , such as addressing a misconception or showing how a concept was developed over time. I also provide the theoretical backgrounds of the stories. Each subsection contains a description of how the stories were created and presented for each topic in the laboratories and lectures.

3.4 Stories for physics practicals

Before I present how I created the stories for physics practicals, I will outline how they were used. The stories were designed to be placed on the first page of the laboratory notes for each practical. Printed versions of the laboratory notes were placed on the table for each group. Many of the students had the stories open on the large Mac computer screens. In short, the stories were on display when one entered the laboratory. A glance of the laboratory was quite relaxing and colorful. One of the goals was to transform the laboratory into a welcoming place.

A combination of heroic, discovery, declarative, and politically correct science stories was created (Milne, 1998), while adhering to the guidelines presented by Stinner (1995), Whitehead (1929), and Matthews (1994). Here follows the explanation of how I created the stories for the various physics laboratories.

3.4.1 Thermal physics

For the pilot study of the project, I created a colorful, historical story for a thermal physics practical on the concept of heat transfer.

I undertook a literature search to find common underlying misconceptions about the topics concerned (Lewis and Linn, 1994; Cotignola et al, 2002; Sozbilir, 2003; Georgiou and

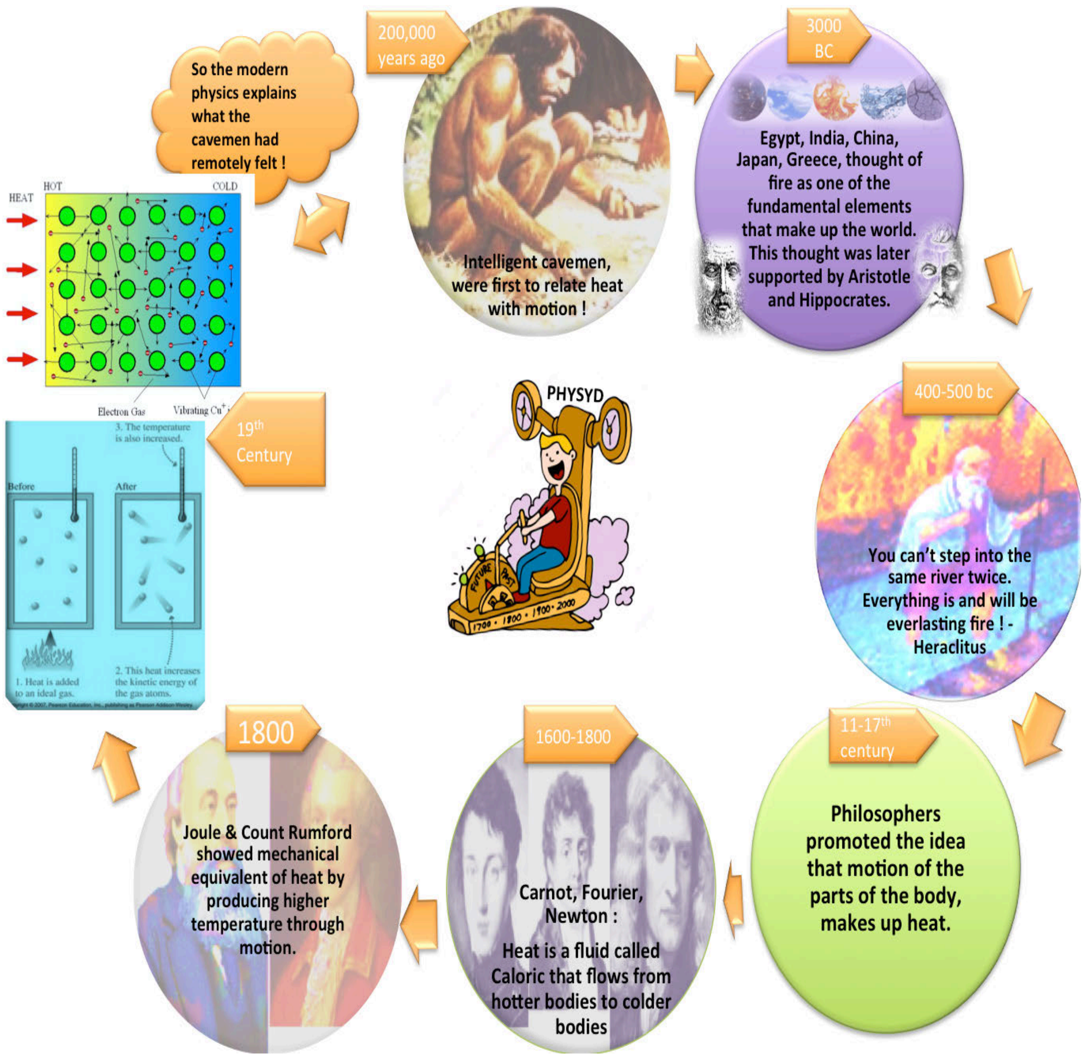


FIGURE 3.1. Thermal physics story: Journey through centuries

Sharma, 2013; Wegener et al, 2015). Specifically, a study by Georgiou and Sharma (2010) showed that many first and second year university students struggle with the concept of heat as energy transfer. Meltzer (2004) reported that university students have trouble distinguishing between the concepts of heat, temperature, internal energy, and thermal conductivity; misinterpreting heat as a mass-independent property of an object; and thinking of temperature and heat as the same concept. Hence, I have incorporated the historical development of the concepts as a time travel to provide a **vehicle for conceptual change**

(Matthews, 1994). Time travel here refers to the historical development of the concepts as presented in the figure 3.1.

I have aimed to **capture students' imagination with a central idea**, a journey in a time machine to discover the concepts of thermal physics through the ages. I have aimed to **present concepts that relate to everyday life alongside concepts explained by scientists**. While leading the students from the age-old (preliminary/primary/naive) to the modern day (sophisticated) concept, I have employed the thoughts, assumptions, and misconceptions of the thinkers, philosophers and scientists, linked in a gradual manner. In the process **a dramatic story has been created highlighting the major idea** of heat being related to motion with interrelated ideas developing from each other or conflicting opinions of the scientists, not extensively worrying about particular facts, i.e., whether cavemen actually discovered fire or not. I made sure that the **practical naturally flows** from the story. I intentionally presented broad ideas, followed by more scientifically refined thinking on these ideas, to the present-day conceptions of heat, leading students from romance to **to precision**.

Throughout the laboratory notes, separated by each activity section, thumbnails from the story along with the taglines were presented. This was visually appealing and made it easy for students to reflect back on the story, to take a stand on the conceptual disagreement, or to find a parallel between their ideas and those of the scientists.

3.4.2 Electricity

I created the next set of the stories for a series of four practicals on electricity; DC circuits, AC circuits, RC filters, and solar cells, for the first-year second-semester laboratory.

The series of four stories form a time machine from Galvani (1750s) to Einstein (1920s) and each story covers a time period within this larger time machine. The overall story line directs students from the early discoveries to the modern-day. The time machine instead of being circular is now a snapshot containing four pictures in each story. The four stories take students on a ride of interwoven historical discoveries and their applications. For this series, selected aspects from Stinner's guidelines were applied in each case. At the end of each

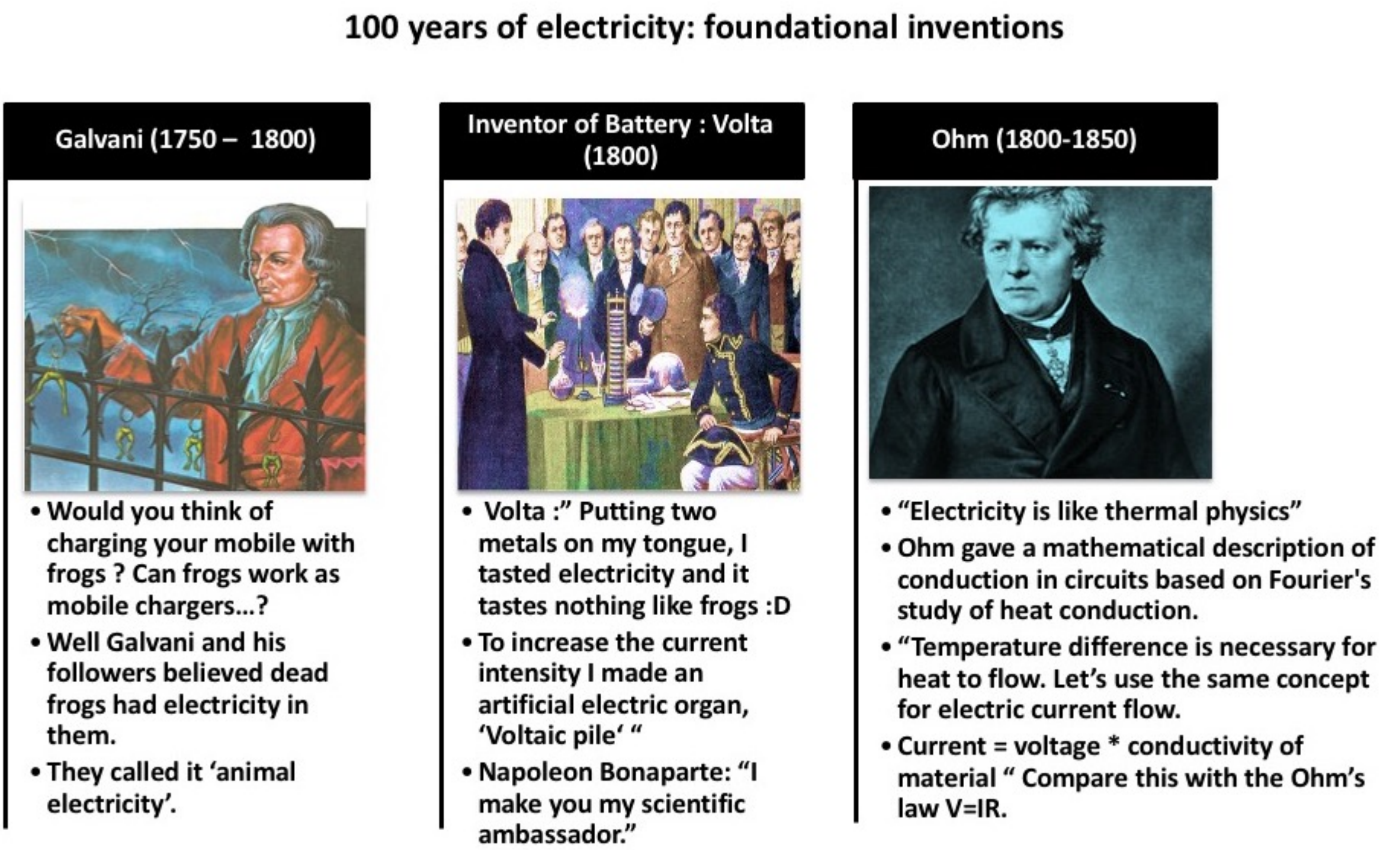


FIGURE 3.2. Electrical story 1: 100 years of electricity: Foundational inventions

practical, reflection questions were inserted linking the story to the interpretation of the experimental results.

The development of the stories for the series of four electricity practicals along with their experimental aims and the reflection questions are presented below.

The guidelines suggested by Stinner (1995) and Whitehead (1929) are addressed, presented in Bold font.

Practical 1:

Aim: To measure voltages and currents in DC circuits and analyse and interpret your measurements using resistance.

Story Description: I have aimed to **capture students' imagination with a central idea** of the development of static electricity from the 1750s to 1850s. I **presented concepts that relate to everyday life along with those explained by scientists**. Concepts used by Volta, Galvani and Ohm are rendered in an interconnected and relevant manner. **A dramatic story has been created highlighting the major ideas** showing the conceptual development of electricity, being thought of as a specific animal property, to rejecting that idea, and finally coming to terms with the nature of current flow. Ohm's story provides a context from which **the practical naturally follows**. Using the storyline relating electricity to students' everyday experiences as well as to the practical at hand, I have aimed to lead the students from **to precision to generalisation**.

Reflection Question: 'Do your results support or disprove Ohm's idea that thermal conduction and electrical conduction are similar principles?'

Practical 2:

Aim: To become familiar with the oscilloscope and its role in observing signals and measuring different parameters for the observed signal.

Story Description: I have aimed to **capture students' imagination with a central idea** of the influence of money and power on science. **A dramatic story has been created highlighting the major idea** of the famous war of currents. The photos are selected to highlight alternative opinions for a single phenomenon. **The practical naturally follows** as the story provides a context of the advantages and need for AC as AC currents are introduced. The story presents the progression from Edison, the supporter of DC electricity and a stubborn obstacle for popularisation of AC electricity, along with Westinghouse, the farsighted businessman, and Tesla, the lover of science. Thus, students are taken on a ride from **romance, to precision to generalisation**.

Reflection Question: 'Whom should I acknowledge my ability to construct differentiators and integrators?'

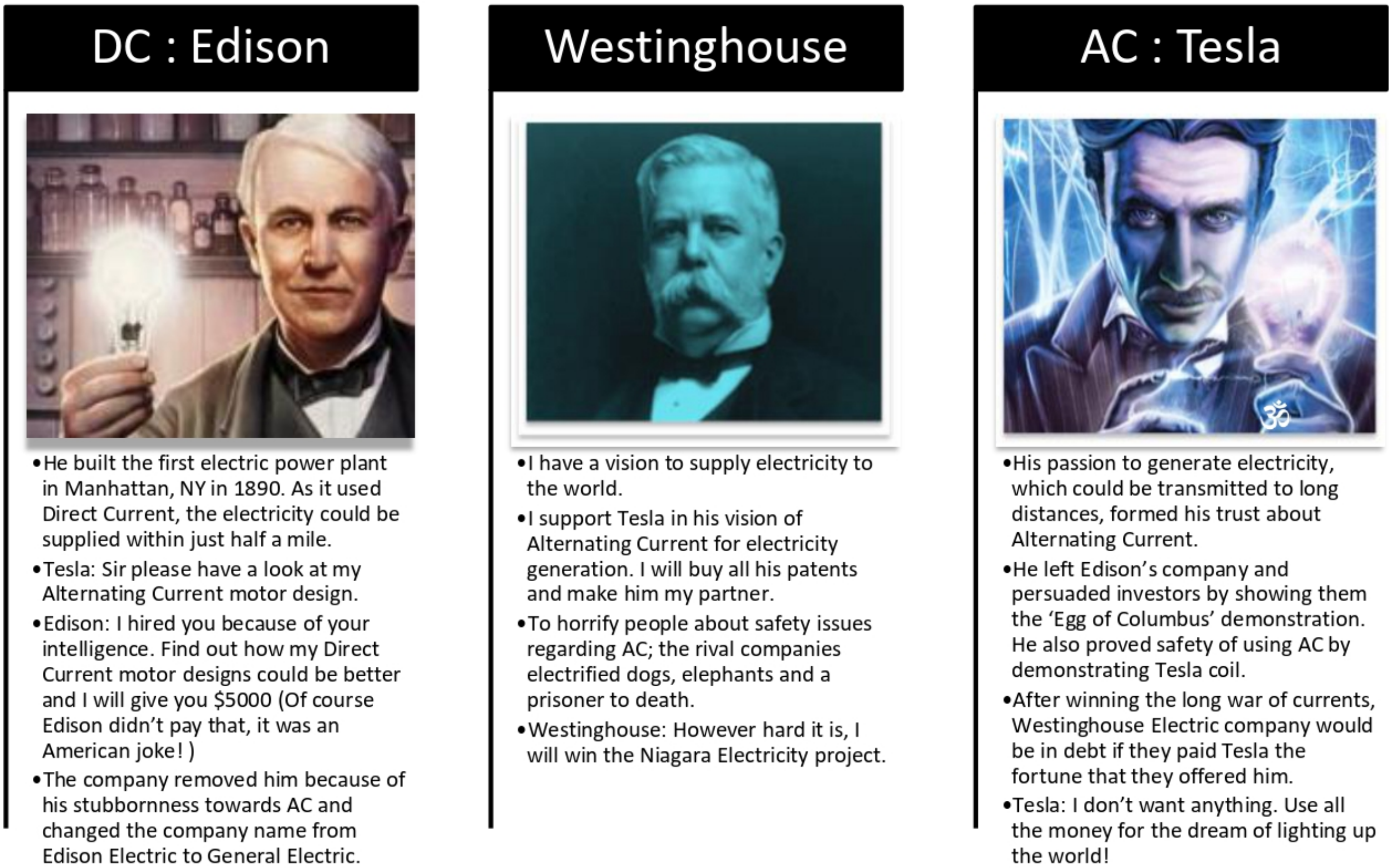


FIGURE 3.3. Electrical story 2: Electricity in business - The ultimate war

Practical 3:

Aim: To become familiar with the construction of circuits and to visualize how filters are used to allow a specific frequency band while attenuating others.

Story Description: I have aimed to **capture students' imagination with a central idea** of the historical development of the use of a particular frequency signal in electricity. **A dramatic story has been created highlighting the major idea** of the use of electricity in medicine from 400 BC to the modern day, i.e., Hippocrates prescribing shock from torpedo fish as a treatment, to modern day electrotherapy for various medical purposes. **The practical naturally follows** as the story provides a context for the application of the practical in the real world. The **romance** stage is represented in the first story where the father of

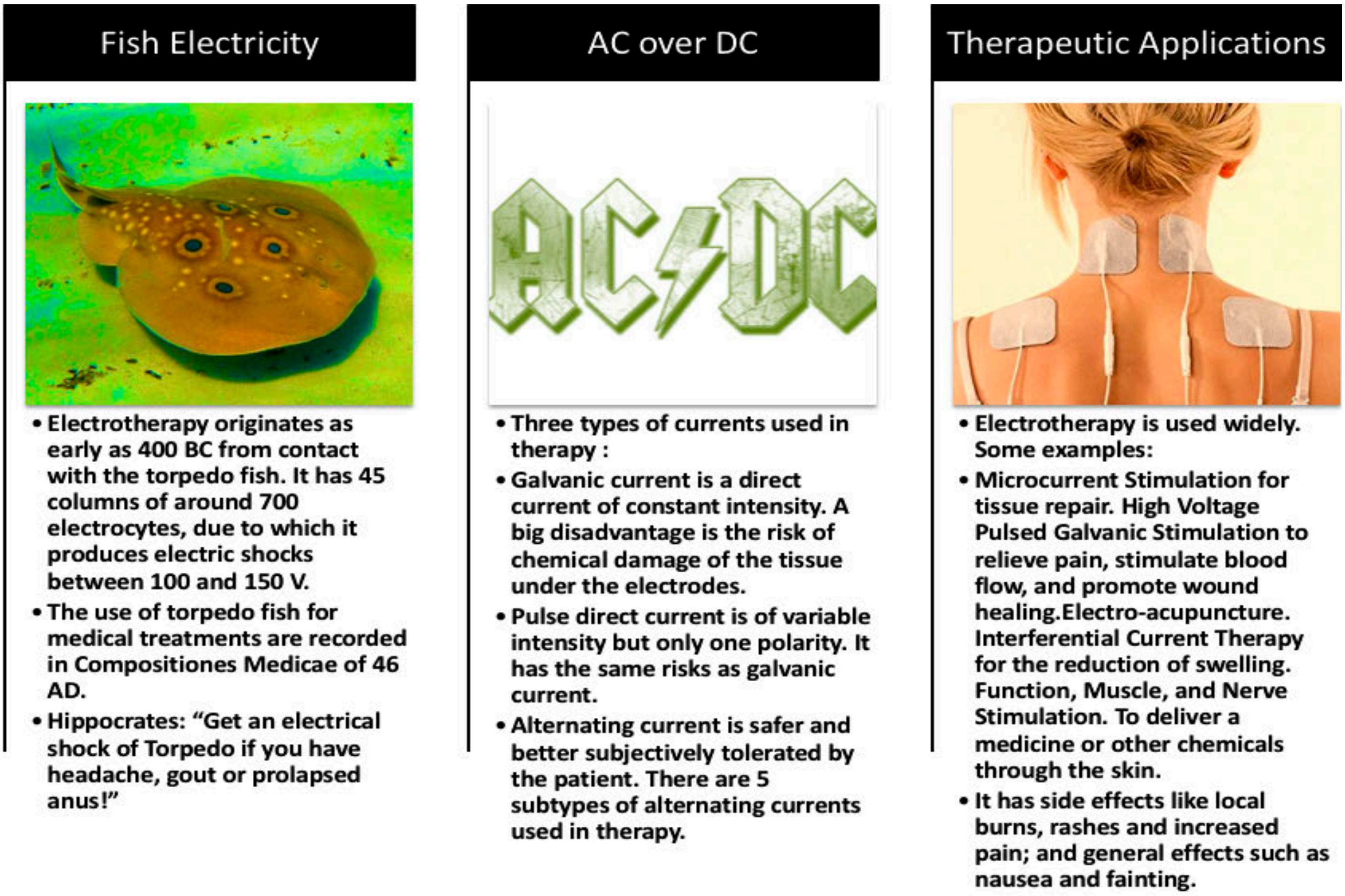


FIGURE 3.4. Electrical story 3: Electricity as medicine

medicine, Hippocrates, prescribes electrical shocks as a medical cure. The **precision** stage is represented by the development of safer use of AC-DC currents in therapy, which range from galvanic and pulse direct to alternating current. The **generalisation** stage is represented in the last story with the applications of the different types of currents for medical purposes.

Reflection Questions: 'In the intro I refer to medical applications, conduct a quick search and indicate how the 'filters' you have investigated would be used in medicine', 'Where else would these filters be used?', 'Where would these LCR resonant circuits be used in medicine and/or any other applications?'

Practical 4:

FIGURE 3.5. Electrical story 4: Solar energy - Milestones

Aim: To investigate solar cells and calculate the optimum load for power output when considering the load, resistance, and irradiance, the amount of light actually reaching the surface of the solar cell.

Story Description: I have aimed to **capture students' imagination with a central idea** of the use of solar power through the ages. **A dramatic story has been created highlighting this major idea** with the hope of conjuring up the notion that solar power should be more widely used today. The stories includes Archimedes' use of the power emanating from the sun to set fire to Roman ships, the invention of the first solar energy collector, and Einstein's explanation of the photoelectric effect that built the theoretical grounds for the instruments that use solar energy. With each story students are led from **to generalisation**.

Reflection Question: ‘Can we interpret our results and consider their importance in applications?’

3.4.3 Mechanics

The topics covered in the mechanics practicals series were terminal velocity, collisions, and projectile motion. Below I present the stories I created for each along with the aim of the practical and the story description. I have identified how Stinner’s guidelines, presented in bold, have been addressed. These topics offered an opportunity for inclusive representation with more documentation about women explorers and about scientists in modern times.

Practical 1:

Aim: To explore the relationships between shapes and sizes of objects and their terminal velocities.

Story Description: The **unifying idea** of free fall is explored through a series of engaging anecdotes. The contributions of people from different walks of life, including a polymath, Leonardo Da Vinci, and a parachuter, Georgia Broadwick. Georgia Broadwick’s thoughts on and execution of free fall are established with scientific explanation by Galileo, Descartes and Newton, **providing experiences from the everyday world as well as scientifically explainable concepts**. A **dramatic story-line** is created for each of the pictures with reference to Leonardo’s ideation of the parachute long before the first model was constructed, to Newton’s first law being discovered by other scientists and to Broadwick becoming the first person to fall free. The **practical then naturally follows** as the students collect data for a falling glider, and analyse it to find the drag force, and that force’s dependence on mass and velocity. Here, the **romance** stage is represented in the first story - Leonardo’s imaginations and ideas, the **precision** stage in the second story - Newton and his predecessors' theories on balancing forces, and the **generalisation** stage in the last story – Broadwick's free fall.

Practical 2:

Aims:

- To explore momentum and energy in collisions between a steel and a ceramic ball.
- To explore impact force, impact duration, and impulse

Story Description: The **unifying idea** of energy is explored within the context of a 250 year journey of physics relating to collisions in the 1700s to the 1950s. Emilie du Chatelet's experiments dropping balls into soft clay alongside Lise Meitner's concerns about the tremendous energy released during mass to energy conversion provide students with experiences related to the **everyday world as well as scientifically explainable concepts**. A **dramatic story-line** is created with interesting and surprising facts about each scientist, such as Emilie du Chatelet's participation in historic debates, the opposition Joule faced from the establishment during his time, and Lise Meitner's refusal to work on the atomic bomb. The **practical naturally follows** from the progression of ideas presented in this historic story. The **romance** stage is represented by the thinker Emilie du Chatelet, the **precision** stage is represented by Joule's discovery of 'heat - as energy in transit' through his experimentation, and the **generalisation** stage is represented by the use of nuclear collisions.

Practical 3:

Aim: To explore the relationships between the initial velocity and the angle of projection, and the range of a projectile.

Story Description: A **context based on a unifying idea** of the history of projectiles is utilized, from Australian hunters in 10,000 BC to NASA in the present day. A **dramatic story-line** is presented with anecdotes such as the contrasting ideas of Aristotle and Galileo in relation to the description of the path of a projectile, and NASA astronauts trusting Katherine Johnson over computers. As the stories are focused on projectile motion, the **practical then naturally follows**. Here again the first story represents the **romance** stage, the second story of theorising of the projectile motion by Galileo represents the **precision** stage, and third story of use of the projectile motion in space research represents the **generalisation** stage.

3.4.4 Waves

The topics for waves series were Ultrasound, Microwave, and Vibrations. I present the discovery of waves, i.e., microwave, ultrasonic, and standing waves discovered by Faraday. In the stories of the journey from discovery to application, three stages of intellectual progress are addressed (Whitehead, 1929).

Practical 1:

Aim: To investigate the interactions between microwaves and materials, including reflection, absorption and transmission.

Story Description: The **unifying idea** of microwaves is presented through a journey of discovery to use, while putting forward the contributions of different scientists, including Eleanor Reed Adair, Hertz, and Percy Spencer. A **dramatic story-line** is created for each of the sub-story relating to each of the scientists, i.e., Hertz's discovery of microwaves; Adair's demonstration of the safety of microwaves resulting in our excessive mobile usage; and the discovery of the widely used microwave-oven. The **practical then naturally follows** as the students investigate the interactions between microwaves and materials. Here, the **romance** stage is represented in the middle story - Hertz' playful discovery, the **precision** stage in the left story - Adair's work on the safety of the waves, and the **generalisation** stage in the last story - Spencer's invention of the microwave-oven.

Practical 2:

Aims: To measure the amplitude and frequency of ultrasound.

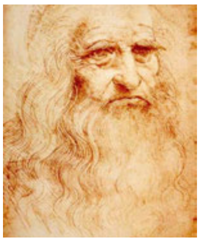
Story Description: The **unifying idea** of ultrasound waves is explored within the context of the experiment. As students are using the piezoelectric effect in the experiment, the discovery and application of piezoelectric effect are presented while relating students' **everyday world as well as scientifically explainable** concepts. A **dramatic story-line** is created with interesting and surprising facts about discovery and application of the ultrasound waves; Marie Curie being the first woman to receive a Nobel Prize, piezo-electricity in our bodies, and ultrasound waves being used in the detection of submarines. The **practical naturally follows** from the story. **Romance** is represented in all three substories with some interesting/engaging facts/history and the **generalisation** is represented in the applications of ultrasound waves.

Practical 3:

Aim: To predict the natural fundamental frequency of a taut wire with tension; keeping length, linear density and the mode number constant.

Story Description: A **context based on a unifying idea** is presented with the discovery and applications of standing waves. As the stories are focused on standing waves, the **practical then naturally follows**. Here again, **romance** is presented by the intriguing statement like Faraday got Einstein his first job and **generalisation** stage is presented with the applications of standing waves in string instruments.

Falling



- Leonardo da Vinci,ca 1485 sketched the first sophisticated parachute, a pyramid attached to the person with 4 ropes, which was successfully tested in 2000s.
- He also worked on the physics of free fall. "The heavy body in free fall acquires a degree of motion with each degree of time, and a degree of speed with each degree of motion."
- He generated the idea that a ball travelling 'twice as far has twice the velocity'.

Physics of air resistance

- Galileo understood that air resistance to a falling object increases with speed. But he did not think as we do in terms of forces.
- René Descartes, formulated the Law of Inertia when Newton was still a newborn! Newton studied his work and drew inspiration.
- Newton's First and Second laws help us formulate balancing forces that result in terminal velocity.

Free-fall

- Georgia Broadwick made 1100 jumps in her lifetime. She was the first woman to parachute from an airplane, and also the first woman to parachute into water.
- On one of her demonstration jumps she cut off the static line and deployed her chute manually, thus becoming the first person to jump free-fall.
- This demonstrated that pilots could escape aircraft by using what was later called a ripcord.

(A) Story for Terminal velocity practical

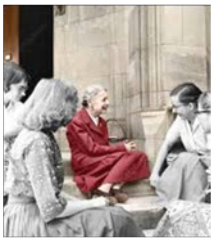
Conservation of Energy

- 1706 to 1749
- Émilie du Châtelet translated Newton's 'Principia', adding the conservation law. At that time transfer of energy wasn't well understood.
- Being a thinker, she participated in historical debates on the best ways to measure energy and force.
- Dropping balls from different heights onto soft clay, she discovered E_k=1/2mv^2.

Energy in the form of heat

- 1818 to 1889
- James Joule managed his family brewery, with access to fine equipment he made the ground breaking discovery that heat is energy in transit.
- Today the unit of energy is Joule but he had faced a lot of opposition from the establishment.
- Heat as energy in transfer is a critical aspect of conservation of energy in 'real' systems. It is everywhere!

Tremendous energy



- 1878 to 1968
- Lise Meitner studied the effects of collisions between neutrons and uranium.
- Einstein's E=mc^2 - 'conversion of mass into energy' showed that tremendous energy would be released. She worried about its use.
- During the war, she refused to work on the atomic bomb. Later on, the Swedes established a lab for her to continue her work on nuclear collisions.

(B) Story for Collisions practical

FIGURE 3.6. Stories for the mechanics practicals

Hunting

- The <u>Australian icon</u> - Boomerang date back to <u>10,000 BC</u>.
- It was used by the Aboriginal Australians as a weapon for hunting as they are designed in a way that they return to the hunter.
- Returning boomerangs — needed curved aerofoil wings to whip back around to the thrower, whereas regular projectiles -- non-returning boomerangs — were flatter, heavier, and more symmetrical.

Physics of Projectiles

- **Aristotle** said that heavier objects fall faster than lighter objects. He also believed that a projectile's path was 'linear'.
- Galileo disagreed and performed his famous experiment. His experiments proved that projectiles have parabolic paths with two components; vetical and horizontal.
- Newton's 'Principia' formulated force, gravity and the three laws of motion, but with multiple loose ends which were later fixed by other scientists.

trajectories

- Katherine Johnson was the first woman in the Flight Research Division of NASA to be credited as an author on a research report

–

- Although NASA had started using computers, they called upon Johnson to calculate and verify trajectories by hand.
- As NASA prepared to send astronauts into orbit around the earth, the first astonaut said: 'If she says the numbers are good, then I'm ready to go.'

(A) Story for Projectiles practical

Safety

Eleanor Reed Adair performed the first human studies demonstrating the safety of microwave radiation.

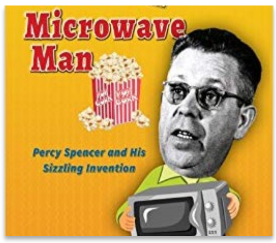
Thanks to her, we are on our cell phones all day!

Discovery

Hertz wanted to finish his PhD on time, so he ignored Maxwell's theory.

After getting a job as a lecturer, he played around with jumping electron sparks (and Maxwell's theory) and discovered Microwaves!

Application



Percy Spencer noticed that a candy bar he had in his pocket was starting to melt, and by accident the microwave oven was invented!

Take away: Have candies!

(B) Story for Microwaves practical

FIGURE 3.7. Stories for the mechanics and waves practicals

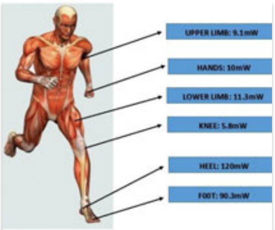
Applications

Guess what was used to take your first photograph!

Mysterious ultrasonic waves.

First used to detect submarines!

Inventions



The piezoelectric effect was discovered by Pierre Curie.

You are using this effect to generate and detect ultrasound waves.

Piezoelectricity is in action in your body and it can be harvested too!

The Scientists

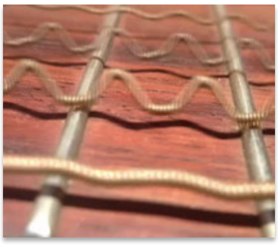
Pierre and Marie Curie were the pioneer scientists of radioactivity.

They won the Nobel Prize in Physics in 1903. Marie Curie also won the Nobel Prize in Chemistry in 1911!

Marie Curie was the first woman to receive a Nobel Prize as well as the first female professor at the University of Paris.

(A) Story for Ultrasound practical

Application

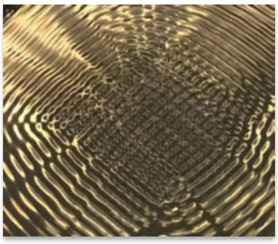


Guess why different strings produce different sounds in guitar and violin.

Check out this real-time video of the magic of standing waves!

https://www.youtube.com/watch?time_continue=87&v=9L9AOPxhZwY

Discovery



Michael Faraday was the first to observe standing waves!

Faraday waves appear on the surface of liquids enclosed in a receptacle!

Faraday discovered Electromagnetic Induction – you are using it in this experiment!

The Man

The father of electromagnetism, Michael Faraday had a basic education and was a book binder. He learnt science from the books he had to bind.

He got Albert Einstein his first job!

(B) Story for Vibrations practical

FIGURE 3.8. Stories for the waves practicals

3.5 Stories for physics lectures

Stories were crafted for the 17 lectures of the Newtonian mechanics lecture series. There was a different flavour to the stories crafted for physics lectures compared to the practicals, as the medium of sharing, the lecture slide, wasn't static. The stories were presented in a live lecture as a single slide with text and visuals in color and minimal historical content. I have presented each lecture with single color title bars. In terms of the physics content the lectures went on as usual except that the lecturer spent a minute on the lecture slide containing stories. The stories appeared once in each lecture at a planned but random moment. The purpose of the stories was to make students' feel engaged without hampering or altering the content being covered. The lecturer just paused on the story slide and let the students read and chat on it for a minute, sometimes talking them through the stories.

I referred to resources like *Stanford Encyclopedia of Philosophy* along with famous anecdotes related to the history of science while crafting and creating the stories. Naturally, popular scientists like Newton, Galileo, Descartes, and Einstein were selected in order to get quick attention from students. The stories contained design features from Nielsen and Thomsen (1990), Martin and Brouwer (1991), Matthews (1994), and Stinner (1995). In particular, a story in the lecture on "Uniform circular motion, free body diagrams and Newton's first law" contained the following features:

- Presenting physics as a human activity for positive change of students' attitudes (Martin and Brouwer, 1991; Nielsen and Thomsen, 1990), i.e., the scientists behind the discovery of physics being taught are presented.
- Providing an authentic picture of how science progresses and builds with the contribution from different scientists (Matthews, 1994), i.e., the work on the law of inertia is presented as contributed to by Galileo, Descartes and Newton.
- Inventing a dramatic "storyline" highlighting the main idea (Stinner, 1995), i.e., the acknowledgement of the work attributed to a particular scientist while passing by the contributions of others is addressed interestingly.

Figure 3.9 presents what the lecture slides looked like for a particular lecture, with examples of a slide for content learning, active learning, problem solving, and the story. Figure 3.10 presents slides containing stories for other lectures of the Newtonian mechanics lecture series.

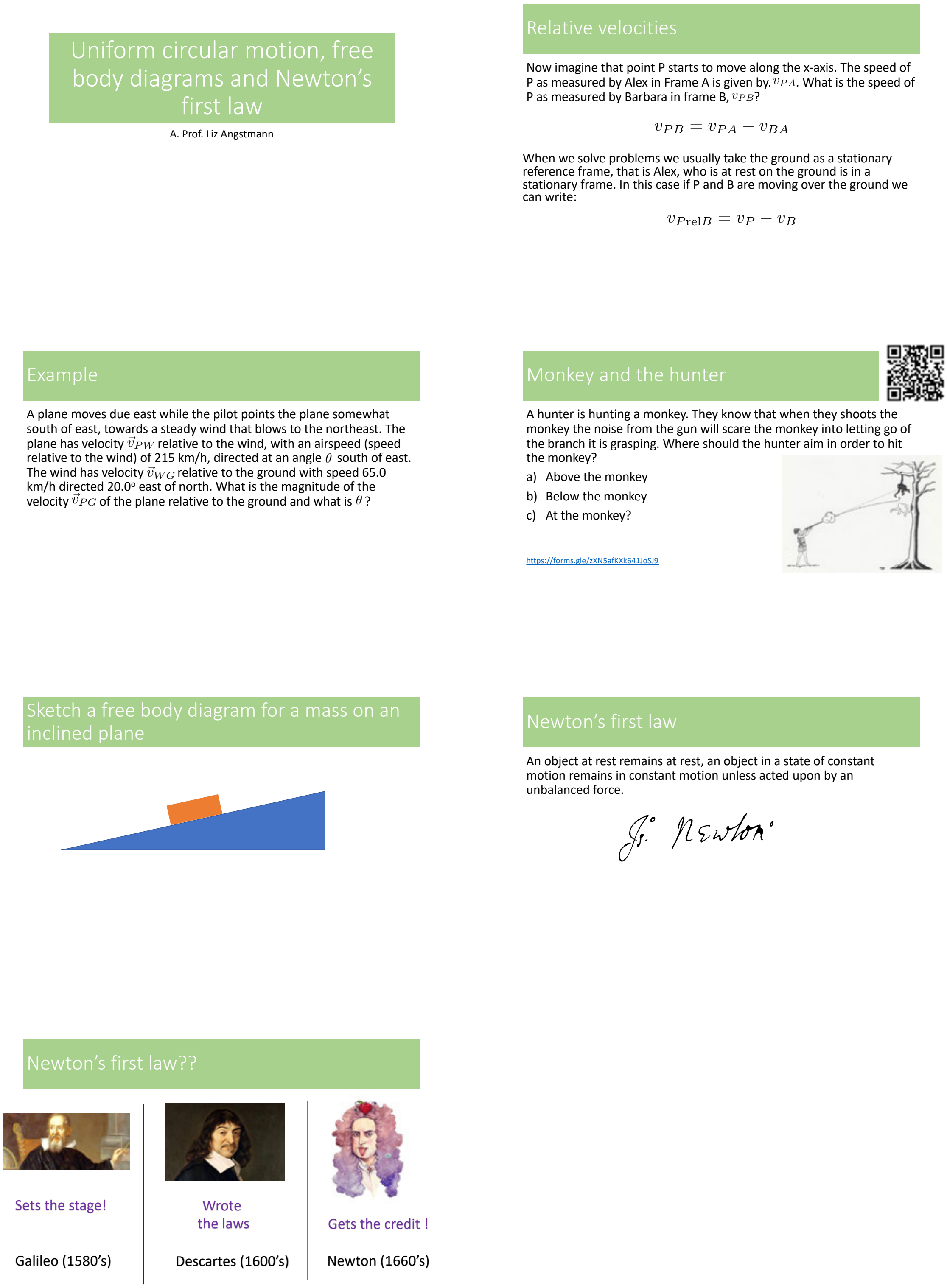


FIGURE 3.9. Lecture slides for 'Uniform circular motion, free body diagrams and Newton's first law' showing the different types of slides in a single lecture.

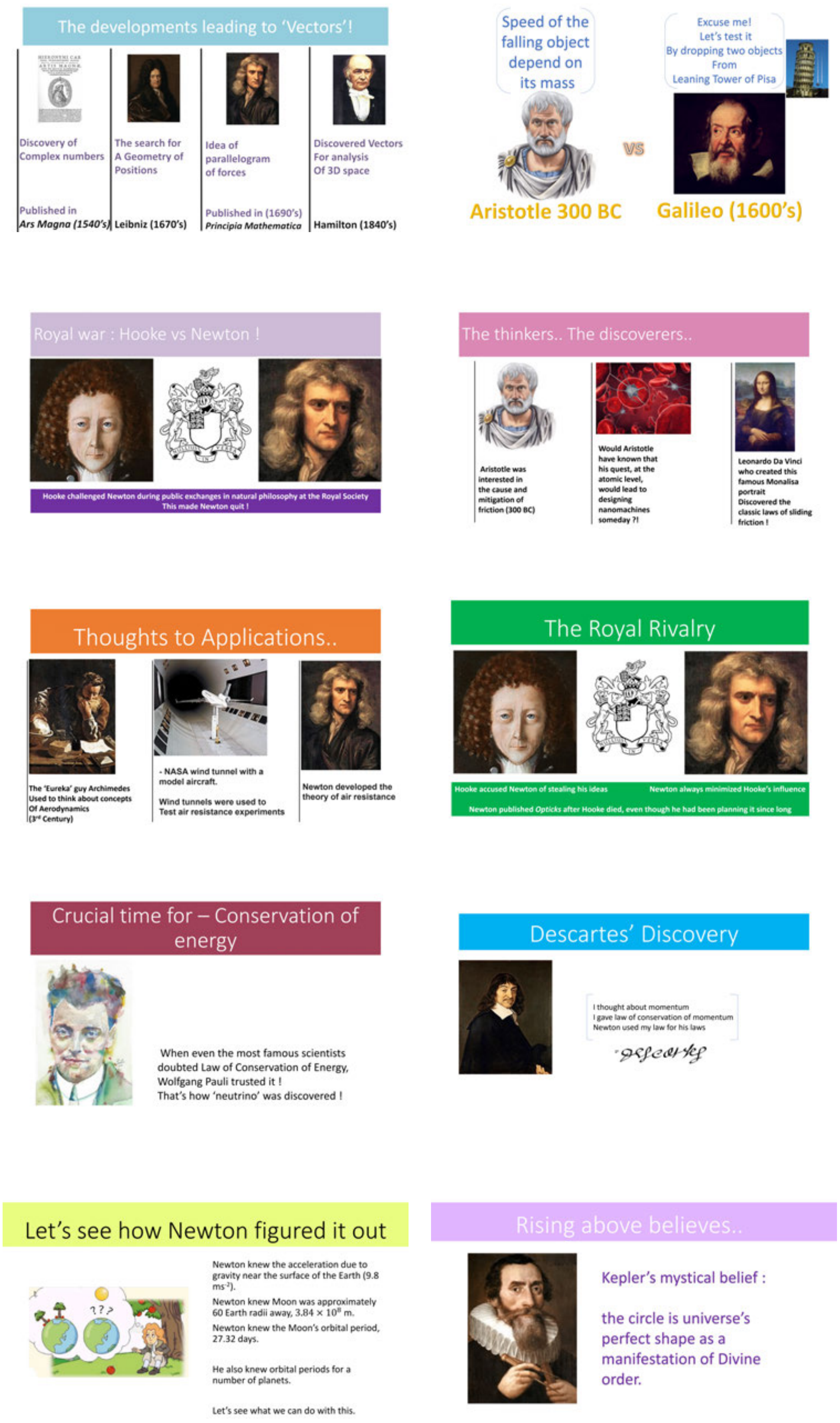


FIGURE 3.10. Slides containing stories for other lectures of the Newtonian mechanics lecture series at University of New South Wales first-year physics

3.6 Summary

In this Chapter, I provided the process I followed to craft the ‘colorful historical stories’. I also presented the stories created for the physics practicals and lectures along with the description of the theoretical underpinning for the same.

CHAPTER 4

The Research methodology

4.1 Introduction

In Chapter 3, I present the development of a set of teaching materials, the 'colorful historical stories' for physics practicals and lectures. The development of these stories required research into the literature presented in Chapter 2. The next stage of my research involved gathering feedback on how the teaching material was received, by measuring the emotions of students.

In this Chapter I present my research methodology. I describe the process and criteria for checking the reliability and validity of an adapted survey tool to measure students' emotions. The adaptation of the survey itself is described in Chapter 5. I elaborate on the statistics used to analyze the quantitative data gathered by the survey questions. I also discuss the theoretical basis and the process of analysis conducted on the qualitative data collected in the form of open-ended responses, observations and interviews.

4.2 Overview of my positionality statement

Here I position myself as a researcher. I am a physicist grounded in quantitative methods. Hence for me, quantitative methods are a natural way of investigating the natural and social world. However, physics also has a rich qualitative and exploratory approach. The lens I use, my theoretical perspective, is that of post positivism in that I am not looking for one objective truth but rather any realist truth that can be measured (Crotty, 1998; Patel et al, 2015). "Positivism is an epistemological position that holds that the goal of knowledge is simply to describe the phenomena that we experience while Post-Positivism recognizes that the way

FIGURE 4.1. Research methodology for my research

scientists think and work and the way we think in our everyday life are not distinctly different. Further where the positivist believed that the goal of science was to uncover the truth, the post-positivist believes that the goal of science is to hold steadily to the goal of getting it right about reality, even though we can never achieve that goal" (Manuel, 2013; McInnes, 2021).

I have designed interventions containing 'colorful historical stories' which I have described in Chapter 3. My research is a way of surveying and viewing students' experiences of their learning as they engage with these interventions. Figure 4.1 indicates the theoretical perspective, the methodology and the methods of the research methodology I used.

Sauro (2015) has presented four ways through which researchers participate as observational researchers:

- Complete observer: The researcher acts as an aloof observer, not getting recognized or noticed by the participants.
- Observer as participant: The participants are aware of the researcher and the research goals. The researcher engages in limited interaction with the participants, with a neutral stance.
- Participant as observer: The participants are aware of the researcher. The researcher engages in a lot of interactions with the participants, behaving as their friend or colleague rather than taking a neutral stance.
- Complete participant: The researcher acts as a participant, totally interacting with other participants and taking part in the activities, while the participants aren't aware of the research being conducted.

I have designed and deployed an intervention in a natural setting of teaching environment. Hence, my stance was that of an 'observer as participant', often referred to as a 'participant researcher'. My lens was that of action research (Sharma and McShane, 2008) so there is a possibility of some amount of influence introducing a bias in the observations. Hence, my research may have underlying biases, ranging from my role as a participant observer to being the developer of the tools which students are using.

4.3 Research context

Since I am using both qualitative and quantitative methods, my approach is that of mixed methods research. Further, Creswell and Plano (2007) have described four types of mixed method research:

- Triangulation: Here the qualitative and quantitative data both have equal importance. They are collected simultaneously, and the results are compared.
- Embedded: Here one of the data types is primary while the other is just to provide a support to the conclusions made by primary data.

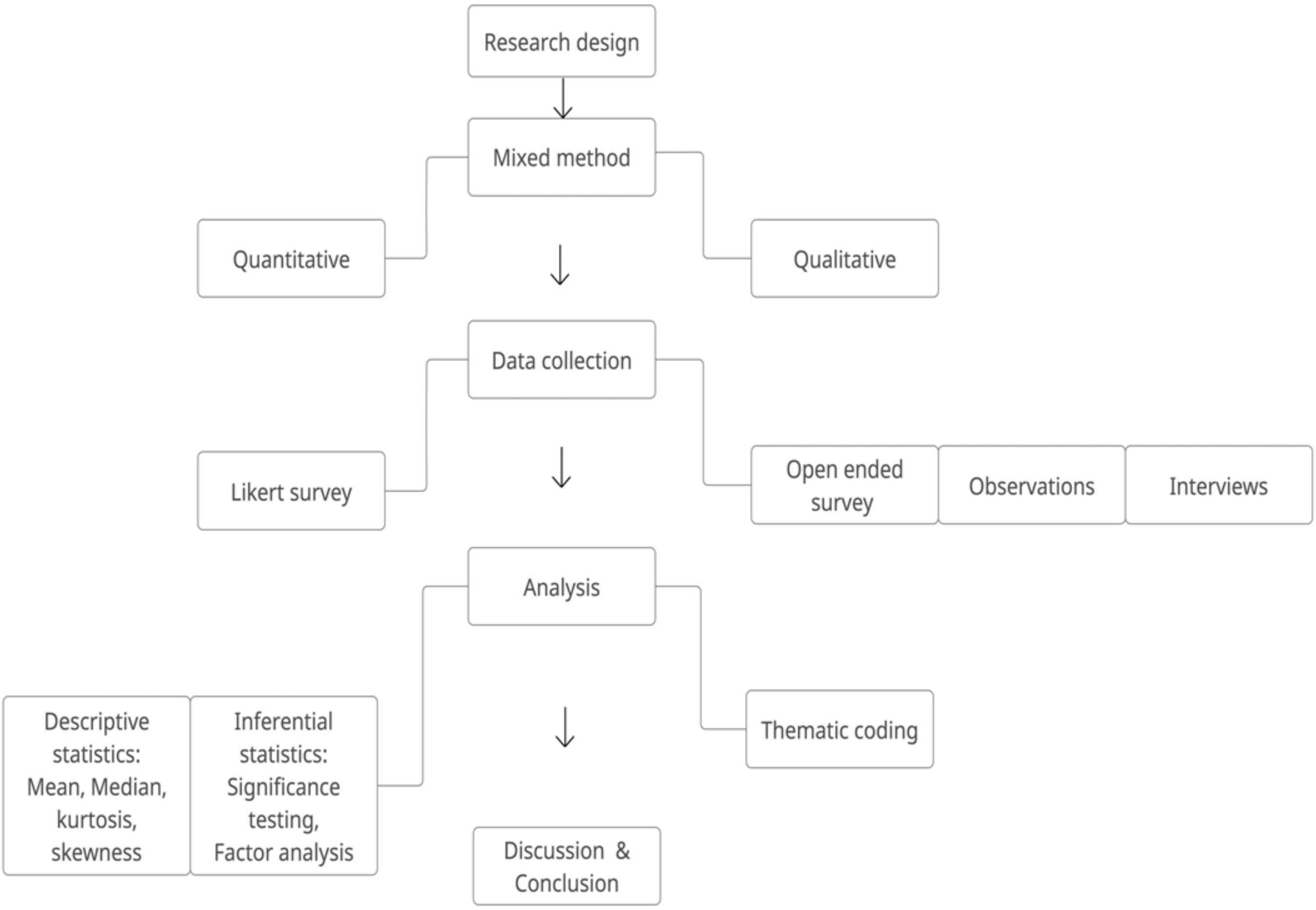


FIGURE 4.2. Research design used in my thesis

- Explanatory: Here the primary data collected is qualitative. Qualitative data are collected later to validate the hypothesis.
- Exploratory: Here the primary data collected is quantitative. Qualitative data are collected later to interpret the results.

My research approach is mixed method using triangulation. Figure 4.2 presents my research design showing qualitative and quantitative methods positioned as equals. I have collected quantitative as well as qualitative data through surveys with AEQ items and open-ended questions, class observations and focus interviews.

DeCarlo (2018) lists the sampling strategies as follows:

- Purposive: Participants with specific characteristics are chosen.
- Snowball: Current participants refer the new participants.
- Quota: Subgroups are created out of which participants are chosen.
- Convenience: Participants are chosen on convenience basis, e.g. those who are easily available.

My research used convenience sampling because I administered the surveys to all the students present in the teaching environment. This is nonprobability or nonrandom sampling, so every student in the class had equal possibility of getting selected. All my data are primary; I have collected all the data myself. Furthermore, the data are anonymous (Etikan et al, 2016). More details about the specifics of sample and data collection will be covered in later Chapters. Figure 4.3 shows the timeline for data collection over three years of study.

I have obtained approval from the Human Ethics Committees of both The University of Sydney and the University of New South Wales. I have followed all appropriate protocols for my project, forms and approvals from the committees are provided in Appendix. All data collection occurred with informed consent according to protocols approved by the relevant Institutional Human Ethics Committees. With the switch to online, approvals for online data collection were sought and granted. Data management also adhered with those protocols. No incentives were offered.

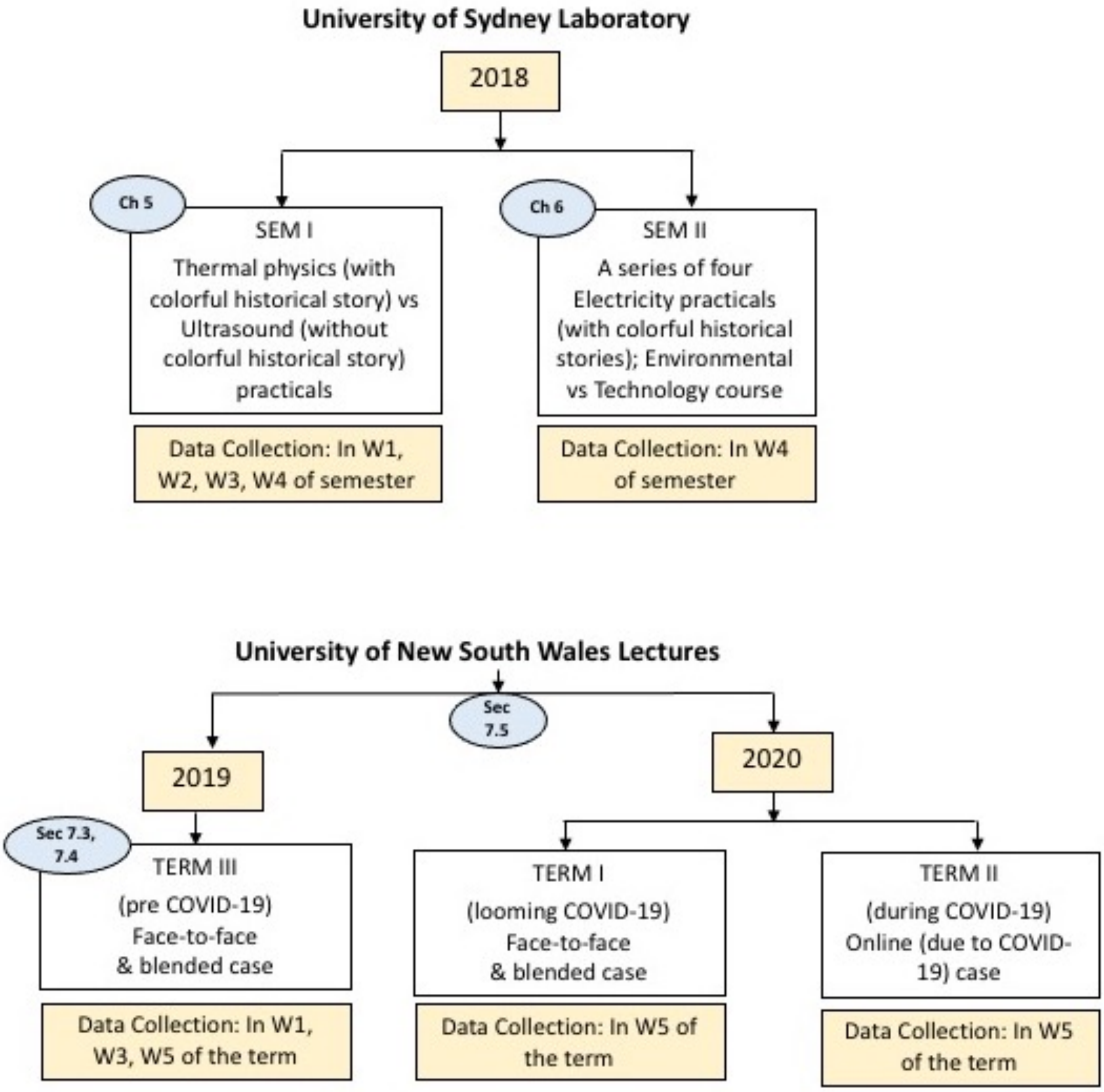


FIGURE 4.3. Data collection at The University of Sydney and the University of New South Wales over three years; 2018, 2019 and 2020. (The relevant Chapters and sections, where the particular sample was used, are indicated in the ovals. Particular weeks in which the data was collected, are indicated in the rectangular boxes.)

4.4 Quantitative data analysis

The quantitative data I used were collected through surveys. The AEQ described in Chapter 2 has been adapted (further details are given in later Chapters). Students provided responses on a five-point Likert scale by selecting from: Strongly Agree (5), Agree (4), Neutral (3), Disagree (2), Strongly Disagree (1). The data were scanned using Remark software and exported into EXCEL. I then 'cleaned' the data by removing forms with more than three blank responses as well as some that were 'mischievous', i.e., jokes, not sincere or obscene comments. Next, the data were exported into SPSS Version 24 for analysis. The steps in my quantitative data analysis were as follows:

- The first step was an adaptation of the AEQ survey. It is good practice to validate the surveys in their context so the adapted AEQ surveys were checked for their reliability and validity.
- The second step was performing a Confirmatory Factor Analysis (CFA) to check that the model follows hierarchical structure of interrelated and distinct emotions as conceptualized by Pekrun et al (2005a).
- The third step was carrying out descriptive statistics to measure and demonstrate students' emotion profiles.
- Fourth step was to do inferential statistics; significance testing: Independent samples *t*-test, Mann-Whitney test, and Pearson's correlations. The subsections below describe these four steps.

4.4.1 Exploratory Factor Analysis (EFA)

For the first step, I carried out extensive data exploration to see if the data were appropriate for EFA and if the assumptions for further analyses were satisfied. The data exploration included:

- Checking the distribution of responses for individual items for normality.
- Ascertaining the reliability of each factor using Cronbach's alpha and accepting those with values greater than 0.5 (Field, 2000).
- Confirming that the Kaiser-Meyer-Olkin (KMO) Sampling Adequacy was greater than 0.5 (Field, 2009).
- Checking the absence of multicollinearity by using Bartlett's sphericity test for correlations that had to be significant at $p < 0.05$ and the determinants had to be greater than 0 (Dziuban and Shirkey, 1974; Lindstrøm and Sharma, 2010).

- Ascertaining that the inter-item correlations for each factor were in the range 0.3 - 0.8 (Cohen, 1988; Sharma et al, 2013; Peixoto et al, 2015), this indicates that the items were distinct.

For the factor analysis, the inflexion point on the Scree plots as well as eigenvalues greater than one were considered in determining the number of factors to be retained as per Kaiser (1960) and Field (2000). For a better interpretation of the interrelated emotions 'factors rotation' was done using direct oblimin method of oblique rotation. Factor loadings greater than 0.4 were accepted as suggested by Field (2000) and Stevens (2002).

4.4.2 Confirmatory Factor Analysis (CFA)

For the second step, CFA was conducted to check that the internal structure of the emotions tested by my model of adapted AEQ surveys was consistent with the literature (Pekrun et al, 2011). CFA was carried out using SPSS Amos Version 24.0. For the CFA, I report items loading onto each emotion and correlations between the emotions (Jackson et al, 2009). In addition, I report model fit statistics; the chi-squared test, the root mean square error of approximation (RMSEA) and the comparative fit index (CFI) as recommended by Kline (2010). The parameters and associated criteria used to assess the goodness of fit of my model are shown in table 4.1.

As the data is continuous and distributed normally, Confirmatory Factor Analysis (CFA) was conducted using the maximum likelihood estimation. The model generated with CFA was expected to be similar to the model containing six interrelated factors in a multi-dimensional structure presented in Peixoto et al (2015). The factor loadings for the items were expected to be > 0.6, indicating that they load appropriately on their respective emotions. The latent factor correlations were expected to have a positive relationship between emotions of the same valence and a negative relationship between the emotions of opposite valence as in Pekrun et al (2011).

Parameter	Criteria	Reference
Comparative fit index (CFI)	Permissible at > .80 good fit at >=.90	Hooper et al (2008) Sharma et al (2013) Hu and Bentler (1999) Hair et al (2010)
Root Mean Square Error of Approximation (RMSEA)	Moderate fit at .05-.10 good fit at <.08	Hooper et al (2008) Sharma et al (2013) Hu and Bentler (1999) Hair et al (2010)
Relative $\chi 2$ ($\chi 2$/df)	Permissible at < 5 reasonable fit at < 3	Pekrun et al (2011) Sharma et al (2013) Marsh and Hocevar (1985) Hu and Bentler (1999) Hair et al (2010)
Average Variance Extracted(AVE)	Should be > .4	Huang et al, 2013
Composite Reliability (CR)	Should be >.6	Sharma et al, 2013

TABLE 4.1. Confirmatory Factor Analysis: Parameters, Criteria, and Reference

4.4.3 Descriptive and inferential statistics

For the third step, I had to generate a score for each student for each emotion. To do this, I took the items which, according to EFA and CFA, clustered as *emotion*, a factor in my study. I summed the ratings that each student had entered for those items, giving me a score for an emotion for each student. Hence, I could generate score distributions for each emotion. Descriptive statistics were computed for the emotions using Statistical Package for the Social Sciences (SPSS); including means, medians, standard error of the mean (SEM), standard deviation (SD) and boxplots. Furthermore, I considered kurtosis and skewness where appropriate. I compared the emotions across different cohorts and groups of students. These underpin decisions regarding the use of parametric or non-parametric inferential statistics shown below. The statistics reported and the criteria followed for significance were as suggested by Field (2000):

- Parametric test: The data is normally distributed.

  - Independent samples *t*-test: Test conducted to compare means of two groups. The statistics reported were *t*-statistics and significance *p*. Significantly different means were reported at '*' $p < 0.05$ and '**' $p < 0.01$ level.
  - Pearson correlations: Test was conducted to check the correlations between the emotions, which are the factors of my study. The correlations were found to be significant at '*' $p < 0.05$ and '**' $p < 0.01$ level. Correlation coefficients range from +1 (indicating a perfect positive correlation) to -1 (indicating a perfect negative correlation). Values between 0.5 and 0.7 indicate moderate correlation and between 0.3 and 0.5 indicate low correlation.

- Non-parametric test: The data is not normally distributed. To test for normality, I carried out the Kolmogorov-Smirnov and Shapiro-wilk tests. These showed that the data were not normal. Consequently, I performed the non-parametric Kruskal Wallis test. I chose Mann Whitney U test as a post hoc test to find significant differences between two groups in each case.
  - Mann-Whitney test: Test conducted to compare medians and means of two groups. The statistics reported were Mann-Whitney Test statistic *U*, significance *p*, effect size *r* are shown in the tables for comparing the emotions of students studying in different modes. Significantly different medians/means were reported at '*' $p < 0.05$, '**' $p < 0.01$ and '***' $p < 0.001$ level.

4.5 Qualitative data analysis

Sandelowski (2004) mentions that qualitative research generates knowledge grounded in human experience. My research seeks to explore students' emotional engagement with physics practicals, an engagement that is inherently grounded in human experience. In order to understand students' emotional engagement in more depth, qualitative data were collected through open-ended survey questions, observations and interviews (figure 4.2). The processes followed in gathering and recording data are described below:

- I entered the students' handwritten open-ended survey responses into EXCEL.

- I recorded observational data by hand on paper or computer with flexibility in 'what and how' I could record.
- I audio taped the interviews and later transcribed the tapes to WORD documents.

In the next subsection I describe the theoretical background underlying the approach and the method I used for the analysis of the qualitative data.

4.5.1 Theoretical background

Researchers argue that starting with an absolutely clean theoretical slate is very difficult to achieve (Strauss, 1987; Richards, 1993) and it is not preferred as well (Perry and Jensen, 2001). I also started with a little theoretical background while inductively coding students' emotional engagement and finally triangulating my results with the earlier research. My approach is helpful for advancement of the research on students' emotions being an interplay between the inductive and deductive approaches (Parkhe, 1993).

Perry and Jensen (2001) have described five approaches for combining inductive and deductive coding methods. These approaches are as follows:

- Ethnography. The researcher gets immersed in the group to be studied and records, categorises and codes the observational data to provide a holistic picture (Sanday, 1979; Neuman, 1994).
- Grounded theory. The researcher develops hierarchical theories based on interviews and observations in natural settings. Interviews are collected in ways that evolve as the research proceeds.
- Modified version of grounded theory. The categories are developed from other theories and then the sampling and coding occurs (Brytting, 1990; Skytte, 1992).
- Convergent interview approach. The researcher is involved in designing, conducting and analysing a series of in-depth interviews. The researcher refines the questions after each interview, to converge on the research aims after all the interviews.
- Action research. The researcher conducts activities that involve planning, acting, observing and reflecting to formulate or revise the theories (Carson et al, 2001). As

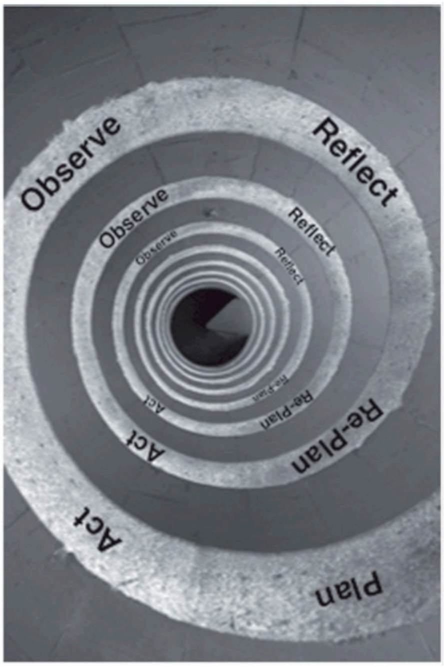


FIGURE 4.4. Action research 'self-reflective cycle' as presented in Kemmis et al (1970)

> shown in fig 4.4, Kemmis et al (1970) presents the cyclic process of planning a change, putting the plan into action, observing the process and consequences of the change, reflecting on the observations and reformulating the plan.

Action research has been an exemplary approach for scholarly inquiry into university teaching and student learning (Sharma and McShane, 2008). It appeared to be to be suitable for my study and so I opted for the action research approach. I designed intervention to enhance students' emotional engagement. I adapted a survey tool to measure emotions and observe the change due to intervention. I reflected on the results with inductive and deductive approach. I referred to the control-value theory (Pekrun, 2006) at different instances in the research like the survey development, data analysis and triangulation with the results.

4.5.2 Data exploration and thematic analysis

Though analysing the qualitative data is a complex task (Thorne, 2000), Braun and Clarke (2006) write that thematic analysis, described by them as a "rich and detailed, yet complex account of data", is a widely used method. For early career researchers like me, thematic

2	Pr	positive		yes	pride	-	they are intriguing so yes	experiment were bad for me as I was alone for most experiments or only with one other person	intriguing	Interested and think this is helpful towards emotional engagement.	✓ IE
3	Pr, Ho	positive	no	yes	Pride, hopelessness	not really, it was a nice touch to understand how the experiment came from	yes, it was fun understanding the background		interesting to know where the experiment came from. Fun	interested and think this is helpful towards emotional engagement and learning	ILE ✓
4	pr		yes	yes	pride	yes	yes	no			-blank msc
5	pr	positive	yes	yes	pride	yes insightful/inspiring	yes, it is entertaining	no, good job :)	insightful. Inspiring. Entertaining	interested and think this is helpful towards emotional engagement and learning	✓ ILE

(A) Exploring and color coding students' responses as they report which emotion they felt, and whether they thought the stories were engaging and motivating

				Numbers	
Code: the colourful historical stories ...	Emotion	Examples		ENV	TEC
are interesting I	Enjoyment	Interesting history; relive history. A must in my opinion. 5 Although I didn't look at them, I found it good to have a colourful picture. Sorry, I didn't read them. 6 I love this. 8 It was a fun read 17 Yeah it is cool. 10 Interesting 14 Found them interesting as light read before the experiment. Add if we are not tested on it. [Issues lab] 15 It is good 20 I didn't pay attention to the stories, but I appreciate them being there. Keep them in the lab notes but do not make them integral to it 32 I didn't read them, they should have been motivating. 34 They were interesting. Add, why not. 43 Refreshing. 45		4	8
are interesting and helpful for learning IL		I liked the stories and realistic applications 3 They were interesting and relevant. They did motivate, but more so the content of the pracs/circuit building. 7 It makes me understand physics 11 Enjoyment, they are useful 20 Interesting, more colour and side notes for a lab note 21 Gave us knowledgeable insights 24 It was interesting learning background information. It is cool. 25 Context is good, as long as they are not too long. 27 Learnt background information. 40		5	4
are interesting and helpful for emotional engagement IE		It excites me and absorbs my attention 9 It's good for my feelings about physics. It's fun. 10 History made conducting experiments more interesting. This insight was motivational and entertainment. 12 It is always nice to hear about the greatness of Einstein-I idolise him. I love this oscilloscope. 14 Those stories just inspire me. 19 Read through them, they were interesting, they gave us an appreciation of history 2 I feel good, All Good. 6 It's funny, maybe motivating, but experiment is still hard 7 Something new, not old repetitive stuff, motivating as entertainment, but waste of paper. 9		5	11

(B) Analysing and coding students' comments and creating categories

FIGURE 4.5. Thematic Analysis

analysis was more accessible than other forms of analyses. While the flexibility of thematic analysis was advantageous, it could also lead to inconsistency in the research. I chose thematic analysis. Figure 4.5 shows the glimpse of how I analysed students' open-ended survey responses. The thematic analysis included the following steps:

- The data were inductively analysed so as to find patterns in students' comments. I numbered students' responses and highlighted the important sections of the comments.
- Deductive coding occurred with students' responses being sorted and color coded as per the emotions reported. Data were also sorted according to whether students found stories engaging and motivating.
  Inductive coding followed for the next three steps.
- Responses that seemed similar or repeated sections of the comments were written together.
- A label, phrase or word was given to comments or references that clustered together as a code.
- Comments in each category were checked, some were moved to other categories and the categories were reduced for concise results.
- Next step included deductive coding. The categories were relabeled to form meaningful terms that were triangulated with the literature.

In the initial coding I identified broad patterns. Line-by-line coding occurred next where the broad patterns guided intricate and detailed codes. Similar codes were grouped and distinguished from others; boundaries were identified in an iterative process generating categories that were consistent with the broad patterns but provided detail that was sufficiently nuanced to address the research questions. Here iterative process refers to the process where I generated broad categories, met with my supervisor and condensed the categories while rearranging students' responses to the relevant categories, tried to make the categories tight and related to theory while generating meaningful results. Interviews and observations followed a similar thematic analysis process as explained in relevant Chapters later.

I met my supervisor for the analysis conducted in Chapter 6, and my co-supervisor for the analysis conducted in Chapter 7, regularly to discuss the process, broad patterns, content of the codes, categories, and their boundaries. My supervisors independently coded some responses at various stages and fully coded all the responses into the final categories. The inter-coder reliability (ICR), also known as inter-rater reliability (IRR), was assessed and accepted as per O'Connor and Joffe (2020). They write, "ICR is a numerical measure of the agreement between different coders regarding how the same data should be coded". As a consequence of the COVID pandemic, I was unable to consult a third party to check the inter-coder reliability.

4.6 Triangulating quantitative and qualitative results

As discussed in section 4.3, quantitative as well as qualitative data analysis are of equal importance to my study. I pursued a triangulation method to provide a rich account of students' emotional engagement. Earlier published research has indicated that qualitative and quantitative data can provide inconsistent results, with Patton 1990 commenting, "it is likely that quantitative and qualitative methods will eventually answer different questions that do not come together to provide a single, well integrated picture of the situation". The qualitative data in my study is collected through responses to open ended questions, hence is not typical rich interview data. The lens adopted by Johnson and Onwuegbuzie (2004) integrates the data in my study as one example of mixed methods research. Furthermore, Onwuegbuzie and Leech (2005) shed light on researchers in naturalistic settings using mixed methods.

In order to get convergent and meaningful answers and also to provide an in-depth picture the open-ended questions were modified or redesigned at each round of iteration. Those modifications were based on students' previous responses and the research aims of the study. As a result, I finished with quantitative and qualitative results that are internally consistent and explain much about students' emotional engagement. Basically, the quantitative survey responses provide numerical scores to students' emotions and the qualitative survey responses along with the class observations and interviews, elaborate on students' feelings and moods.

4.7 Summary

In this Chapter, I have presented my research approach and stance, together with methods and techniques, while illustrating the analytical framework for my research.

Since my research is on students' emotions, I rely on self-reports and observations: this may introduce biases. Furthermore, bias may be introduced by my role as 'observer as participant' (often referred to as a 'participant researcher').

However my research had large samples and repeated measurements, using mixed methods triangulation, which was used to generate meaningful interpretations and findings that can be used in the teaching and learning of physics.

CHAPTER 5

The Achievement Emotions Questionnaire: Validation for Practicals

5.1 Introduction

In Chapter 2 of this thesis the Achievement Emotions Questionnaire (AEQ) was discussed as part of the Literature Review. Here, in this Chapter, I tell how I adapted that Questionnaire to measure emotions of students in the first-year physics laboratory classes at the University of Sydney. This adapted survey tool is called AEQ -PhysicsPrac. This tool needed to be validated. The adaptation and validation and the results of the study have been published in Bhansali and Sharma (2019) and are presented in this Chapter.

In order to validate the survey, it has to be implemented. As presented in section 2.6, earlier projects have shown that physics is often perceived by students as context-less and overwhelming. Emotional engagement is a necessary factor not just for retention but also for achievement in science. Contexts and a story line can engage and motivate students. In this Chapter, I also describe how AEQ-PhysicsPrac was implemented for two practicals to probe students' emotions in two practicals. The first practical, 'ultrasound', was the control. 'Ultrasound' is a long-standing practical which was taught without any colorful stories. The second practical, 'thermal physics', was the newly developed intervention. color and historical aspects were incorporated into this practical with the aim of generating positive emotional engagement.

In this Chapter, I address the following research aim:

To adapt and then validate the Achievement Emotions Questionnaire (AEQ) within the context of undergraduate physics practicals.

5.2 Adaptation of the AEQ

The AEQ has been used for different subjects (Pekrun et al, 2005b). Similarities in the difficulties students face in mathematics and physics (McBride, 2012) mean that they are likely to experience similar emotions during classes in these subjects. With this in mind I used items from AEQ-M (Pekrun et al, 2005a; Peixoto et al, 2015), where M stands for mathematics, as the foundation for AEQ- PhysicsPrac. The AEQ- PhysicsPrac measures students' pride, enjoyment, anger, anxiety, hopelessness and boredom. The valence of these emotions, positive or negative, and the activity level, activating or deactivating, range over three of the quadrants shown in figure 2.3A which illustrates classification of emotions in the control- value theory (Pekrun, 2006).

When I adapted the AEQ-M, I selected 19 items for the AEQ-PhysicsPrac. I can classify the changes I made to the selected AEQ-M items into four categories. The classification is shown in Table 5.1. The 'Minor change' category includes changes in tense introduced so as to capture students' emotions during the laboratory. The 'Removing subjectivity' category includes adding or removing qualifiers which introduce relative subjectivity while not significantly changing the meaning of the items. The 'Simplify' category includes changes made to simplify ambiguous items; some of these changes involved inserting a substitute word from the emotion wheels presented in section 2.3.2, the *Junto Emotion Wheel* (2020) and Geneva Emotion Wheel (Scherer et al, 2013). The 'New items' category includes creating new items that are coherent to original AEQ-M items, while avoiding any extreme sentiment.

Table 5.2 shows the items of AEQ-PhysicsPrac sorted according to positive emotions and negative emotions. The first column shows the number of the item as it appeared for the original item in the AEQ-M for the reader's reference and to tally. To understand the gist of the feelings captured with a fleeting eye, the 'Short names' of the items are mentioned. The

Category	Explanation	Example
Minor change	The tense was changed and/or explicit reference was made to physics practicals/experiments.	'I am happy that I can cope with the Math test.' was changed to 'I am happy that I could cope with this experiment.'
Removing subjectivity	Words which introduce relative subjectivity were removed, while maintaining the sentiment of the item e.g. 'fairly'.	'After a math test, I am fairly annoyed' was changed to 'I felt annoyed by this experiment.'
Simplify	Double barrelled items were simplified. In some cases suitable words from the Geneva Emotion Wheel were used.	'Because I take pride in my accomplishments in mathematics, I am motivated to continue' was changed to 'I felt elated by my accomplishments during this experiment.'
New items	New items were constructed remaining congruent with the original AEQ items. The items avoid any extreme sentiment.	'After the Math test, I feel very angry' was changed to 'I resented doing this experiment'

TABLE 5.1. Categories of adaptation of the items for the AEQ-PhysicsPrac

'Item names' presented were used in analysis for convenience. The category of change to the item from AEQ-M items is also indicated in the table. Content validation was provided by the peers, tutors from the Sydney University Physics Education Research (SUPER) group.

9 Positive items				
Item no.	Pride items	Short name	Item name	Change from AEQ
1	During this experiment, I was satisfied with my work.	Satisfied	Pr1	Removing subjectivity
4	I felt elated by my accomplishments during this experiment.	Elated	Pr2	Simplify
8	I took pride in being able to keep up with the tasks in this experiment.	Keep up	Pr3	Removing subjectivity
9	I made important contributions during this experiment.	Important contribution	Pr4	Simplify
	Enjoyment items			
2	For me this experiment was a challenge that was enjoyable.	Enjoyable challenges	En1	Minor change
6	I felt this experiment was exciting.	Exciting	En2	Removing subjectivity
11	I was glad that my efforts during this experiment paid off.	Efforts paid off	En3	Removing subjectivity
12	I enjoyed this experiment.	Enjoyed	En4	Minor change
17	I am happy that I could cope with this experiment.	Cope with	En5	Minor change
10 Negative items				
	Anger items			
3	I felt annoyed by this experiment.	Annoyed	An1	Removing subjectivity
7	It was irritating that my efforts were not useful during this experiment.	Irritating	An2	Removing subjectivity
15	I resented doing this experiment.	Resented	An3	New items
	Anxiety items			
5	I got scared that I might do something wrong while doing this experiment.	Scared	Anx1	Simplify
10	I felt nervous during this experiment.	Nervous	Anx2	Minor change
16	I felt panicky during this experiment.	Panicky	Anx3	Minor change
	Hopelessness items			
13	During this experiment I felt like giving up.	Give up	Ho1	Minor change
22	During this experiment, I was so resigned that I felt that I had no energy.	Resigned	Ho2	Minor change
	Boredom items			
18	I found this experiment dull.	Dull	Bo1	Minor change
19	I was bored during experiment.	Bored	Bo2	Removing subjectivity

TABLE 5.2. AEQ-PhysicsPrac: Items and their classification as per the emotions (Bhansali and Sharma, 2019)

5.3 Method

5.3.1 Sample, survey administration and data collection

The sampled students in this study were enrolled in a first-year physics course at The University of Sydney. This course includes three-hour practical sessions that run multiple times during the week. Students work in teams of three and each team is assigned to one practical session each week. There are four practical exercises named: 'microwaves', 'vibrating wires', 'thermal physics', and 'ultrasound'. Each team of students is assigned to complete three of these four practicals during a three-week period. There are three students in each team. The cohort were predominantly straight from school, 18 to 21-years-old, with around 25 percent females. Only some of the students were undertaking a physics major.

The AEQ-PhysicsPrac was administered to students who were assigned both 'thermal physics' and 'ultrasound'. The thermal physics practical, the intervention, contained a 'colorful historical story' as described in section 3.4.1, whereas the ultrasound practical, the control, did not contain any story. Intervention and control practicals ran in parallel in the first-year physics laboratory, with different teams of students doing them each week. As shown in the table 5.3, for the control, 136 students returned surveys out of 193 present; a 70 percent response rate. For the intervention, 184 students returned surveys out of 213 present; a 86 percent response rate. The data collected from both the practicals were used for validation of the AEQ-PhysicsPrac. While collecting the data, I did not ask for students' identities following the ethics protocols, so I could not track which practical out of the two was done first by a particular student. Later in the Chapter I provide a comparison between the emotional profiles of students for these practicals.

Practical	No. of students present	No. of surveys returned	Response rate
Control/Ultrasound	193	136	70%
Intervention/Thermal physics	213	184	86%

TABLE 5.3. Students' response to the survey administration for the control and intervention practicals

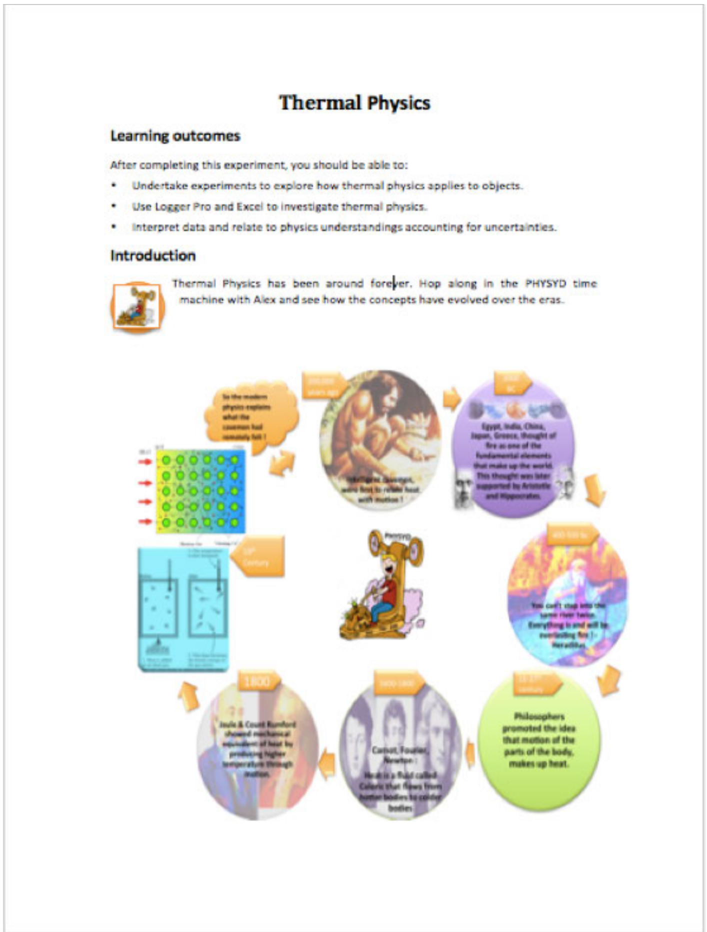
Prior to the start of the practicals, I provided students with a brief introduction to the AEQ-PhysicsPrac survey. I read from a script, explaining the purpose of the study and making it clear to students that their participation in the survey was voluntary. I then distributed the paper surveys to the students to be completed and collected before the end of the laboratory session.

5.3.2 The intervention and the control

The intervention was a newly developed practical on thermal physics involving measurements of temperature and the feeling of hot and cold, measurements of heat conduction through different metals using real time data collection, and modelling heat conduction using an Excel spreadsheet. I developed this practical with help from technical staff and my supervisor. The 'colorful historical story', available to students on paper and on computer, is presented on the first page of the laboratory notes in the form of a cyclic depiction of how humans' understanding of 'heat' has evolved over time. My variable is 'colorful historical story' as a wholistic idea, rather than colors or stories separately. While color is not a distinct variable, harsh, contrasting colors were avoided as they may not have the desired effect. I have paid attention to the color palette, selecting tasteful color combinations (Gremillion, 2020). Some of the images reappear as thumbnails in the laboratory notes, as shown in the figure 5.1. All other content in the laboratory notes is black and white.

The control was an established practical involving ultrasound which focused on measuring the speed of sound in air using ultrasound waves, measuring wave properties of ultrasound waves like its wavelengths and frequencies, using the signals displayed on a digital oscilloscope, and modelling the relationship between amplitude/intensity and distance from source for ultrasonic waves. The first few pages contained the theoretical background without any 'colorful historical story'. The student notes were entirely in black and white.

There were many common features between the control and intervention practical. They were delivered to the same cohort of students. The lab notes presented to the students had the same length in terms of number of pages and had comparable structures. They were of equal complexity in terms of subject matter and skills, as well as measurement and analysis requirements. Each practical was intended to be completed in three hours.



Thermal Physics

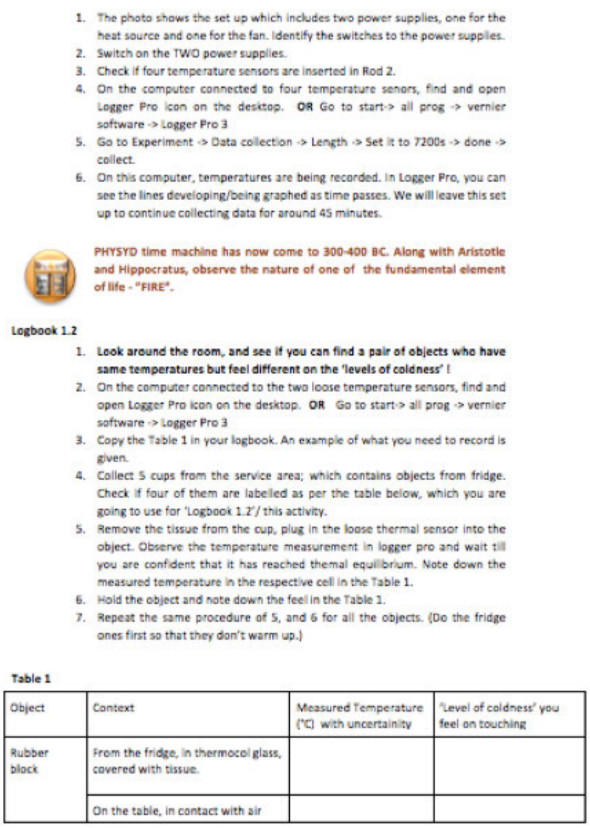
Learning outcomes

After completing this experiment, you should be able to:

- Undertake experiments to explore how thermal physics applies to objects.
- Use Logger Pro and Excel to investigate thermal physics.
- Interpret data and relate to physics understandings accounting for uncertainties.

Introduction

Thermal Physics has been around forever. Hop along in the PHYSYD time machine with Alex and see how the concepts have evolved over the eras.



1. The photo shows the set up which includes two power supplies, one for the heat source and one for the fan. Identify the switches to the power supplies.
2. Switch on the TWO power supplies.
3. Check if four temperature sensors are inserted in Rod 2.
4. On the computer connected to four temperature senors, find and open Logger Pro icon on the desktop. **OR** Go to start-> all prog -> vernier software -> Logger Pro 3
5. Go to Experiment -> Data collection -> Length -> Set it to 7200s -> done -> collect.
6. On this computer, temperatures are being recorded. In Logger Pro, you can see the lines developing/being graphed as time passes. We will leave this set up to continue collecting data for around 45 minutes.

PHYSYD time machine has now come to 300-400 BC. Along with Aristotle and Hippocratus, observe the nature of one of the fundamental element of life - "FIRE".

Logbook 1.2

1. **Look around the room, and see if you can find a pair of objects who have same temperatures but feel different on the 'levels of coldness' !**
2. On the computer connected to the two loose temperature sensors, find and open Logger Pro icon on the desktop. **OR** Go to start-> all prog -> vernier software -> Logger Pro 3
3. Copy the Table 1 in your logbook. An example of what you need to record is given.
4. Collect 5 cups from the service area; which contains objects from fridge. Check if four of them are labelled as per the table below, which you are going to use for 'Logbook 1.2'/ this activity.
5. Remove the tissue from the cup, plug in the loose thermal sensor into the object. Observe the temperature measurement in logger pro and wait till you are confident that it has reached themal equilibrium. Note down the measured temperature in the respective cell in the Table 1.
6. Hold the object and note down the feel in the Table 1.
7. Repeat the same procedure of 5, and 6 for all the objects. (Do the fridge ones first so that they don't warm up.)

Table 1

Object	Context	Measured Temperature (°C) with uncertainity	'Level of coldness' you feel on touching
Rubber block	From the fridge, in thermocol glass, covered with tissue.		
	On the table, in contact with air		

FIGURE 5.1. First two pages of the thermal physics labonotes

ADV 1: Ultrasonic Waves

Have you done your pre-work on your CANVAS account? It must be done before you come to your laboratory class.

1 Aims and Objectives

After completing this experiment, you should be able to:

- use ultrasonic waves to measure the speed of sound in air.
- use a digital oscilloscope to display signals and make measurements.
- determine the relationship between amplitude/intensity and distance for ultrasonic waves.

2 Introduction

The object of this experiment is to measure the speed of sound and compare it with the value expected for air at a standard temperature. We will also test whether sound waves obey the inverse-square law. In order to do this experiment without creating a lot of noise a frequency of 40 kHz has been chosen, well above the limit of hearing. Audible sound waves lie in the frequency range 20 Hz to about 18 kHz. Sound waves with frequencies above 20 kHz are called ultrasonic waves. They have the same properties as audible sound waves but the wavelengths are shorter, typically $< 1\,\mathrm{cm}$.

Ultrasonic waves have a speed in air at room temperature around 340 $\mathrm{m.s^{-1}}$. Hence at 40 kHz the wavelength is about 8.5 mm. Ultrasonic waves have many practical applications such as the non-invasive imaging of soft tissue in the human body.

3 Theory

Like all other waves, ultrasonic waves propagate at a well-defined speed. For a sinusoidal wave the speed v is related to the wave frequency f and wavelength λ by the formula:

$$v = f\lambda. \tag{1}$$

Sound waves propagate by compression and rarefaction of the medium such that the molecules of the medium move back and forth in the direction of propagation of the wave. Compression increases the temperature of the medium while expansion decreases the temperature. Since the frequency is too high for appreciable heat flow to occur in the available time, the compressions and rarefactions are adiabatic rather than isothermal. For an ideal gas, which has resistance to compression proportional to the specific heat ratio, γ, the speed of sound is given by

$$v = \sqrt{\frac{\gamma RT}{M}}, \tag{2}$$

where

γ is the ratio of the heat capacity of an ideal gas at constant pressure to heat capacity at constant volume. An ideal monatomic gas has $\gamma = 5/3$, a diatomic gas has $\gamma = 7/5$ and a triatomic gas has $\gamma = 9/7$. Air, with an approximate composition of 80% N_2 and 20% O_2, is diatomic.

R is the universal gas constant, 8.3145 $\mathrm{J\,mol^{-1}\,K^{-1}}$.

M is the molar mass. The mean molar mass of air is 28.9635×10^{-3} $\mathrm{kg.mol^{-1}}$.

T is the absolute temperature in Kelvin.

Since v is proportional to $\sqrt{T}$, eqn (2) can be rearranged to

$$v = v_0\sqrt{\frac{T}{T_0}}, \tag{3}$$

where v_0 is the speed of sound at a standard temperature of T_0.

Note: At low frequencies the velocity of sound, in dry air containing 0.03% CO_2 by volume is $v_0 = 331.46 \pm 0.10$ $\mathrm{m.s^{-1}}$ at a temperature T_0 of 273.15 K (i.e., 0 °C); this value is very close to the theoretical value given by Eqn (2). At typical room temperatures of 20–25 °C, v_0 increases with humidity by up to 1 $\mathrm{m.s^{-1}}$.

Reference: Online edition of Tables of Physical and Chemical Constants by Kaye and Laby.

4 Apparatus and Techniques

4.1 Design of Apparatus

The apparatus includes a fixed ultrasonic transmitter and a receiver mounted on sliding supports. Both the transmitter and receiver contain a small piezoelectric quartz crystal, which has the property that it will expand or contract when an electric field is applied to it. Conversely, if a mechanical stress is applied to the crystal an electric field is induced, which results in a voltage across the crystal.

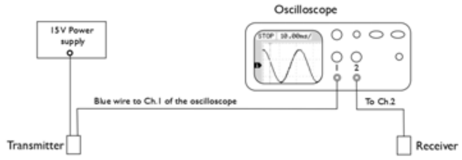


Figure 1: A schematic diagram of the apparatus in this experiment.

The transmitter works by applying an oscillating voltage to the crystal so that it vibrates. This vibration is communicated to the air molecules surrounding the crystal and a sound wave is produced. The receiver works in reverse: the pressure of the sound waves produces an oscillating stress in the crystal, which causes an alternating voltage to appear across the crystal. In addition to generating ultrasound, the piezoelectric properties of quartz crystals

FIGURE 5.2. First two pages of the ultrasound labonotes

5.4 Results

5.4.1 Exploratory Factor Analysis (EFA)

I carried out extensive data exploration in SPSS Version 24 on the 320 ‘clean’ responses. The assumptions discussed in section 4.4.1 were found to be satisfied, the data were found to be appropriate for EFA, allowing further analyses to be conducted. The data exploration showed the following:

- Distributions of the scores produced by individual items were found to be normal.
- Cronbach’s alpha was found to be 0.75, indicating acceptable reliability (Field, 2000).
- Kaiser-Meyer-Olkin (KMO) Sampling Adequacy was acceptable at 0.69 satisfying the recommended criterion (Field, 2009).
- Bartlett’s sphericity test for correlations had significance p=0.00, the determinant 0.06; indicating absence of multicollinearity (Dziuban and Shirkey, 1974; Lindstrøm and Sharma, 2010).
- The inter-item correlations were in the range 0.3 to 0.8, medium to high, indicating that the items were distinct and multicollinearity was not an issue (Cohen, 1988; Sharma et al, 2013; Peixoto et al, 2015).

The factors were extracted using scree plots and factor rotation following the criteria presented in Chapter 4. EFA produced two factors; one containing items from positive emotions of pride and enjoyment, and the other containing items from negative emotions of anger, anxiety, hopelessness and boredom as theorised by Goetz et al (2006) and Russel (1980).

5.4.2 Confirmatory Factor Analysis (CFA)

The EFA indicated that the data were appropriate for CFA to test the internal structure of the emotions. CFA was carried out using SPSS Amos Version 24.0. Analysis was conducted using maximum-likelihood estimation. The parameters and associated criteria used to assess the goodness of fit of the model are shown in table 4.1.

Figure 5.3 shows the model containing six interrelated factors in a multi-dimensional structure as per Peixoto et al (2015). The factor loadings, the left most digits in Figure 5.3, are > 0.6 for all except two emotion items which had reasonable factor loadings of 0.52 and 0.56. The items load appropriately on their respective emotions; hence all items were retained. The latent factor correlations show positive relationship between emotions of the same valence and negative relationship between the emotions of opposite valence as in Pekrun et al (2011).

The measured goodness-of-fit indexes presented in table 5.4 validate the six interrelated factors in a multi- dimensional model of the AEQ-PhysicsPrac survey. Since reliability scores were > 0.6 for all the emotions, the AEQ-PhysicsPrac model is seen to be reliable. The performance of this version of the AEQ in discriminating emotions as per Pekrun's model aligns with AEQ-M (Pekrun et al, 2005a; Peixoto et al, 2015). Furthermore, the model manifests the emotions as differentiated and discrete. This allows them to be probed separately, they can be compared across treatments and their relationships investigated.

Validity Measures - Goodness-of-fit parameters of the model	Score
CFI	good fit at 0.902
Root Mean Square Error of Approximation (RMSEA)	good fit at 0.077
Relative $\chi 2$ ($\chi 2/df$)	reasonable fit at 2.89
Average Variance Extracted (AVE)	Acceptable at 0.5

Reliability measures for each Emotion	Composite Reliability
Pride	0.68
Enjoyment	0.82
Anger	0.73
Anxiety	0.79
Hopelessness	0.72
Boredom	0.83

TABLE 5.4. Validity and Reliability measures of the model

5.4.3 Correlational analysis of the emotions

There are strong positive correlations found between the two positive emotions - pride and enjoyment - and between three of the negative emotions - anger, boredom and hopelessness.

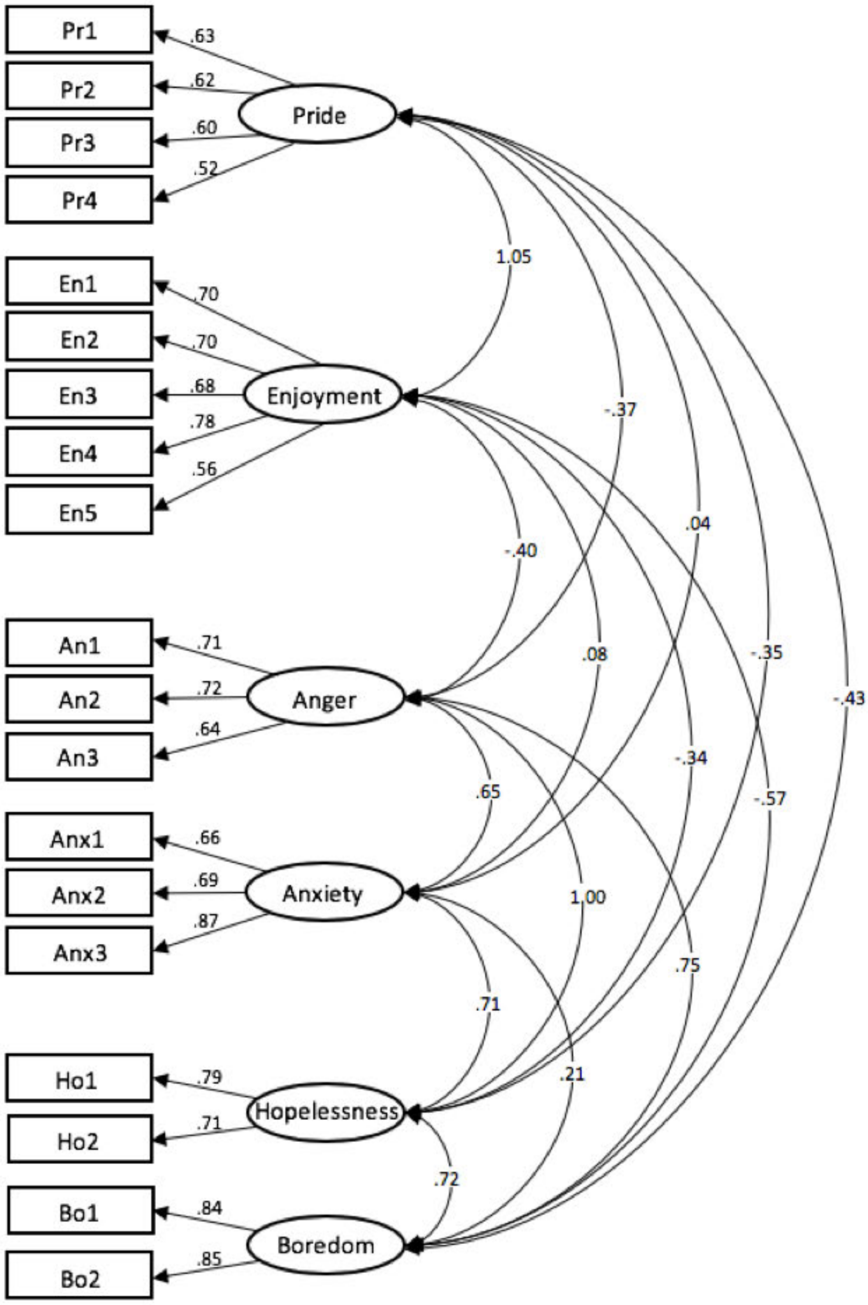


FIGURE 5.3. Six-factor model for physics experimental activity related emotions. Pr, pride; En, enjoyment; An, anger; Anx, anxiety; Ho, hopelessness; Bo, boredom. Each box represents a separate item. (Read from left to right the digits represent factor loadings and latent factor correlations.)

Moderate negative correlations are found across the positive and negative emotions. A strong positive correlation was found between anxiety with anger and hopelessness, yet there is no significant correlation between anxiety and boredom or between anxiety and any of the positive emotions. This situation with anxiety is consistent with earlier research (Pekrun et al, 2011). Table 5.5 shows this trend in correlations for both the intervention and control separately. AEQ-PhysicsPrac has the like valence correlations and opposite valence correlations consistent with expectations from the AEQ model. The correlations show that the emotions are clearly separable. The strongest correlations were found between pride and enjoyment, and between anger and hopelessness, as expected for the like valence trait-like emotions (Pekrun et al, 2011). The strongest negative correlation was found to be between enjoyment and boredom. It should be noted that enjoyment is a positive activating emotion and boredom is a negative deactivating emotion. Thus, my results indicate that not only valence, but the activity level also matters while considering relationships of emotions following the control-value theory presented in section 2.3.3.

	Pride	Enjoyment	Anger	Anxiety	Hopelessness	Boredom
Pride	-	.654**	-.268**	-.028	-.160*	-.287**
Enjoyment	.834**	-	-.293**	.075	-.252**	-.474**
Anger	-.164	-.188*	-	.537**	.711**	.576**
Anxiety	.083	.070	.472**	-	.547**	.139
Hopelessness	-.243**	-.227**	.707**	.517**	-	.541**
Boredom	-.284**	-.375**	.502**	.171*	.522**	-

**. Significant at the 0.01 level (2-tailed).
*. Significant at the 0.05 level (2-tailed).

TABLE 5.5. Correlations between the emotions for the intervention (above the diagonal) and control (below the diagonal)

5.5 Comparing the means for intervention and control

The data were checked for assumptions prior to t-tests being conducted. Table 5.6 shows statistics relevant for comparing the intervention with the control. Pride has 4 items so with a Likert scale, the lowest score is 4 and the highest score can only be 20 as shown in the column labelled ‘Range’ in Table 5.6. Similarly, for boredom there are 2 items so the lowest score is 2 and the highest possible score is 10.

Independent samples *t*-test shows statistically significant differences between the intervention and control for five of the six emotions. For positive emotions, pride and enjoyment, the means are statistically significantly higher for the intervention when compared with the control. For the negative emotions, anger, hopelessness, and boredom, the means are statistically significantly lower for the intervention when compared with the control. There is no significant difference for anxiety.

Emotion	Mean (SD)		Range	*t*	*p*
	Intervention(n=187)	Control(n=133)			
Pride	15 (2)	14 (3)	4-20	2.25	<.05
Enjoyment	18 (3)	17 (4)	5-25	3.66	<.01
Anger	8 (2)	9 (2)	3-15	-4.08	<.01
Anxiety	7 (3)	8 (3)	3-15	-1.85	>.05
Hopelessness	5 (2)	6 (2)	2-10	-3.88	<.01
Boredom	5 (2)	6 (2)	2-10	-3.55	<.01

TABLE 5.6. Comparing intervention with control for each emotion: descriptive statistics and *t*-statistics

5.6 Trends in student responses to each item

I looked to discern patterns in student responses for each item in the intervention and control. I combined the percentage responses: strongly agree is combined with agree to give ‘percentage agreement’, neutral stays as ‘% neutral’, strongly disagree is combined with disagree to give ‘% disagreement’. Figure 5.4 shows these data for the intervention and control for all the items, sorted according to valence, i.e., positive emotions followed by negative emotions. Analysis of the data revealed four noteworthy points. First, for both the intervention and control, the percentage agreement is higher than percentage disagreement with the positive valence items, vice versa is true for the negative valence items. Students’ emotional responses indicate both practicals are positive learning experiences. Second, the percentage neutral responses are relatively similar across the items. Third, there is higher percentage agreement with positive valence items for the intervention than for the control. So, the intervention attracts more positive emotions compared to the control. Fourth, now considering the negative emotions items, I found a higher percentage agreement for the control than for the intervention. Specifically, hopelessness and boredom show double the percentage agreement for the control compared to the intervention. So, the control attracts more negative emotions compared to the intervention.

Item	Summary	% agreement		% neutral		% disagreement	
		Intervention	Control	Intervention	Control	Intervention	Control
Positive Items							
Pr1	Satisfied	80	69	16	23	2	8
Enj5	Cope with	72	62	24	32	4	6
Pr4	Important contribution	72	59	24	29	4	12
Enj3	Efforts paid off	66	56	29	35	4	9
Enj1	Enjoyable challenges	63	50	32	32	6	17
Enj4	Enjoyed	62	39	29	36	10	25
Pr3	Keep up	59	52	34	36	7	12
Enj2	Exciting	45	32	35	38	19	30
Pr2	Elated	42	37	46	45	10	18
Negative Items							
An1	Annoyed	28	32	24	27	48	41
An2	Irritating	26	40	28	27	46	32
An3	Resented	19	38	30	32	50	30
Anx1	Scared	19	33	35	35	46	32
Anx2	Nervous	18	35	37	36	44	29
Anx3	Panicky	18	38	38	36	42	26
Ho1	Give up	17	23	24	25	58	52
Ho2	Resigned	15	19	25	22	61	59
Bo1	Dull	12	23	31	42	57	35
Bo2	Bored	10	17	24	26	66	56

FIGURE 5.4. Percentage Responses for AEQ-PhysicsPrac for intervention and control. Combined as: '% agreement' (SA/A), '% neutral' (N) and '% disagreement' (SD/D)

5.7 Discussion

In this Chapter, I have presented evidence showing that AEQ-PhysicsPrac is a valid and reliable tool. I also described its utility in a physics education study to distinguish between the students' emotion profiles for intervention with the colorful historical story and control with no story.

First, I presented the adaptation and validation of the Achievement Emotion Questionnaire (AEQ) for the first-year physics laboratories. The results from the Exploratory Factor

Analysis (EFA) and Confirmatory Factor Analysis (CFA) show that the AEQ- PhysicsPrac is a valid and reliable tool as per the norms of Peixoto et al (2015). The emotions are found to be differentiated and discrete. The correlational analysis shows that positive emotions pride and enjoyment are found to be highly positively correlated with each other, and negatively correlated with negative emotions anger, hopelessness and boredom. The negative emotions are positively correlated with each other, except for the emotion of anxiety which has also been noted as a special case by Pekrun et al (2011). It is noteworthy that earlier studies have found anxiety to have complex effects on students, occasionally affecting them positively, sometimes negatively and other times not affecting them altogether (Pekrun, 2009).

Second, I showed that both the practicals, intervention and control, are positive learning experiences overall. A comparison between the control and the intervention containing a 'colorful historical story' revealed that the intervention produced more positive emotions and less negative emotions. This suggests that the 'colorful historical story' was effective in emotionally engaging students. Results also indicate that the AEQ-PhysicsPrac is able to successfully measure the differences in students' emotion profiles; this opens up the possibility of obtaining different profiles of emotions experienced by students for different practicals.

Here I have shown the utility of the AEQ-PhysicsPrac for differentiating two practicals with the intent of discerning differences in achievement emotions; in the next Chapter I will utilize the survey to investigate differences in emotional engagement of students within different cohorts.

5.8 Summary

In conclusion, adaptation and validation of the survey tool AEQ- PhysicsPrac are presented in the Chapter. The tool is shown to be successfully measuring first-year physics students' emotional engagement. It also discriminates the emotion profiles for two practicals, the control and intervention. I also incorporate 'colorful historical story' in the intervention, which shows better emotional engagement of students compared to the control.

CHAPTER 6

Influence of Stories on Different Physics Cohorts

6.1 Introduction

In Chapter 5, I looked at the practicals 'Thermal physics' and 'Ultrasound' in order to validate the AEQ-PhysicsPrac. In this Chapter I look at a series of practicals on electricity in two courses designed for different cohorts; one the cohort for physics majors and those interested in more technological fields, the other that for those pursuing environmental and health disciplines. Please refer to figure 4.1 for further detail.

It seems likely that there would be inherent differences between how students in the two courses feel about their physics courses and physics itself. 'Colorful historical stories' were inserted into a series of four practicals on electricity and the influence of the stories on students' emotions in the two courses was investigated.

In this Chapter, I address the following research aim:
To investigate the differences in students' emotional engagement as measured with the AEQ between two different cohorts, Environmental and Technological.

6.2 Method

6.2.1 The courses, sample and procedure

The stories were deployed in two parallel first-year physics courses, with different practicals from the ones presented in Chapter 5. The Environmental Physics (ENV) course is for students interested in environmental and health disciplines. Students studying ENV mostly do not continue further in physics. The Technological Physics (TEC) course is for students studying chemistry, engineering, and physics with approximately half the cohort continuing onto further physics studies. The two courses have identical structures, including three one-hour lectures, a one hour tutorial and a three hour practical each week. The sequence of the content taught is same for both courses. The format of the assessment is also similar for both courses. There is a minimum participation requirement in the laboratory component. A total of 25% of the marks are attached to laboratory-based assessments: an individual laboratory report, a written test and a practical test. In each course a third of the lectures and tutorials cover electricity and magnetism; thereby a four-week series of laboratory practicals on electricity. The practicals are as follows:

- Practical 1: 100 years of electricity: Foundational inventions
- Practical 2: Electricity in business - The ultimate war
- Practical 3: Electricity as medicine
- Practical 4: Solar energy - Milestones

The 'colorful historical stories' presented in Figures 3.2, 3.3, 3.4 and 3.5 in Chapter 3 were inserted in the student laboratory notes for these four practicals. Sometimes, students were briefed about the stories, other times not. Some students discussed the stories and the physics related to them, some others referred to the humor in the stories, cracked a joke, and laughed amongst their groups, others just smiled looking at the pictures, yet others hastily started the practicals and did not look at the stories.

Students worked in teams of three on the practical. A total of 46 students from ENV of 62 present (74%, responded to our surveys, and 118 from TEC of 187 present (63%) responded. The response rate was 74% for ENV and 63% for TEC.

6.2.2 Data collection

As mentioned in section 4.3, data collection consisted of three components, a written survey with rating scale and open-ended responses, direct observations of the laboratory sessions and tutors' feedback.

I carried out the observations for entire three hours during three practical classes, one in an ENV class and the other two in TEC classes. Students had been informed that I would be observing the laboratory class. I moved slowly around the room, hovering as I took notes in my book, not looking directly at the teams. The observation protocol was the ‘fly on the wall’ approach in which the notetaking does not identify participants during the process. I noted the distribution of students in teams, including their gender. Observations were recorded under the column headings of behavior, emotion, quotes, and notes (covering the interactions of students within their teams). The time spent observing each group varied according to the amount of activity taking place, but I sampled all teams carefully.

AEQ-PhysicsPrac was administered when the students had completed all four electricity practicals. At the start of the practical a short introduction to my study was provided, and students were informed that participation was voluntary and anonymous. I requested students to either place the filled surveys in a box or leave them on their bench by the end of the laboratory class.

Immediately after the laboratory class, I individually asked for the tutors’ reflections to get their feedback. I wrote down their responses for the analysis to be conducted.

6.2.3 Quantitative data analysis

It was confirmed using the results from confirmatory factor analysis (CFA) conducted in a similar manner to Chapter 5, that the AEQ-PhysicsPrac was a valid tool to measure emotions in first year physics laboratory context (Bhansali and Sharma, 2019). Quantitative analysis was completed by examining the correlations between the emotions and comparing means of the emotions for the ENV and TEC courses. Inferential statistics: Pearson’s correlations and *t*-tests were conducted as mentioned in section 4.4.3.

6.2.4 Qualitative data analysis

The open-ended survey questions were intended to gauge the effect of stories on students’ emotions. The set of four open-ended survey questions were:

(1) The four practicals had little colorful historical stories in the Introductions. Did you have a quick look or read through them? What did you feel? Circle the relevant emotions and explain.

(2) Did the stories motivate you to positively engage with the practicals? Explain.
(3) Would you like such short colorful historical stories to be added to your laboratory instructions?
(4) Any other comments.

During the initial scan of the data, the four responses from each student were read together. From the responses of open-ended question three, I counted the number of students who circled each emotion as well as the number of students who indicated that such stories be retained. I also counted the number of students who clearly stated that they were motivated by the stories. The tallies were tracked as the categories were developed and formalised as shown in figure 4.5B. The categories formed and emotions selected for each category are presented in table 6.1 and figure 6.1.

The open-ended responses were coded using a mix of inductive and deductive coding as explained in Chapter 4. I scanned the data and identified broad patterns inductively as well as deductively, with the six emotions in mind. In the next stage, my supervisor and I generated detailed codes from the broad patterns. Grouping similar codes, we generated the categories through an iterative development process as described in section 4.5.2. The inter-coder reliability was 89%. The constraints of the COVID-19 pandemic precluded the consultation of any third party.

Thus, the responses of each student to all the questions, analysed one-by-one, were used to generate broad patterns as well as 'qualifiers' which provided nuanced insights into the categories. The categories were robust enough for students' responses to be consistently placed into distinct categories. Hence, for each category, I was able to provide category descriptions as well as nuanced 'qualifiers'. Furthermore, since I had been tracking which emotion students had circled, how many had indicated retaining the stories, and how many had indicated that they were motivated by the stories, I can provide this information for each category for each course.

Category	Short form	Meaning of the category	Number of responses	
			ENV	TEC
Interesting	*I*	Stories were interesting	5	10
Interesting and helps feelings	*IF*	Stories helped students emotionally engage with the practical	8	18
Interesting and helps learning	*IL*	Stories helped students learn physics better	6	5
Interesting and helps feelings and learning	*IFL*	Stories helped students emotionally engage as well as learn better	2	14
Interesting but not helpful	*IN*	Stories were interesting but did not help in any way, neither for students' engagement nor for their learning	5	4
Uninteresting	*U*	Stories were neither interesting nor relevant to the practical	4	16
Comments on lab	*C*	Students had issues with the practical	1	6

TABLE 6.1. Categories, their meanings and number of responses from both the courses. Environmental (ENV) and Technological (TEC)

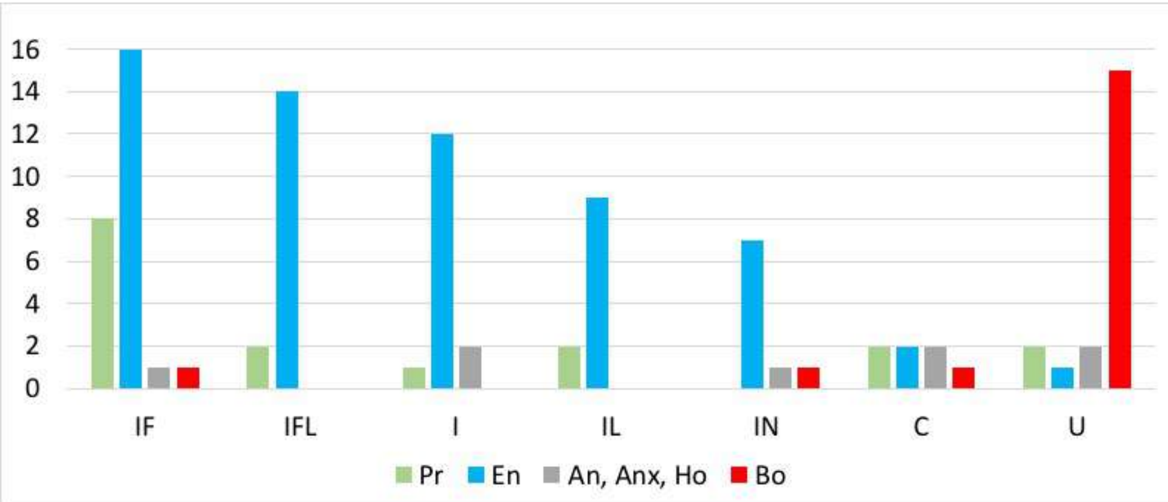
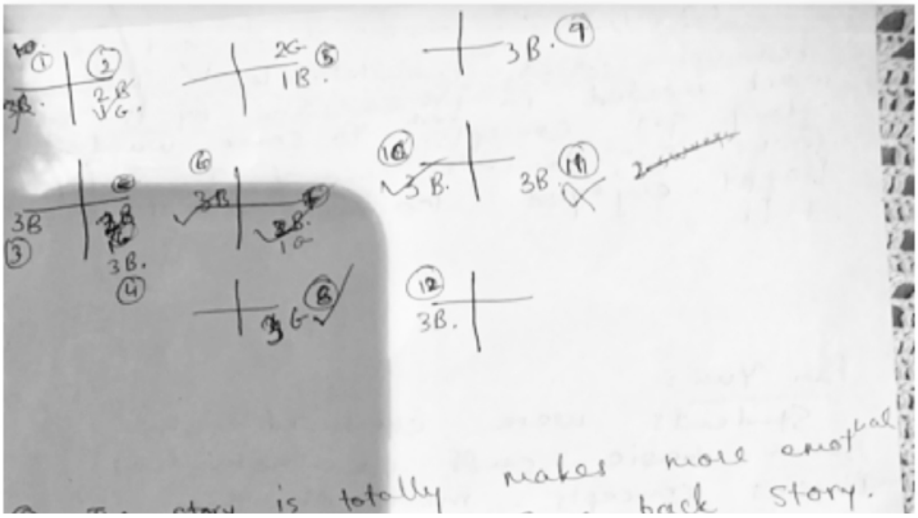
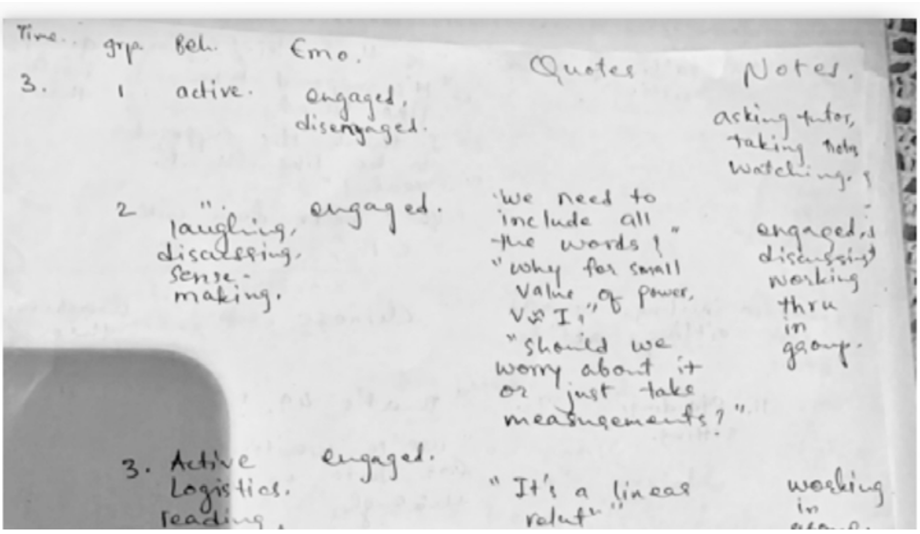


FIGURE 6.1. Emotions selected by students in each category



(A) Student distribution in the class



(B) Students' behavior, emotions, quotes and my comments

FIGURE 6.2. Typical observational notes for a physics laboratory class

In addition, I conducted class observations with a focus on students' emotions and activities. Figure 6.2 shows an example of the raw data I gathered in the 3-hour laboratory classes. Figure 6.2A shows how I recorded and numbered the student distribution in the class, while figure 6.2B shows the columns and example of observational data. I recorded students' behavior, emotions and quotes in the first four columns. In the last column my comments on the particular observation have been recorded.

I typed these data into EXCEL, identified groups which showed similar patterns, gathered the types of comments connected to certain segments of the practical work and generated a narrative threading the ambiance or mood over the practical session. I analysed the observational notes seeking to paint a picture of the atmosphere in the laboratory and how emotions flowed, intensified and ebbed.

I conducted brief tutor reflections with a focus on tutors' perspectives on students' capability and competence in completing the tasks and tutors' approach to the support that students needed. I tried to probe tutors' take on 'how relaxed' they themselves were with regards to students' focusing on their tasks and learning. The interviews provided rich descriptions of how the tutors influenced or reacted to the moods and emotions of the students.

Hence, the qualitative analysis helped deep understanding and allowed triangulation of student perspective on the stories and stories' influence on the students, adding words to the scores provided by the quantitative results.

6.3 Results

6.3.1 Quantitative results

I use three methods of analysis: Pearson's correlations, descriptive statistics along with *t*-test, and percentage responses for each item for the two courses, ENV and TEC.

The Pearson's correlations, as presented in table 6.2, show that the positive-valence emotions, enjoyment and pride, are statistically significantly correlated with each other for both courses. Furthermore, three of the four negative-valence emotions, anger, hopelessness, and boredom are positively correlated with each other. Anxiety is anomalous: in ENV, anxiety is positively correlated with enjoyment, but not with anger; in TEC, anxiety is positively correlated with pride, enjoyment and anger. The correlations are found to be in agreement with those seen in earlier studies as mentioned in section 5.4.3.

Table 6.3 shows the descriptive and inferential statistics. The means for each of the emotions in both the courses are presented. The *t*-statistics show no statistically significant differences between the means of the emotions for the two courses.

Figure 6.3 shows that the largest percentage of agreements and the lowest percentage of disagreements were recorded for the positive items. While large percentage disagreements and low percentage agreements were recorded for the negative items, these were not as polarised as those for the positive items.Next I explore the patterns in the rich qualitative data.

	Pride	Enjoyment	Anger	Anxiety	Hopelessness	Boredom
Pride	-	.740**				
Enjoyment	.742**	-		.400**		
Anger			-		.702**	.497**
Anxiety	.285**	.250**	.625**	-	.398**	.325*
Hopelessness			.728**	.652**	-	.683**
Boredom			.578**	.292**	.468**	-

**. Significant at the 0.01 level (2-tailed).
*. Significant at the 0.05 level (2-tailed).

TABLE 6.2. Correlations between the emotions for the ENV (above the diagonal) and TEC (below the diagonal)

Emotion	Mean (SD;SEM)		Range	*p*
	ENV (n=46)	TEC (n=117)		
Pride	14.20 (2.90; 0.43)	14.47 (2.49; 0.23)	4-20	>.05
Enjoyment	16.78 (3.41; 0.50)	17.35 (3.80; 0.35)	5-25	>.05
Anger	8.15 (2.20; 0.32)	8.21 (2.43; 0.23)	3-15	>.05
Anxiety	7.87 (2.68; 0.40)	7.93 (2.89; 0.27)	3-15	>.05
Hopelessness	5.30 (1.95; 0.29)	5.42 (1.94; 0.18)	2-10	>.05
Boredom	5.48 (2.19; 0.32)	5.50 (2.06; 0.19)	2-10	>.05

TABLE 6.3. Comparative ratings for ENV and TEC for each emotion: descriptive statistics and *t*-statistics

6.3.2 Qualitative Results

6.3.2.1 The categories

A total of 127 students, 36 in ENV and 91 in TEC, provided relevant responses. In answer to the question asking if they would like short colorful historical stories added to their

Item	Summary	% agreement		% neutral		% disagreement	
		ENV	TEC	ENV	TEC	ENV	TEC
Positive Items							
Pr1	Satisfied	76	76	18	22	7	3
Pr4	Important contribution	71	65	20	30	9	5
Enj3	Efforts paid off	62	61	33	33	4	6
Pr3	Keep up	62	60	31	35	7	5
Enj5	Cope with	60	60	32	34	9	6
Enj1	Enjoyable challenges	57	65	37	27	7	9
Pr2	Elated	52	38	32	53	16	10
Enj4	Enjoyed	45	51	39	34	16	15
Enj2	Exciting	40	39	29	40	31	21
Negative Items							
Bo1	Dull	34	28	27	33	39	39
Bo2	Bored	32	25	25	33	43	43
Anx1	Scared	31	34	27	25	42	41
An2	Irritating	27	23	27	34	47	43
An3	Resented	25	17	36	40	39	43
Anx2	Nervous	24	30	27	28	49	42
Ho2	Resigned	20	17	36	41	43	43
Ho1	Give up	18	25	36	35	46	40
Anx3	Panicky	16	17	30	31	55	52
An1	Annoyed	13	23	47	42	40	34

FIGURE 6.3. Percentage responses to AEQ-PhysicsPrac for ENV and TEC. The results have been combined as '% agreement' (SA/A), '% neutral' (N), and '% disagreement' (SD/D).

laboratory instructions, 60% answered 'yes' and 20% answered 'no', common comments were, 'a must in my opinion' and 'sure, add the stories'.

The initial scan of the open-ended survey data showed that responses to the four questions listed in section 6.2.4 were internally consistent in that pattern was emerging. It also provided a cohesive student perspective on the stories and their influence on the student. This perspective suggests that the stories and feelings, as well as the task at hand and doing the practical, could be interconnected. It was found that students' responses could be reliably placed into the seven descriptive categories shown in table 6.1.

The second finding of note emerging from the line-by-line coding is the pivotal role of 'interest'. The description of the seven categories sheds light on these two findings as well as reveal other nuances.

As mentioned earlier in section 2.2, interest manifests itself as a two-step process in engaging students, latching on and then holding their attention (González and Paoloni, 2015; Renninger and Hidi, 2015). If interest catches and holds then the chances of behavioral and cognitive engagement increase, resulting in more effective and productive time spent on the task being undertaken (Renninger and Hidi, 2015). On the other hand, students' gaze can be caught fleetingly without their attention being held. Sometimes students provide a qualifier that can shed light on other matters that are at the forefront in their minds.

The first category, called *interesting I*, is where the responses indicated that the stories had caught the student's eye, even though they may not have held their attention. It contained simple comments such as,

They were interesting

It is good

Refreshing

Yeah it is cool

Sometimes motivated by the story

Others acknowledged that they had not read the stories, but had noticed them,

Although I didn't look at them, I found it good to have a colorful picture

I didn't pay attention to the stories, but I appreciate them being there

Some students, predominantly from the TEC course provided qualifiers, commenting on aspects of the stories and the process of learning physics:

Found them interesting as a light read before the practical. Add if we are not tested on it.

I didn't pay attention to the stories, but I appreciate them being there. Keep them in the laboratory notes but do not make them integral to it.

It is good, but we generally did not read. Not interesting practical, need more clear information, there is a lot of work we need to do.

The comments placed in category *I* were proportionately distributed between the ENV and TEC courses; eighteen had circled enjoyment, one pride, three anger/anxiety/hopelessness, and one boredom. Nineteen of the twenty-three students recommended retaining the stories; seven of them said stories motivated them to engage positively with the practical.

The second category, called *interesting and helps feelings IF*, is where the responses indicated that the stories had caught a student's eye and the stories had touched them, leaving an impression on their sentiments. Students' comments contained a tone, a mood, or a frame of mind, such as,

Excites me and absorbs my attention

It's good for my feelings about physics

Those stories just inspire me

Others connected the stories with prior experiences or things beyond physics,

It is always nice to hear about the greatness of Einstein-I idolize him

Read through them, they were interesting, they gave us an appreciation of history

I like the historical stories

Wonderful to connect with historical figures. Sometimes provides a small break

Some students, mostly from the TEC course, provided qualifiers similar to those for the category *interesting I*:

It was more fun to read the history then conduct the practical (I am not good in labs. If they can do it, so can I).

They were pretty cute, I enjoyed them. Add, as long as we don't get examined on them.

They are intriguing. Practicals are bad for me ...

I like seeing real-world applications. I enjoyed having them. Really annoyed when the graph did not work.

Once again, the distribution in the *IF* category was proportionate across the ENV and TEC courses; sixteen had selected enjoyment, eight pride, one anger/anxiety/hopelessness, and one boredom. In terms of retaining the stories, twenty-three of the twenty-seven selected retaining the stories, while twenty said stories motivated them to engage positively with the practical.

The third category, called *interesting and helps learning IL*, is where responses indicated that the stories had caught the students' eye and the students saw benefit directed at the task at hand or with disciplinary knowledge and skills. Comments ranged from overarching statements, *'It makes me understand physics'* and *'gave us knowledgeable insights'*; to those focusing on skills and ways of learning, *'Stories help with thinking individually and critically'* and *'it provides another way of study'*. Others commented specifically on the task at hand, *'we can learn more things about the practical'* and *'Learnt background information'*. This category did not attract qualifiers. The students were again proportionate from both courses; nine had selected enjoyment, two pride and none from anger/anxiety/hopelessness and boredom. In terms of retaining the stories, ten of the twelve recommended retaining the stories, while seven said the stories motivated them to engage positively with the practical.

The fourth category called *interesting and helps feelings and learning IFL* contained more elaborate responses indicating that the stories had caught students' eye and held their attention. Category *IFL* articulated aspects of both 'feelings' and 'learning'. The responses in this category are more thoughtful and cohesive. This category combines the earlier categories.

In general, the thread from category *IL*, that there is something from prior experience which held their interest, compelling them to pause, read, and connect, continues. For some, the stories from history were captivating and were appreciated.

It was good to learn the history, somewhat helps create a direction of work and helps you get into the 'scientist' mindset

Background history is interesting and relevant, feel a sense of excitement

It is always interesting to read the history behind certain practicals. It gives us a better understanding and gives us some context

Enjoyment on the achievement of our predecessors. Motivating, gives further understanding of the practical

Others found the provision of context inherently interesting, responding to the notion of a story anchoring the practical (Stinner, 1995; Corni, 2014).

Provided context on the applications of physics... Provided an interesting use of the science ... Engaging texts are ones that can use them to great effect.

They added context to the practical, they alloyed my resignation and left me in a better mood.

Yet an other student was hooked on applications, eloquently commenting on how connecting with utility in real life resonated with them.

It's quite intriguing that we can actually see how this practical can be applied in real life, and how these products have historically developed. Seeing these stories actually make me think this practical is useful in real life.

Qualifiers were not provided by the students in this category. Students were distributed equally between the two courses for responses in this category. Fourteen had selected enjoyment, two pride, and one from anger/anxiety/hopelessness and boredom. In terms of retaining the stories, sixteen of the seventeen recommended retaining the stories; twelve said the stories motivated them to engage positively with the practical.

The fifth category was called Interesting but not helpful *IN* is where the students explicitly stated that that is what the stories are. The responses again hint at the stories containing elements that caught their eye, but qualifiers indicate that there is a 'cloud' overriding the appreciation of the stories. The focus in the qualifiers was on the relationship between the stories and the practical, assessment, or the course. In essence, the responses suggested that the stories did not meet students' strategic priorities. The stories did not serve the direct process of learning physics. These students were not ambivalent. For some, the comments captured an appreciation of the historical stories but also conveyed a sense that historical stories were not useful in doing the practicals.

Cute fun facts made lab seem more relaxed and less strict in attitude, less pressure, but not useful, less efficient

These stories are interesting and exciting but can't give me much help to do the practical

Interesting historical context but had no effect on my attitude towards engaging with the practicals

Others were focused on assessment, noting that the stories were neither core nor required.

Amused, but not relevant, beyond the scope of lecture content and examinable practical skills

Interesting historical context, they didn't have any impact … unless crucial knowledge for exams

I enjoy history but not in the labs. Was useful but not required. ... I was expecting more interesting labs

Looking further at this group of ten students, I found that seven had selected enjoyment, two pride and one anger/anxiety/hopelessness and boredom; once again the distribution was similar across the ENV and TEC courses. In terms of retaining the stories, five of the ten selected retention, while two said stories motivated them to engage positively with the practical.

The sixth category called *uninteresting U* contained responses ranging from the ambivalent to those who expressed the reverse of what was in the *I, IF, IL, IFL and INH* categories and a few who were generally indifferent. The students did notice the stories, but the stories did not catch their attention. Some comments were,

I felt nothing. I wasn't interested.

Wasn't too invested in history, usually just brushed over them to start the practical. Do not mind the stories.

Didn't really complement content in the practicals. I am indifferent. The engagement was independent of the content of the stories ...

Didn't really pay much attention to the introduction, it is not really necessary.

Only looked at them when required for checkpoint, I didn't read them

The stories happened long time before. I got all the checkpoints during the laboratory session

Some students, predominantly from the TEC course had provided qualifiers which indicated that the stories were viewed as a deterrent or were hampering the process of learning physics. Category *U* qualifiers were more intense and more focused than qualifiers from other groups; bemoaning the practicals, equipment, or other aspects.

Stories didn't motivate me. University is difficult. So is life ;)

Could not relate to practical studies. Not motivating, felt irrelevant. Solar panels (practical) was good, oscilloscope work was irrelevant/ uninteresting

Often felt more like irrelevant background information rather than necessary information, felt like a bit of a waste of time. these labs need more explanation of the tasks and the equipment required rather than the background of history. It would be nice if the laboratories related to the course work and were more engaging rather than boring

The story does not show much appeal, do not need to read to complete the test, make them integral to the practical.

Some expressed dislike of history, pointing out explicity that they were studying physics, not history.

I didn't read them because I am disinterested in history and was more focused on getting the practical over and done with. These practicals have been the perfect balance between challenging and achievable so I always feel good about getting them done

I don't like history, and that is why I study physics. I don't wanna see historical stories. The study makes me happy

Once again, the distribution was similar across the ENV and TEC courses; one had selected enjoyment, two pride, three from anger/anxiety/hopelessness, and fourteen selected boredom. In terms of retaining the stories, five of the 20 selected retaining the stories, while none said stories motivated them to engage positively with the practical.

The last category called *comments on laboratories C* contained responses which captured issues that students faced during the laboratory. A few comments were, *The labs were poorly run . . .*

Want this lab weighted more in the whole course

Perhaps the instructions in the manual to be clearer

I felt very unprepared. The practicals also had low relevance to lecture.

The labs weren't particularly helpful. ...

Staff not helpful. Only one tutor explained

Once again, the distribution for the seven students in this Group was similar across the ENV and TEC courses. Two of them selected enjoyment, two pride, two anger/anxiety/hopelessness, and one boredom. In terms of retaining the stories, three recommended retaining the stories, while two said stories motivated them to engage positively with the practical.

Thirteen students just circled an emotion; these students were not categorized. I found that six of them selected enjoyment, five pride, and two anger/anxiety/hopelessness/boredom. In terms of retaining the stories, five recommended retaining the stories, and three said stories motivated them to engage positively with the practical.

I note that the majority of students who completed the open-ended responses circled positive emotions, enjoyment, and pride and that these emerged in their written responses with 'interest' as the cornerstone (see figure 6.1). This Enjoyment and pride are activating, and it shows in the responses, especially in the two categories with learning. The most circled negative emotion was boredom which is associated with the category uninteresting. Students across all categories recommended retaining the stories. In summary, the colorful historical stories did not detract from the core learning tasks, were interesting for most students, and led to emotional engagement.

6.3.2.2 Class Observations

I observed three laboratory classes. I will present the overall picture of the laboratories observed, I will present the conversations of the students in groups, that I came across during my observations. Some observations were common across the group conversations in a class so while presenting those conversations I will not refer to the specific student-group. Each of the observed laboratory classes was led by one supervisor supported by two tutors. The students worked mostly in teams of three, though some were in pairs. The first observed laboratory class was an ENV session which ran from 10 AM till 1 PM on a Thursday with twenty-nine students, twenty-three males, and six females.

The session started at 10:09 with the supervisor providing a brief introduction to frame the session and settle the students. He asked for a series of responses for the following,

Define AC

About any voltage, is it zero?

We'll explore shapes of AC

Capacitor doesn't conduct, so why is it used in a circuit?

The supervisor attempted to make use of PowerPoint slides to get students into a mindset for practical work, getting them excited. Students responded well, they chatted within their teams, glanced at the equipment, and quickly gave answers. The supervisor made use of their responses to weave together the aims of the practicals, highlight key ideas, and discuss the instruments, measurements, and activities.

Students were actively engaged, connected with their teams, paying attention to the equipment, and were ready to learn. A scan of the room showed that students had turned on the large computer screens on their workbenches, most were on the first page of the laboratory instructions displaying the historical colorful stories, others had moved to other pages.

At 10:15 the students started their practical work. During the next half hour, the students were dynamic, starting with figuring out the logistics and getting organized, chatting within their groups. This morphed into figuring out how to set up and use the equipment,

Regarding horizontal cursor

What does cursor A mean?

This is horizontal

Not really sure. How to get 10.5 volts/div scale

Why 8.6 and not 10?

Some were smiling, laughing, and happily adjusting and toying with the Digital Storage Oscilloscope (DSO) buttons to see how the graphs were changing. Three teams tagged as teams 6, 10, and 11 were vibrant and quite chatty, contributing to the positive ambiance in the room. Others, teams 2 and 3, were diligently consulting their notes, somewhat silent and focused within their group learning environment. Yet others, teams 4, 7, and 8, were more tentative and were waiting for a tutor's guidance. Students appeared confused and lost. There was some sharing between teams of what they had learned.

Just before 11 AM, the mood dampened, and the room quietened a little. Some students had their heads cupped in the hands and some were leaning on the bench,

I wish I could do…

I think it's…

Is this 1 or 2?

They were persisting, collaborating, and going through the logistics. Others were all engrossed, not at all despondent, engaged in taking measurements using the DSO. For example, team 11 was smiling, laughing, and active,

There you go!

Your cursor was...

and the tutor commenting,

Don't worry about it. You've done it well

One team member leaning on the table, a bit lost started following and actively participating again. The supervisor made an announcement walking casually around the room, *'don't spend much more time on this section'* indicating to teams to finish off and move to the next section. He connected with individual groups where this was particularly pertinent, helping them to finish off and move on.

By 11:15 the room was vibrant again, discussions were animated, all the students were active, and their faces were curious. Team 10 was confident and curious after successfully setting up the DSO independently and in discussions understanding how to use the different functions,

Oh!!! Freq

So we have to move cursor? 10.2

What's freq... what's unit? ... that's micro or nano? ... Ah ok! ... haha..yeah that makes sense

Team 11 was very excited as they changed frequency and watched the graph change, making sense of the physics involved and playing around with the DSO,

'in 1 microsecond it moves back and forth these many times'

In contrast, team 8 were tired and were lying their heads on the bench, but were still putting in efforts to progress in the practical. They were asking other students' and tutors' for help.

At 11:30, the supervisor set the pace again by reminding students that they should be close to finishing the second section of the practical and should be moving on to the last section. Students were engaged, teams were working well together. Team 7 who had been tentative at the beginning were now happy active and manipulating the DSO, changing the frequency, and trying to get good shapes to take measurements,

'Yeah'

Team 10 was not so confident with their results; they were busily deliberating with a tutor. Team 6 was curious trying to make sense of the physics,

How you did that?

Oh!! You changed frequency

So it has lower time...

Oh..

Cool!

By noon most of the teams were realizing that they were close to finishing. Interestingly, instead of finishing quickly, many teams were discussing what they had learned and taught each other. Group discussions focused on how to read measurements off the graph on the DSO and what this meant in terms of the physics. The lack of time pressure made students comfortable: it gave them time to complete their records, revisit any confusing points, and tidy up. There were several questions to be answered, one was on the colorful historical story on Tesla and Westinghouse. Students discussed the story as they were finishing up. Students did not leave immediately after the laboratory activity was completed, they would sit and chat- discuss the stories and relate them with the practical that they did. The process at the end allowed them to linger in the space and savor the moments, closing the loop by ending with the story that had been the starting point. It is important to note that the tutors took a relaxed stance with the ENV class, their focus was on having an outcome where students comfortably completed the session.

Two TEC sessions were observed. Compared to the ENV session these sessions were more intense. The laboratory seemed noisier, with more students than there were in the ENV session. Students were seen to be engrossed in the practical throughout the session. The first of these sessions ran from 2 PM till 5 PM on Thursday with thirty-six students, twenty-nine males and seven females.

In the first half of the session, students were engaged in discussions, seeking the tutor's help, observing the instruments and noting the readings down in their logbooks. Teams 2 and 10 worked deliberately and enjoyed themselves thoroughly, starting the session by making sense of the data, then analyzing it, thinking over the physics concepts and where they made missteps, enjoying, laughing, and smiling throughout the laboratory. They were excited about what they had learned in the laboratory saying,

Oh cool! Interesting!

When asked about their outlook on the story by the researcher, the female in the group reported,

The story totally makes more emotional engagement. I have some back story. I like the colors.

The two males in the group agreed.

At repeated intervals throughout the session students were seen to be standing, rather than their normal mode of sitting; this explicitly indicated the high energy level of the class. The emotional expressions of team 3 while reading the laboratory instructions out loud indicated their focus on the logistics, *It's a linear relation*

What you doing? We haven't done it yet. It's the same thing, you're wasting time. Hurry up.

Circuit fit in..

Yeah that's better

We use... oh no!

Yes cool

Na it's variable

Use keywords, underline

And then...

While team 6 was seen to be concentrating intently, discussing within their group,

'just finish the other one.

oh, that part?

yeah I know!

Team 9 was engrossed in sense-making while connecting the circuit

It's parallel

Voltage is...

Oh!

They were able to complete the task without a tutor's help,

Is that alright?

It's supposed to be like that

I think it's supposed to be that

Yeah!

Yes! we're done!

Teams 5, 7, and 11 were seen to be working relatively silently, asking fewer questions to the tutor and smiling towards the last hour of the laboratory. Some students were singing and clapping at a point. Overall, the students wrapped up the laboratory relatively silently with fewer discussions than during the laboratory session. Students' engagement was bona fide, a few students were discussing the applications of the practical with the tutor after the session ended. Throughout this session, students displayed a wide range of moods from straight-faced to singing and clapping, alongside a range of engagement levels from focusing on logistics, to physics sense-making, to applications of the practical. Their focus was on the processes of learning physics with all its associated technical details.

The second TEC session took place from 2 PM to 5 PM on Wednesday with thirty-nine students, thirty males, and nine females. The session started with the supervisor explaining the physics behind the practical. Students were paying close attention, listening with pin-drop silence. Once the practical activities started the noise level increased: students were seen to be agile and emotionally involved. Six teams were seen to be anxious, bored, and confused at points during the session, while four teams were seen to be happy, smiling, and confident throughout the session. It was also evident that concerned and confused students became happier, indicated through their smiles, once they came to an understanding of the material or obtained practical results they believed were correct. For example, upon getting the expected result by changing a circuit connection a group said, *'oh great! I love this lab!'*

In the first hour, students were setting up the instrument, carefully reading the laboratory instructions, working on the laboratory task, resolving their doubts with the tutor, and turning to data collection. A few students started working on the laboratory activity but quickly lost interest, turning their attention to their mobile phones.

Team 8 was bored and confused but still, they persisted and were forthcoming in making sense through raising questions within their team,

How does low pass circuit work?

Is it attenuation?

So, what's...

Team 11 worked with earnestness and peculiarly,

Dude! It doesn't work!

Seriously!

Hang on! Look! Look! (watching graph on DSO)

They were perturbed when it didn't work, leaning on the table looking into DSO as the tutor was helping, and becoming happy after getting the correct results,

Is this what we are supposed to find?

Lovely!

Team 9 was spirited during the first half of the session and later was found to be in a mixed mood, oscillating between tired/bored, and singing/dancing, whoof...

yeah it's bad!

oh my god!

Team 3 was observed to be confident and forthcoming, team-members helping each other to learn concepts while conducting the practical,

we make different scales

yeah that's easy

so that's the resistance of the capacitor

if you have high freq... That's why it's changing so fast

you know what I mean?

Does it make sense?

Teams 5, 7, and 10 were seen to be confident, cheerful, smiling through the laboratory. Team 2 was seen to be excited and laughing

'oh! Damn!', 'But our values are ok...', 'hey!' 'this is good!'

Towards the end students were chatting and finishing up quickly. Team 2 finished with a high five, exclaiming,

'Beautiful! Yeah! We are done!'

Again, there were a lot of technical in-depth discussions and exclamations associated with the processes of learning physics during the session.

6.3.2.3 Tutor reflections

I tried to probe tutor's take on how relaxed they themselves were with regards to students focusing on tasks and learning through tutor reflections. Tutors' were asked to reflect post-practical, that is, I was relying on tutors noticing without prompting so as to not introduce bias. Tutors asked to share their perspective of students' engagement and mood during the laboratory. While tutors' were not asked to specifically comment on student emotions in response to the stories, the mood served as a proxy for the ambience.

Directly after the laboratory session, I asked three tutors about their outlook on the students' experience during the laboratory session. All the tutors who provided reflections tutor both the courses. These reflections lasted two minutes or so. The tutors commented on:

(1) Completion of the tasks, level of independence and, factors affecting students' laboratory-work.
(2) Students' emotions, interest, and engagement.

Tutors said that majority of students could complete most of the tasks in the laboratory, and that students found tasks to be simple and not complex. A few students needed a little help, some of these did not feel comfortable asking questions due to shyness. There were a few students who tried to rush through the practical and didn't check the laboratory instructions or the circuits; some thought that laboratory instructions should be made clearer, and some faced issues regarding the instrument, the DSO. While this was generally consistent across ENV and TEC, the TEC class was more focused on understanding the physics and learning the skills and techniques.

Students were pretty happy and enjoyed the laboratory session, they were not seen to be angry or frustrated. Students got bored when they couldn't figure something out or got confused over basic things like uncertainties in the measurements. Overall, students were seen to be less bored than during earlier practical sessions, where there were no stories included in the laboratory instructions.

Students' emotions had definitely improved. They looked interested in doing the practicals. Students were engaged consistently with the practical, with no mobile phones, common sources of distraction, being played with. Most of the students knew the physics concepts behind the practicals and others achieved that understanding through the practicals. While such sentiments were similar in the two courses it was noted that the ENV group was happy to simply comfortably complete the session while the TEC group displayed more emotion while they were 'getting the physics'.

6.3.3 Relationship between quantitative and qualitative results

Two key aspects stood out as I reflected on the quantitative results. Firstly, the range of emotional reaction of the students in both courses was found to be very similar. The same proportions of students in each course have circled positive and negative emotions. Table 6.3 shows that there is no statistically significant difference between the means for the two courses. Colorful stories emotionally engage the students of both groups. At a fine-grain level, figure 6.3 shows that for each item on the survey, the pattern across the two courses is much the same. This result was a little surprising given that course selection is related to students' inclination, experiences, choices, and future intentions for study. One may have expected students who intend to continue studying physics, TEC, to report different emotions to those selecting to study a single physics course, the ENV cohort but the experience here is that they didn't.

Secondly, I found that there are differences in the qualifiers Comment: by "qualifiers" do you mean the free comments that the students are making? You probably made that clear earlier but, if you did, I've forgotten. Perhaps you should make it clear again.. Student in the TEC course returned more qualifiers expressing their concerns, mostly reporting that the stories adversely affected their process of learning physics. This emerged as a noticeable difference in correlations between the two courses. The TEC numbers show more correlations with anxiety. The difference between the two courses could possibly be due to the different approaches and goal of the Courses. The TEC students were seen to be more concerned whether the stories helped them understand the practical. Students who found stories were interesting said things like, ‘I like seeing the real-world applications. I enjoyed having them. Really annoyed when the graph did not work.’, and ‘It is good, but we generally did not read. Not interesting practical need more clear information, there is a lot of work we need to do.’.

In ENV classes supervisors were concerned that students finished all the tasks in the laboratory as the outcome of comfortably completing the session. They calmed the students assuring them that they had done the practical well and encouraged them to finish the task and move on to the next section. At times supervisors set the pace by announcing that students should be close to finishing the Section, and taking time out to help individual teams. ENV class was engaged, pretty relaxed, and they finished with time to spare, allowing them, while finishing up, to revisit the material supplied and discuss the stories. Compared to the TEC laboratory, tutors and students were seen to be taking a more relaxed stance.

In TEC students were seen to be involved with logistics around the physics involved, while at the same time having a larger range of emotions. They often expressed their anger or anxiety when the results didn’t come out as expected or when they had difficulties performing the task.

6.4 Discussion

In this Chapter, I have described how the purposefully crafted ‘colorful historical stories’ were presented as a low-key: introduction to four electricity practicals in two first-year physics courses: ENV and TEC. As mentioned in the earlier Section 2.6.2, stories can work as a vehicle for conceptual change, for the motivation of students, for the development of various skills, and for the stimulation of imagination (Stinner, 1995). Students appreciated such a context given to their regular laboratory saying, for example, ‘*They added context to the practical, they alloyed my resignation and left me in a better mood*’.

In line with Stinner (1995), my purpose was to create a story line to capture students’ imagination, give a context, and help students see the connection to the real-world application. Stories were received with an overwhelmingly positive response from students: 60% responded a ‘yes’ to the addition of the stories in their laboratory instructions, putting in comments like, ‘a must add’ and ‘sure add’. Alluding to specific features of the stories, students wrote words like ‘.helps create a direction of work and helps you get into the ‘*scientist’ mindset*’, ‘*Enjoyment on the achievement of our predecessors. Motivating, gives further understanding of the practical*’ and ‘*Seeing these stories actually make me think this practical is useful in real life*’. In students’ open-ended responses on their feelings about the stories the most common word used was ‘interest’.

Predominantly, students found that stories were interesting; only a limited number of students found that stories were not helpful for their feelings or for their learning. This is a very important result as interest is an important feature that directs academic and career paths while engaging students (Renninger and Hidi, 2015).

When I looked at the quantitative data gathered by the AEQ-PhysicsPrac, I observed that the mean and the item responses display no significant difference between the emotions of the students in the two courses. In addition, when I triangulated the quantitative data with the qualitative categories generated from students’ responses, the results assured that the ‘story’ tool generated emotional engagement in most students, irrespective of their predilection for physics, i.e. whether they intended to continue or not in physics. However, the correlations between the emotions differ for the two courses. This is not surprising for, as corroborated in the qualitative data, the goals of the two groups of students were different.

TEC students return more correlations and more qualifiers associated with their anxiety shown by comments like ‘*..there is a lot of work we need to do*’ and ‘*I felt very unprepared..*’. In the laboratory observations too, these students are seen to be more sincere and candid; occasionally they express their anxiety and anger. But as mentioned in section 2.3.3 earlier, anxiety and anger can lead to attention at times. These emotions do not always affect the students in a negative way (Pekrun, 2006). Accordingly, the tutors’ approach was also different in both the cohorts, they took a more relaxed stance with the ENV class than with the TEC class. In ENV classes the tutors’ focus was on students completing the session, whereas in TEC classes they had more discussions with the students regarding ’getting the physics’.

I developed stories for the four electricity practicals while following the HIPST model (Höttecke, 2012) and containing features from Stinner's guidelines (1995). While including stories in the laboratory instructions, I met with mild opposition from the laboratory coordinator, supervisors, and tutors. Even a small group of students, very focused on physics,found the stories unnecessary, expressing strong negative opinions such as, '*I didn't read them because I am disinterested in history and was more focused on getting the practical over and done with*' and '*I don't like history, and that is why I study physics. I don't wanna see historical stories. The study makes me happy*'. Given this, I was quite astonished to see a positive response from majority of students. Stories did capture students' interest and attention and engaged them emotionally to the task at hand. Students' 'Yes' came out in strong support for the addition of the stories to provide a context to their laboratory.

6.5 Summary

Overall the 'colorful historical stories' for a series of experiments on electricity were well received by students in the two courses. The key point that came out was the role of interest linking to attention, impacting students' engagement and learning. The quantitative measures of emotions are not significantly different for students in different cohorts, indicating that emotional engagement is similar for both cohorts. I also looked into qualitative responses and it was apparent that both the cohorts found the 'colorful historical stories' interesting.

Laboratory observations and the qualitative responses show that the correlations between emotions show some differences for the two cohorts, TEC students had more correlations between the emotions, showcasing their anger/anxiety. This is clear from the facts that the two cohorts are different in their predilection for physics and that the tutors used different teaching approaches for the groups.

CHAPTER 7

The Achievement Emotion Questionnaire - Validation for Physics Lectures

7.1 Introduction

Having shown the utility of the AEQ-PhysicsPrac survey for measuring achievement emotions within physics laboratory classes, I was keen to extend the utility of this survey to entire first year physics courses. To this end I developed a new tool, called AEQ-Physics, that I have utilized across a first-year physics course. AEQ-Physics was trialed at the University of New South Wales for the mechanics part of a calculus-based physics course.

A different institute was chosen for this part of the study because the same lecturer was presenting two lecture streams during the same term. This allowed for a comparison between students' emotions in a stream with and without 'colorful historic stories' while keeping other variables related to lecturing style as constant as possible. Early in 2020, COVID-19 emerged. It had an enormous impact on teaching, necessitating a quick move to online delivery. In this Chapter I will address the following research aims:

1. To adapt and then validate the Achievement Emotions Questionnaire (AEQ) within the context of undergraduate physics lectures.
2. To investigate whether there are differences in students' emotional engagement as measured with the AEQ between two lecture streams of a course, with and without 'colorful historic stories'.

3. To investigate whether there are differences in students' emotional engagement as measured with the AEQ between modes of studies (face-to-face, blended and online due to COVID-19).

I have divided this Chapter in three sections keeping the COVID-19 pandemic effect on students' emotional engagement in mind.

Section 7.3 uses the data from 2019 term 3 (pre COVID-19). In this section, I validate and test the reliability of this survey, I then examine the correlations between the emotions and descriptive statistics using AEQ-Physics for the case of face-to-face delivery mode of the course.

Section 7.4, to show the utility of AEQ-Physics, a primary analysis is presented comparing students' emotions for face-to-face lecture streams with and without stories.

Section 7.5 uses data from 2019 term 3 (pre COVID-19), 2020 term 1 (looming COVID-19) and 2020 term 2 (during COVID-19). In this section, I show the utility of AEQ-Physics by comparing students' emotions for different modes of studying (face-to-face, blended and online COVID-19).

7.2 Adaptation of the AEQ-Physics

The AEQ-Physics is based on the AEQ-PhysicsPrac which was shown in Chapter 5 to be a valid and reliable tool. The adapted survey measures students' pride, enjoyment, anger, anxiety, hopelessness and boredom like the AEQ-PhysicsPrac. Here again, the emotions cover three quadrants in the two-dimensional space of valence of these emotions, positive or negative, and the activity level, activating or deactivating, shown in figure 2.3A. The items were changed from AEQ-PhysicsPrac so that:

- The tense was relevant as the students completed the survey while still undertaking the course.
- The context was changed from practical work to the entire course.

- New items, based on the original Pekrun survey, were added for negative emotions so that each emotion has at least 4 items as suggested by Wolf et al (2013).

In table 7.1 I present items from the AEQ-Physics. New items are starred.

9 Positive items			
Item no.	Pride items	Short name	Item name
1	During this physics course, I was satisfied with my work.	Satisfied	Pr1
4	I felt elated by my accomplishments during this experiment.	Elated	Pr2
12	I took pride in being able to keep up with the tasks in this physics course.	Keep up	Pr3
14	I made important contributions during this physics course.	Important contribution	Pr4
	Enjoyment items		
2	For me this physics course was a challenge that was enjoyable.	Enjoyable challenges	En1
8	I felt this physics course was exciting.	Exciting	En2
17	I was glad that my efforts during this physics course paid off.	Efforts paid off	En3
18	I enjoyed this physics course.	Enjoyed	En4
23	I am happy that I could cope with this physics course.	Cope with	En5
12 Negative items			
	Anger items		
3	I felt annoyed by this physics course.	Annoyed	An1
5	I felt frustrated during this Physics course.*	Frustrated	An2
11	It was irritating that my efforts were not useful during this physics course.	Irritating	An3
21	I resented doing this physics course.	Resented	An4
	Anxiety items		
6	I got scared that I might do something wrong while doing this physics course.	Scared	Anx1
7	I felt uneasy during this Physics course.*	Uneasy	Anx2
16	I felt nervous during this physics course.	Nervous	Anx3
22	I felt panicky during this physics course.	Panicky	Anx4
	Hopelessness items		
9	During this Physics course, I felt hopeless.*	Hopeless	Ho1
10	I found this Physics course pointless.*	Pointless	Ho2
19	During this physics course I felt like giving up.	Give up	Ho3
28	During this physics course, I was so resigned that I felt that I had no energy.	Resigned	Ho4
	Boredom items		
13	I got restless during this Physics course.*	Restless	Bo1
15	I got tempted to walk out of this Physics course.*	Walk out	Bo2
18	I found this physics course dull.	Dull	Bo3
19	I was bored during physics course.	Bored	Bo4

TABLE 7.1. Items making up the AEQ-Physics survey. Items which are starred are new when compared to the AEQ-PhysicsPrac.

7.3 AEQ-Physics: Validity and reliability

In this section, I address the first research aim and show that the AEQ-Physics is a valid and reliable tool that can measure the interrelated and discrete emotions. I will show this by providing a description of the sample, presenting the confirmatory factor analysis (CFA) and then providing the descriptive statistics and correlational analysis.

My sample group was the students undertaking Physics 1A, an introductory calculus-based physics course at The University of New South Wales, Sydney. The majority of students in the course were studying engineering or science. The first five weeks of this ten-week course are dedicated to mechanics. This part of the course forms the basis for my study.

Each week in the course, students attend a two-hour laboratory, a two-hour problem-solving workshop and four hours of lectures. All of these are in face-to-face mode for this part of the study. The course was offered in the form of three lecture streams; face-to-face lecture stream A, face-to-face lecture stream B and an asynchronous online lecture stream. Though students were allowed to swap between the lecture streams, they generally did not swap. The attendance of lecture stream A remained around 20-30 and it remained at an average of 60 for lecture stream B throughout term 3 in 2019. There were no differences between the programs of study that might influence the engagement between the streams. However, the influence of timetabling cannot be eliminated.

Surveys were administered during either problem-solving workshops or online via the learning management platform Moodle at four points; 2019 term 3 week 1, week 3 and week 5, and 2020 term 1 week 5, as shown in table 7.2. The data from all the administrations were combined giving 395 responses which were included in the analysis.

EFA was conducted as for the practicals. Unsurprisingly two factors were found as theorised by Goetz et al (2006) and Russel (1980). This means that emotion survey items branch into two: positive and negative emotions. Preliminary data exploration showed that the data set was adequate for confirmatory factor analysis (CFA); for example, the distributions of ratings

Cohort and module description	Data Collection	Enrolled students	Student responses	Total
2019 term 3 Mechanics	W1, W3 & W5	213	256*	395
2020 term 1 Mechanics	W5	487	139	

TABLE 7.2. Sample details. *no. of responses are larger than students enrolled because survey was repeated in this instance. Choice for lectures shows which lecture stream the students enrolled in.

for each individual item, each emotion and the entire data set were all normal. Figure 7.1 shows the result of the CFA.

The interpretation of the figure 7.1 is as follows:

- The set of items representing each emotion emerge grouped together. This means that each set of items is interpreted by respondents as aligning with the same construct, that particular emotion.
- The set of items for each emotion is separate from those for the other emotions. This means that the sets of items is interpreted by respondents as being different constructs.
- These results illustrate that the emotions are discrete and distinguishable. The items for each emotion do not overlap and intertwine with the items for the other emotions.
- The numbers next to the rectangular boxes are loadings. Factor loadings are mostly reasonable, loading onto the intended latent factors which are the emotions.
- The numbers on the arcs are coefficients which indicate the latent factor ‘correlations’ and their directions. They behave as per Pekrun et al (2011).
- Finally, the six emotions are interrelated factors in a multi-dimensional hierarchical structure (Peixoto et al., 2015). The conceptual model is sound.

Table 7.3 shows the model fit parameters that meet with specified criteria described in section 4.4.2 and table 4.1.

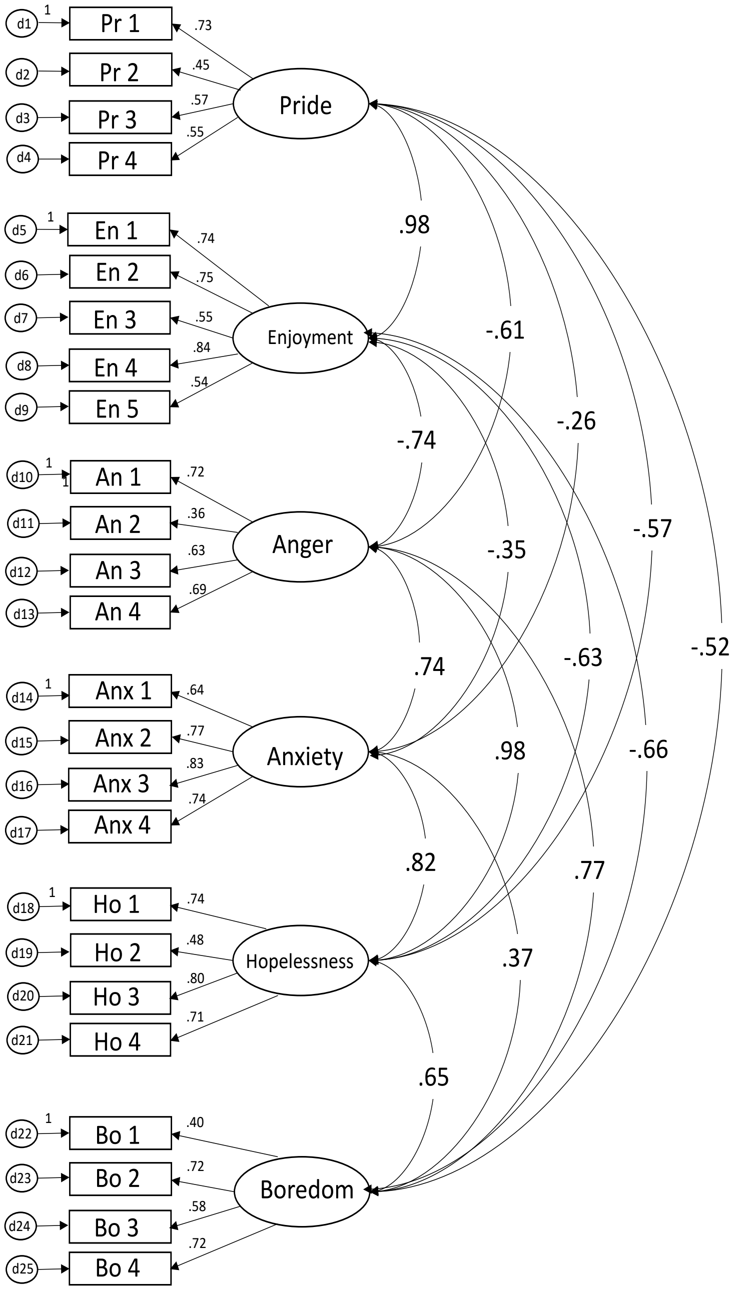


FIGURE 7.1. Six-factor CFA model for the face-to-face physics course; En is enjoyment, Pr is Pride, An is anger, Anx is anxiety, Ho is hopelessness and Bo is boredom. Each box represents a separate item which load onto distinct and discrete latent factors that are interrelated

Measures	Values
Comparative Fit Index (CFI)	Permissible at .80
Root Mean Square Error of Approximation (RMSEA)	Moderate fit at .098
Relative $\chi 2$ ($\chi 2/df$)	Permissible at 4.8
Composite Reliability (CR)	Acceptable at 0.95
Composite Reliability (CR) for individual emotions:	En 0.67; Pr 0.82; Ang 0.70; Anx 0.84; Ho 0.55; Bo 0.70

TABLE 7.3. Validity and reliability measures of the model and measured emotions

The composite reliability (CR) values for most individual emotions are also above 0.6, apart from one at 0.55, which indicates the reliability of the model. The acceptable values for these validate the multi-dimensional hierarchical structure of the AEQ-Physics survey.

After checking the validity of AEQ-Physics using CFA, I checked the correlations between the emotions measured. Table 7.4 shows bivariate Pearson correlations. I found positive correlations between positive emotions, positive correlations between negative emotions, and negative correlations between positive and negative emotions; all statistically significant at $p < 0.01$, except for an exception was anxiety which is not correlated with pride in face-to-face mode. This means that the polarity of the correlation for each of the cases matches the Pekrun conceptual model. Anxiety is anomalous in that it has different patterns for the different cases (Pekrun, 2006; Bhansali and Sharma, 2019). In terms of the conceptual model, the correlations show that the emotions are interrelated and distinct, and that the polarities of the correlations are as expected.

Emotion	Pride	Enjoyment	Anger	Anxiety	Hopelessness	Boredom
Pride	-	0.72	-0.31		-0.36	-0.30
Enjoyment		-	-0.51	-0.25	-0.51	-0.45
Anger			-	0.57	0.75	0.63
Anxiety				-	0.63	0.41
Hopelessness					-	0.62
Boredom					-	

TABLE 7.4. Pearson Correlation coefficients between the emotions. The correlations are statistically significant at $p < 0.01$ (2-tailed) level.

Emotion	Range	Mean(SD; SEM) (n=395)
Enjoyment	5-25	14.2(2.6; 0.13)
Pride	4-20	18.6(3.3; 0.17)
Anger	4-20	11.5(3.0; 0.15)
Anxiety	4-20	13.1(3.6; 0.18)
Hopelessness	4-20	10.2(3.2; 0.16)
Boredom	4-20	10.3(2.9; 0.15)

TABLE 7.5. Descriptive statistics: mean, sample standard deviation (SD), estimated standard error of the mean (SEM)

Further, descriptive statistics in table 7.5 show the range, means, SDs and SEMs of the emotions. I confirmed that the data sets were normally distributed, allowing t-tests to be applied as stated in Chapter 4.

7.3.1 Discussion

The results indicate that the AEQ-Physics is a valid and reliable tool that can measure students' emotions in physics courses and that it is conceptually sound, aligning with the Pekrun model (Pekrun, 2006; Peixoto et al, 2015). The interrelated hierarchical structure of discrete emotions follows the statistical criteria described in Chapter 4. Additionally, the survey was able to discriminate between the emotions while examining the effect of different variables on students' emotional engagement. AEQ-Physics is a more balanced tool compared to AEQ-PhysicsPrac, because during the adaptation items were added for some emotions so that there are four or more items for each emotion in the AEQ-Physics (Bieleke et al, 2020).

7.4 Comparing emotions for the 'Colorful historical story' variable

This section addresses the second research aim. In this section, I will investigate whether there are differences in students' emotional engagement as measured with the AEQ between two lecture streams of a course, with and without 'colorful historic stories'.

7.4.1 Sample

I will start this section by giving further details about how the Physics 1A course ran. A brief introduction to this was given in section 7.3. When enrolling, students choose between three different streams for the lecture component of the course. They choose between two face-to-face streams and an online stream. All students attend face-to-face laboratories and problem-solving workshops. I refer to students enrolled in the face-to-face lecture streams as studying in face-to-face mode and students taking lectures online as studying in blended mode. Students chose their lecture mode during the preceding term. All three streams offer the same content knowledge. The two face-to-face streams, A and B, were taught by the same lecturer with the same engagement elements including predict-observe-explain interludes and class discussions. The difference between these streams was the inclusion of 'colorful historical stories'. Chapter 3 describes how the stories were crafted and presented in the lectures. Lecture stream A did not have the lecture slide containing the 'colorful historical story' whereas stream B did. The online lectures were set up as quizzes, comprising of short videos (typically 5 - 10 minutes long) introducing the theory and some demonstrations followed by questions, calculation based and multiple choice, for students to practice applying the theory they had just seen. The online lectures were formative, they did not contain 'colorful historical stories' and they did not count towards the course grade.

In 2019 term 3, I collected data at three points during the five-week mechanics part of the course. Surveys were administered during problem solving workshops via the learning management platform Moodle. Surveys were administered at three points, start, middle and end of the mechanics part of the course. Table 7.8 shows the sample details. The results in next three subsections use the week-wise data, week-1 (W1), week-3 (W3) and week-5 (W5), sorted according to colorful historical story' variable: I compared students' emotional responses to lecture stream A with no stories and to lecture stream B with stories.

7.4.2 Quantitative analysis

My intention in comparing the samples shown in table 7.8 for the story variable was to investigate the effect of 'colorful historical stories' on students emotions in lectures. Both the

Variable	Case	Enrolled students	Number of responses			
			W_1	W_3	W_5	Total
Story	No Story	63	36	27	12	75
	Story	150	87	68	26	181

TABLE 7.6. 2019 term 3 (pre COVID-19) weekwise data (week-1 (W_1), week-3 (W_3) and week-5 (W_5)) of the introductory physics course sorted according to story variable

lecture streams were provided with the lecture slides, black and white for lecture stream A, additionally lecture stream B was provided with slides containing 'colorful historical stories'. Chapter 3 describes how the stories were created and presented in the lectures.

Emotion	Story variable	W_1			W_3			W_5		
		Mean	SD	*p*	Mean	SD	*p*	Mean	SD	*p*
Pride	No Story	15	2	>.05	14	3	>.05	13	3	>.05
	Story	15	2		14	2		14	3	
Enjoyment	No Story	20	2	>.05	19	3	>.05	18	2	>.05
	Story	20	3		18	3		18	3	
Anger	No Story	12	2	>.05	11	4	>.05	11	4	>.05
	Story	12	3		12	3		12	4	
Anxiety	No Story	13	3	>.05	13	4	>.05	14	4	>.05
	Story	12	3		13	4		14	3	
Hopelessness	No Story	9	2	>.05	10	4	>.05	12	3	>.05
	Story	10	3		11	3		11	3	
Boredom	No Story	10	2	>.05	10	3	>.05	10	2	>.05
	Story	10	3		11	3		11	3	

TABLE 7.7. Comparing emotions for the story variable week-wise (W_1, W_3, W_5): descriptive statistics and independent *t*-statistics *p*-values

As seen in table 7.7, independent t-statistics results shows non-significant difference, $p > 0.05$, for all the emotions and for all the weeks. The results clearly indicate that no significant difference exists between the level of emotional engagement for the lecture streams A and B. The qualitative analysis will shed a little more light on this. Given that the experience of students in these streams was very similar I was able to combine them into a single face-to-face mode variable for comparison of delivery modes in section 7.5.

7.4.3 Qualitative analysis

To further understand the emotional engagement of students and to investigate whether the stories had any impact, I conducted class observations. For the observations, my stance was that of a ‘fly on the wall’. Participants were told that they were being observed and that they could opt out, but specific consent for observation was not taken as that would affect the data collection. Figure 7.2 presents how I recorded overall atmosphere and mood of the class. As explained in section 4.5, I gathered the raw observational data on paper and computer, as seen in the figure 7.2. As they were interactive lectures with a lot of students, I recorded lecturer’s comments/questions and students’ collective responses, behaviour and activities. The class observations were not analysed but the mood was assessed for the two lecture streams A and B, which was quite different.

Lecture stream A was seen to be very quiet and serious whereas Lecture stream B was seen to be comparatively noisier, enjoying their lecture more, frequently laughing and discussing with students. It is noteworthy that Lecture stream B was quite a lot larger with over double the number of students.

In addition, I conducted focus group interviews. The interviews are same as the focus group interviews. Interviews are when there is one participant and focus group with more than one. Students were notified of the privacy and anonymity of the interviews. I asked students from all three streams to participate, while administering surveys during the workshops. The focus group interviews were conducted with students who volunteered, no students from stream A volunteered to take part. Eight students attending lecture stream B showed interest in participating in the focus interviews via their survey responses or responding personally to me during the workshops. The focus groups were audio recorded and transcribed to gain deeper insights into students’ perceptions.

I now present notable observations from the semi-structured focus group interviews. The direct answers were used alongside a thematic analysis of the students’ responses to ascertain patterns. While answering the interview questions, students commented on their experiences with the course, whether they noticed any historical stories during the lectures, whether they noticed any color in the lecture slides, and whether the colors and stories had any impact on their emotional engagement.

To elaborate on students’ emotional response, I present the notable observations from the focus group interviews conducted with eight students from lecture stream B of the course.

When asked about the overall experience of the course, students’ answers ranged from ‘*the course is really good because I personally really like physics*’, ‘*It’s a lot of fun*’ to ‘*It is problem solving focused. I don’t know how to do it but it was a good experience*’, ‘*Quite Challenging but interesting*’ to ‘*course itself is kind of hard for me*’, and ‘*course is pointless*’.

Seven of the eight students selected enjoyment as the prominent emotion felt during the course, although four of them also selected anxiety and three of them selected hopelessness alongside. Students said that they enjoyed the course when they could understand the physics, one of them even selected pride. Students felt anxiety when they could not understand the physics. One of them reported that anxiety and hopelessness were overall parts of the university life.

When asked about whether they noticed any stories during the lecture, students commented affirmatively, saying ‘*it’s pretty interesting*’,‘*It’s good providing some context*’, ‘*yeah they were really nice, you get to know what it’s about*’ and ‘*I really like those slides*’. The rivalries between the scientists stayed in students’ minds, whic*h was reflected in their comments like, ‘It was like cheeky comments or something like that. Yes it was fun.’ and ‘definitely laugh. Because professor Liz, she likes she makes quite a lot of jokes about Newton. And so that’s quite funny.*’. Hence, the purpose of designing the stories to hook the students up seemed to be working well.

Along with the stories, slide titles in colorful background were intentionally put on the slides in lecture stream B to engage the students. The slides for lecture stream A were not presented in the color and did not contain stories. In lecture stream B, half of the students didn’t notice the colors on the slides, one student commented, ‘*I like the colors*’, and ‘*it was pretty colorful.. there was lots of visuals and graphics so pretty good*’.

	A	B	
1	1:02 coming in		
2	buzz		
3	chat, smile, smilingly enter, quite a buzz.		
4	hand action, laugh		
5	same blue slide		
6	more people buzz (noise)		
7	bright windy afternoon		
8	mobile		
9	smile discuss		
10	buzz loud		
11	laughs		
12	smile discuss		
13	60 -65 people		
14	chat, smile discuss		
15	loud laugh		
16			
17	1:06		loud laugh
18			silent
19		borrow volunteer	laugh, smile
20			laughs

(A) Initial scan of the room and overall mood

1:06		loud laugh
		silent
	Would anyone like to volunteer for demonstration	laugh, smile
		laughs
		student (male) goes
		very loud laughs
		loud laughs
		straight back
	?	loud laugh
	demonstartion: hammer	students take video of demonstration
		all watch
		laughs loud
		discuss
		would not hurt him, trust me
		laughs
	lets start the momentum, collision, impulse lecture	
		smile mobile
		laugh
		discuss
		chat with the lecturer
		laugh
		all write
		same group discuss, laugh
	reading out the slide, and explaining looking at class and slide	bright room, no orange lights on board
		most write
		most watch
		one student's head resting on table

(B) Lecturer's comments/activities and students' behavior/responses

FIGURE 7.2. Observational notes for the physics lectures

Students reported that the stories were engaging and interesting, commenting, '*They were actually pretty interesting. Especially the part where we had a few pictures of renowned physicists. I think that was interesting. To be honest it does provide a good distraction if you're getting bored*' and '*they were really nice, you get to know what it's about*'. A student reported an additional qualifier saying that, '*I like probably because if something's more interesting, you know, I'm going to pay more attention to it. But like, like overall it's not going to make me want to study physics more. It would just mean that I potentially pay more attention in lectures or I enjoy going to lectures or sometimes it's something like that, but I wouldn't necessarily, yeah, enjoy physics (laughing)*'. While asked whether story provided a good break, a student said that stories were not needed but others might like it, reporting, '*I don't think things were pretty intense that there was any break needed. The things were pretty relaxed and laid back. I could follow so I didn't really need a break . I think it will be helpful for the others. Not everyone is like me.*'

7.4.4 Discussion

In the investigation of the effect of the 'colorful historical story', the week-wise quantitative results showed no significant difference between the lecture stream A that didn't have the lecture-slide containing the story and the lecture stream B that did. As stated in section 7.4.1, most of the engagement elements, are common in both the lecture streams, so the effect of the single element of 'colorful historical stories' is not statistically visible. But when one looks at the qualitative results, the "soft" impact of such a context in generating emotional engagement is visible, supporting the earlier literature (Arons, 1988; Strube, 1989; Stinner, 1995). The qualitative data gathered in the form of the interviews, indicated the positive emotional influence of stories on the students. Students liked the addition of some context in form of the stories. They commented '.. *pretty interesting*' and '.. *really nice, you get to know what it's about*', and mostly reported 'enjoyment' as the prominent emotion they felt. Though half of the students didn't pay attention to the intentionally added color to the slides, the other half appreciated the colors saying for example, '*it was pretty colorful.. there was lots of visuals and graphics so pretty good*'.

7.5 Comparing emotions for the delivery mode variable

This section addresses the third research aim. In this section, I will investigate whether there are differences in students' emotional engagement as measured with the AEQ between modes of studies (face-to-face, blended and online due to COVID-19).

Here I will describe the course in some detail. The majority of students in the course were studying engineering or science.

- The face-to-face lectures were as described in earlier section.
- The online lectures were set up as quizzes within the Learning Management System called Moodle to provide easy access for students. They consisted of short videos (typically 5 - 10 minutes long) introducing the theory and some demonstrations followed by questions for students to practice applying the theory they had just seen. The questions contained both multiple choice and calculation style problems.
- Prior to the COVID-19 pandemic, all students attended a 2-hour face-to-face lab and 2-hour face-to-face problem solving workshops each week. During problem solving workshops students worked in groups of around three to five to solve problems on worksheets.
- The face-to-face and online lectures and the problem solving workshops were formative, they did not count towards the course grade. The labs did count.

The first half of Physics 1A covers mechanics; this half formed the focus of this study. The course runs three times a year, in terms 1, 2 and 3. Figure 7.3 shows the data sample over the years of study. Data were collected over a year from September 2019 through to August 2020. The comparison for face-to-face and blended mode of study for term 3 2019 is presented in section 7.5.1. The data analysis has been conducted that shows no significant difference between the face-to-face mode of term 3 2019 and term 1 2020. Also, there was no significant difference found between the blended mode of term 3 2019 and term 1 2020. Hence in section 7.5.2, the cohorts are combined from 2019 and 2020 to investigate the differences between face-to-face, blended and online mode due to COVID-19. The intention is to find out which mode works best for students' emotional engagement and how could we better design the teaching and learning strategies. As mentioned, variety of results are presented. After all the assumptions are satisfied, Mann Whitney statistics is presented for the comparison of the emotions.

There are three Groups that I looked at. First, there was the Pre COVID-19 sample. In term 3 2019, in order to track students' emotions throughout the course, as described in earlier section, students were surveyed at the start, middle and end of the course. The week-wise sample details can be seen in table 7.8 while figure 7.3 and table 7.9 shows the overall sample details for 2019 and 2020. Students chose and attended either face-to-face lectures or online lectures, but all students did face-to-face problem-solving workshops and labs. Hence two modes were running: face-to-face for those students who did all components face-to-face, and blended for students who did online lectures but other components face-to-face.

Next, there was the Looming COVID-19 sample. In term 1 2020 one of the lecture streams was taken by the same lecturer as in term 3 2019; the other stream was delivered face-to-face in a similar manner by the lecturer who created the online mechanics lectures. During term 1 2020 face-to-face classes were cancelled after four weeks into the term due to COVID-19. This corresponded with the end of the mechanics topic. Students chose and attended either face-face lectures or online lectures, but all students did face-to-face problem-solving workshops and labs for the first 4 weeks which is the focus of this study covering mechanics. Hence two modes were running in the first 4 weeks: face-to-face and blended.

Finally, there was the During COVID-19 sample. At the start of the year students select which lecture stream they want to enrol in. In Term 2 students chose between face-to-face and online lectures. These did not run but there is a record of which stream the students wanted to enrol in. These data have been put in the column of 'choice for lectures' in Table 7.10. During term 2 2020 all classes were online. Students used the same online lectures as before but they did not attend laboratory classes or problem-solving workshops. Students completed laboratory exercises at home, using common household equipment to collect data. Synchronous online drop-in sessions were available to students. Students chose either face-to-face lectures or online lectures because the system was setup this way. However, all students did only one mode for the entire course of lectures, problem solving workshops and labs: online COVID-19, which was not specifically designed to optimize online learning, hence the name 'online COVID-19'.

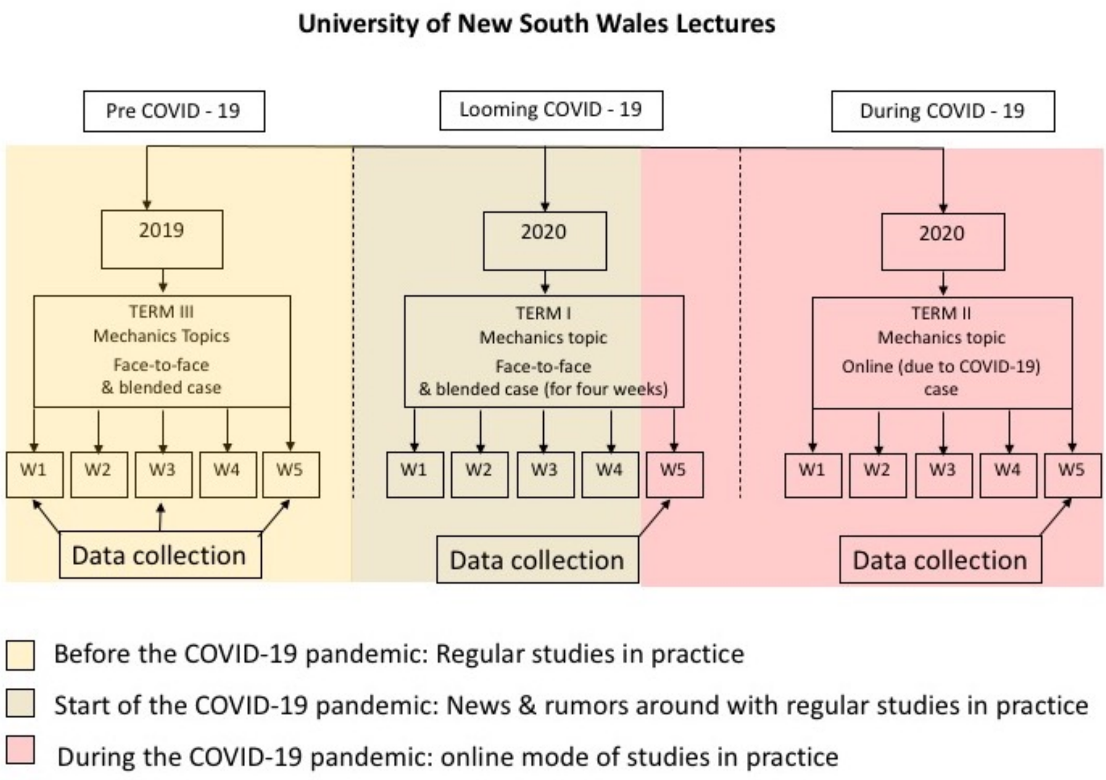


FIGURE 7.3. Sample details over three years of study, considering the effect of COVID-19

7.5.1 For face-to-face and blended streams in 2019 term 3

Surveys were administered at three points, start, middle and end of the mechanics part of the course in term 3 2019. Table 7.8 shows the sample details. The results in next three subsections use the week-wise data, week-1 (W1), week-3 (W3) and week-5 (W5), sorted according to delivery mode variable: I compared students' emotional responses to face-to-face and blended modes of teaching.

The samples listed in table 7.9 were compared for the delivery mode variable with an intention to find out the effect of the delivery variable on students' emotions. Table 7.10

Variable	Case	Enrolled students	Number of responses			
			W_1	W_3	W_5	Total
Delivery Mode	Face-to-face	213	123	95	38	256
	Blended	103	45	26	11	82

TABLE 7.8. 2019 term 3 (pre COVID-19) weekwise data (week-1 (W_1), week-3 (W_3) and week-5 (W_5)) of the introductory physics course sorted according to delivery mode variable

shows the descriptive and inferential statistics produced. The table presents the independent t-tests and descriptive statistics comparing the means scores for the face-to-face and blended modes. Face-to-face is seen to be generating more positive emotions throughout the course.

Overall significantly more positive emotional engagement was found for the face-to-face mode. Enjoyment was seen to be statistically significantly higher for face-to-face mode compared to blended mode throughout the course. At the start of the course, positive emotion pride is significantly higher and hopelessness is significantly lower for face-to-face mode. Midway through the course, no other emotions are significantly different except enjoyment.

Emotion	Delivery mode	W_1			W_3			W_5		
		Mean	SD	*p*	Mean	SD	*p*	Mean	SD	*p*
Pride	Face-to-face	15	2	<.05	14	2	>.05	14	3	<.05
	Blended	12	2		12	4		10	3	
Enjoyment	Face-to-face	20	3	<.05	18	4	<.05	18	3	<.05
	Blended	16	4		15	3		14	4	
Anger	Face-to-face	12	3	>.05	12	4	>.05	12	4	<.05
	Blended	14	3		14	3		14	1	
Anxiety	Face-to-face	14	4	>.05	14	4	>.05	14	3	>.05
	Blended	15	3		14	3		14	3	
Hopelessness	Face-to-face	10	3	<.05	11	4	>.05	11	3	<.05
	Blended	13	3		13	2		14	3	
Boredom	Face-to-face	10	2	>.05	11	3	>.05	11	3	<.05
	Blended	12	4		13	3		14	4	

TABLE 7.9. Comparing emotions for the delivery mode variable week-wise (W_1, W_3, W_5): descriptive statistics and independent *t*-statistics *p*-values

At the end of the course, pride is seen to be higher while all negative emotions, except anxiety, are seen to be statistically significantly lower for the face-to-face mode compared to blended mode.

7.5.2 For face-to-face, blended and online (COVID-19) modes in 2019 and 2020.

As this part of the study was focusing on mechanics which was in the first half of Term 1 of 2020, face-to-face lectures, labs and problem-solving workshops were running. Hence the Term 1 2020 cohort includes the "blended" and "face-to-face" groups. The sample is described in the table 7.10.

Cohort and module description	Choice for lectures	Case	Enrolled students	Student responses	Total
2019 term 3 Mechanics (pre COVID-19)	Face-to-face Online	Face-to-face Blended	213 103	256* 82	338
2020 term 1 Mechanics (looming COVID-19)	Face-to-face Online	Face-to-face Blended	487 166	139 29	168
2020 term 2 Mechanics (During COVID-19)	Face-to-face Online	Online COVID-19	727 109	115 22	137

TABLE 7.10. Sample details. *no. of responses are larger than students enrolled because survey was repeated in this instance. Choice for lectures shows which lecture stream the students enrolled in.

7.5.2.1 Administration, data collection and analysis

The students from both the face-to-face and blended modes were briefed about the research online through the learning management system and in person in the problem-solving workshops. Students were encouraged to complete the AEQ-Physics survey online through Moodle during their workshops, ten minutes was set aside for this, with the option of completing it in their own time later. When the courses shifted entirely online during 2020 due to COVID-19, students were asked to fill out the AEQ-Physics survey voluntarily on Moodle.

The data from 2019 and 2020 were analysed to compare students' emotions for different modes of study. In the following sections I present the process I followed for both the quantitative and qualitative data analyses. Quantitative data analysis The quantitative data were initially analysed in Excel, then cleaned and transferred to SPSS software to generate scores for each emotion as described in Chapter 4. I produced box-plots to graphically explore the emotions of the cohorts. To test for normality, I carried out Kolmogorov-Smirnov and Shapiro-wilk tests. These tests showed that the data were not normal. Consequently, I used the non-parametric Kruskal Wallis test. I chose Mann Whitney U test as a post-hoc test to look for significant differences between two groups in each case. Mann Whitney Test statistic U, significance p and effect size r are shown in the tables for comparing the emotions of students studying in different modes. A value of $p < 0.05$ was considered significant.

Quantitative data analysis

The open-ended survey asked the following questions to gauge the emotional engagement in the class and the effect of stories on students' emotions:

- What aspects did you find most enjoyable and interesting?
- What do you think about the lectures of this course? How will they affect you?
- Do you think the lectures will be engaging? Will you find them helpful for your concept development?
- Compare this course with the other courses. How did it differ?

Qualitative data were thematically analysed and coded for the emotions reported by students. Broad patterns were identified and are presented through students' quotes.

7.5.2.2 Quantitative Results

Box-plots reveal that face-to-face mode of study worked better than blended and online COVID-19 modes for students' emotional engagement. The following subsections present the results. The box-plots in figure 7.4 show how the students undertaking the course in each of the three modes scored their emotions during the mechanics topic. The box-plot also show that students' emotions are most positive and least negative in the face-to-face mode compared to the blended mode and online COVID-19 mode. Boredom was seen to be highest in the online COVID-19 mode.

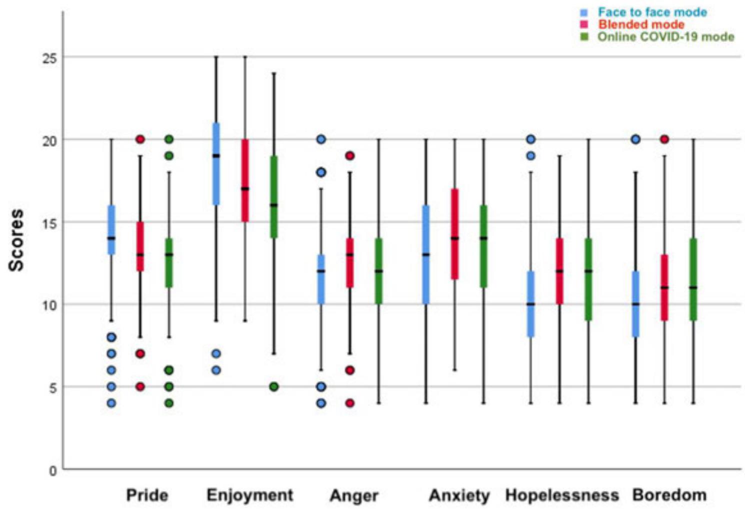


FIGURE 7.4. Boxplots for mode of teaching variable, cohorts combined

	Mean (SEM; SD)					
	Pr	En	An	Anx	Ho	Bo
Face-to-face (n=395)	14.18 (0.13, 2.6)	18.56 (0.17, 3.3)	11.47 (0.15, 3.0)	13.06 (0.18, 3.6)	10.16 (0.16, 3.2)	10.25 (0.14, 2.9)
Blended (n=111)	13.32 (0.25, 2.7)	17.16 (0.33, 3.5)	12.6 (0.27, 2.8)	14.05 (0.33, 3.5)	11.86 (0.29, 3.0)	11.33 (0.29, 3.0)
COVID-19 online (n=137)	12.54 (0.24, 2.8)	16.17 (0.31, 3.6)	12.28 (0.28, 3.3)	13.75 (0.30, 3.5)	11.54 (0.28, 3.2)	11.47 (0.27, 3.2)

TABLE 7.11. Descriptive statistics: Mean (SEM, SD), sorted according to mode of teaching variable

With the intention of further investigating significant differences in emotional engagement between the face-to-face, blended, and online COVID-19 modes of study, a Kruskal-Wallis test was conducted which showed significant differences amongst all the emotions for the three modes; Pride: H(2) = 37.8, $p < 0.01$; Enjoyment: H(2) = 51.1, $p < 0.01$; Anger: H(2) = 17.1, $p < 0.01$; Anxiety: H(2) = 8.5, $p < 0.01$; Hopelessness: H(2) = 37.0, $p < 0.01$; and Boredom: H(2) = 21.5, $p < 0.01$.

	Pr	En	An	Anx	Ho	Bo
U	17712	16584	16758	18558	14887	17358
p	.002**	.000***	.000***	.013*	.000***	.001**
r	-.14	-.18	-.17	-.11	-.23	-.15

(A) Face-to-face vs blended mode

	Pr	En	An	Anx	Ho	Bo
U	6467.000	6481.000	7116.000	7249.500	7013.500	7494.000
p	.042*	.045*	.383	.527	.291	.845
r	-0.13	-0.13	-0.06	-0.04	-0.07	-0.01

(B) Blended vs online mode due to COVID-19

	Pr	En	An	Anx	Ho	Bo
U	18017.500	16691.500	23144.500	23901.000	20404.000	21069.000
p	.000***	.000***	.011*	.041*	.000***	.000***
r	-0.25	-0.29	-0.11	-0.09	-0.19	-0.17

(C) Face-to-face vs online mode due to COVID-19

***. Significant at the 0.001 level (2-tailed).
**. Significant at the 0.01 level (2-tailed).
*. Significant at the 0.05 level (2-tailed).

TABLE 7.12. Inferential statistics: Mann Whitney U test for comparing emotions between two modes of learning at a time

To further probe the comparisons, the Mann Whitney U test was chosen as a post-hoc test. As seen in table 7.11, supporting the box-plots, the Mann Whitney U test results showed that the students who took lectures face-to-face experienced more positive feelings about the course. Positive emotions were seen to be highest at $p < 0.05$ significance level. While the online COVID-19 mode was seen to be the worst for positive emotions at $p < 0.05$ significance.

7.5.2.3 Qualitative Results

Positive emotions for face-to-face mode

First, I present the comments from the students studying in face-to-face mode. Positive emotions were prominent in the qualitative comments: out of 351 students' comments, enjoyment was reported 88 times and pride was reported 12 times. The features contributing to their enjoyment included learning new stuff, the content being interesting, liking physics and its applications in real life, the energy and dedication of the lecturer, fun demonstrations and, finally, enough time spent in the lectures. Upon achieving conceptual understanding students tended to select pride. Students made comments such as:

Fulfilling, awesome learning experience.

Enjoyment, because i can see that the lecturers are trying their best to make the lectures more interesting…

I like learning about new physics laws and watching the demonstrations.

I love physics there is nothing more to say.

I like that there is enough time spent to go through questions and understand the applications.

..Teacher and classmates are humorous, and we do our best to learn.

Students also selected multiple emotions including negative emotions when they could not cope or understand:

I really enjoyed the lectures even if I got confused sometime; and when I do, I would be FRUSTRATED!!

Some commented on enjoyment due to learning through lectures:

There were questions that I didn't know how to answer, and through the lectures the prof. confidently and concisely answered these!

Positive emotions for blended mode

Next I present the comments of students studying in blended mode. Out of eighty-nine students' comments in the blended mode, thirty-three selected enjoyment and three selected pride. A few students enjoyed watching videos:

> *...I feel it is kind of interesting as the videos using many attractive pics and examples*

While some students liked the online learning experience, others selected multiple emotions:

> *Enjoyment and Boredom: I chose these two because I found some lectures to be enjoyable and some lectures a bit hard because I felt that the content they were teaching was a bit dry (nothing to do with the actual presentation itself). Also, the fact that I did the online physics lectures may influence my experience.*

> *Lectures were mostly enjoyable, however some made me feel boredom, but that is to be expected of any course. There seemed like there was a lot of lectures to get through, so this also made me feel a bit of anxiety and hopeless.*

> *Physics and I have a difficult relationship, where I like physics but physics does not like me, and it stresses me a lot but at the end, is a bit satisfying.*

Positive emotions for online COVID-19 mode

Finally, I present the comments of students studying in online mode during COVID-19. Students trying to make the most of the situation, selected enjoyment 41 times and pride 14 times for their accomplishments:

> *Although there isn't face-to-face communication, the online lecture doesn't make me losing interest, and I can understand the content of the course well.*
> *The lecture online makes me feel Pride because l can solve some physics problems by myself.*

Some students selected enjoyment but did note that they disliked some aspects such as the fast pace as they found themselves unprepared for the quizzes:

> *I found the online web stream lectures incredibly engaging and joyful to watch. However, they quite fast-passed, and I didn't feel like i had enough time to absorb the information in a few minutes of video. Additionally, it felt that the ideas and concepts were often told to you, and not explained as well as in a classroom. By the time i got to the questions this was clearly demonstrated as i often didn't know how to apply my knowledge and it was frustrating when I kept getting things wrong.*

Some selected enjoyment but also commented on being resigned to boredom during COVID as new topic of physics were covered:

> *Having covered much of the content in the first half of the course I found the lectures boring as it was relatively slow-paced and revision. I understand that other students may have needed this to learn the basics required. Once the lectures started covering new content, which coincided with them moving online due to the COVID-19 outbreak, I found them more enjoyable as I was learning as opposed to revising.*

They also selected a mix of positive emotions for the experiments and quizzes:

> *Enjoyment: I was surprised and liked that the teacher could put boring knowledge into interesting and impressive experiments. And the web stream has a very consistent lesson can be easily browsed anytime and anywhere. Pride: Learning on this site is a great experience. Because every unit and Chapter have lessons like a test. It is very rewarding to finish each study and get a score.*

Negative emotions for face-to-face mode

Negative emotions were usually selected as a combination of multiple emotions. A total of 12 students reported anger, 41 students reported anxiety, 17 hopelessness, and 30 reported boredom in the face-to-face mode. These comments tended to focus on assessment, the quizzes, the fast pace of the course, the lack of support and hard physics content, and repetition of the content. Though they reported a mix of positive and negative emotions such as feeling enjoyment during lecture demonstrations, pride when they could complete the laboratory activity, help laboratory partners and gain understanding:

> *Enjoyment from learning new physics, anger/frustration from doing the weekly quizzes. It's fun, but a bit fast paced which makes a bit anxious.*

> *Enjoyment because the lectures were funny and engaging, I loved how (name of the lecturer) would do all these practical demonstrations every lecture and I looked forward to the lectures.*
> *Anxiety: because I didn't understand what he was writing on the board and I couldn't ask questions because I didn't know what I didn't know. I often found the weekly quizzes very challenging.*
> *I took pride in the way I completed my laboratory work, the labs helped me a lot with my understanding. even though I had no prior learning in physics, it was nice to be able to contribute during labs and help out my laboratory partner with theoretical questions, which I discovered to be my strength in physics.*

> *Boredom. Most are stuff I have already learned.*

Negative emotions: Blended mode

In the blended mode, three students selected anger, thirty students selected anxiety, fifteen students selected hopelessness, and sixteen students selected boredom in the comments for the Blended mode:

> *It's still tedious when it doesn't work.*

Again, a few students reported a mix of positive and negative emotions:

> *Lectures, in general, are pretty boring for me, I find more enjoyment from online lessons and doing rather than seeing. I do find pride however when I am able to follow along the lecture.*

Negative emotions: Online COVID-19 mode

In online COVID-19 mode, twelve students selected anger, thirty-six students selected anxiety, thirty students selected hopelessness, and thirty-one students selected boredom.

Students were found to be commenting on lack of teaching for the quizzes, on being unable to keep up, resulting in anger and anxiety, on old videos, and on how the lectures were conducted, while some claimed to find face-to-face mode to be easier.

> *Anger: I felt that there was a larger gap between what we learnt in the lecture and what we were expected to solve in the practice quizzes and quizzes, making me angry at myself for not being able to solve them after analysing every part of the quiz. Anxiety: The course is hard, and not the thought of falling has been keeping up at night and affecting me mentally. Before I topped my high school class in physics being very confident in the subject, however now trying to do any question almost always results in a panic attack.*

> *Anger, at times due to COVID19 it was harder to learn because I find it easier face-to-face.*

> *The lectures online for this course were terrible and after the first two weeks, I had given up on the lectures and was just studying from the textbook... Overall the online lectures seem half-hearted and a lacklustre attempt to satisfy the online learning criteria without actually doing any substantial work, bar using old videos that were recorded numerous years ago. The Online lecture format has had a dramatic impact on my learning experience, simply due to the fact that I did not learn anything.*

> *Sometimes anger or annoyance due to how the online lectures were conducted. During the lectures I would have preferred if the lecturer had not only taken us through physics principles but had also done example questions and shown us how to work out answers to questions. Instead I was given questions in the lectures, got them wrong and was then told why I got them wrong. I found this annoying and would have preferred to be first shown how to do the question, and then be given questions afterwards to do myself.*

Anxiety was reported due to the factors such as the lack of worked examples by the lecturers and being unable to ask questions of the lecturer.

> *Anxiety - The online lectures seemed to not explain the content in the depth of a normal lecture, leading to a lot of confusion during the practice and weekly quizzes, particularly regarding certain formulae (torque = dL/dt being an example), which were never explained properly. This is largely due to the lack of worked examples completed by the lecturer, which is missing in the online lectures. There are examples with really good explanations littered throughout the practice quizzes, however, that doesn't replace worked examples by a lecturer, where you get the chance to ask questions.*

A few felt lonely in the pandemic lockdown and confused at the content.

> *Hopelessness, I find it feels quite lonely completing courses online and it doesn't feel as read as sitting in a lecture theater*

> *The online lectures, while they did teach me some things… I was quite confused at the content and even bored because of the confusion. I was confused at how to answer the practice quiz questions and I always got them wrong leaving me hopeless and even when I watched the lecture video and tried to answer the*

questions, I didn't really learn how to do the questions. But I guess physics is a tough course and I am not good at it.

A few selected boredom as their prominent emotion, feeling that there was no interactive and collaborative work with their peers; they missed the hands-on laboratory.

I miss the experience for doing laboratory with a partner in a more advanced laboratory than doing it at home with nothing.

Although I did find the web stream lectures very helpful in my understanding of mechanics, I found them to be quite boring at times. I think this may be because I see Physics as something that should be studied hands-on through many many experiments. Although it does help to see video demonstrations, PHYSICALLY (haha) performing experiments to understand concepts is something I highly value for my learning.

Comments relating to transition to online mode due to COVID-19

There were some specific comments from students on their experiences of the switch to online learning.

Students reported a loss of enjoyment due to the shift online. Illustrative comments include:

Initially it was enjoyable, but due to the shift to online learning the started getting more boring.

Whilst the in person lectures were enjoyable with an enthusiastic lecturer and engaging interactive sections and experiments, I have felt more anxiety in the transition to the online course material. For the first week of the transition I was lost in what to do and when, I felt boredom when watching the videos and a frustration when the learning was cut off for interactive quiz sections. Whilst these quiz *sections do help me by allowing me to teach myself, I feel like that is already accomplished in the weekly quizzes and homework material, lectures, I feel, are for learning from people who have a better understanding of the topic, to go into more depth with answering questions than 5 minute video hints on what to do for the questions below and actually learn a new way to think and learn about the material.*

Enjoyment, the first half of the mechanics lectures were very well done, however being pushed onto the online lectures by COVID-19 I feel there was a decline in the quality and my enjoyment of the lectures.

A few students were seen to really miss the elements of the face-to-face lectures most enjoyable for them,

The practical demonstrations from our lecturer (Joe I think??) were always a highlight, sad to see them go because of COVID-19…

laboratory exercises were most enjoyable and interesting until they were cut off due to COVID.
The lecture online makes me feel Pride because l can solve some physics problems by myself.
..I also enjoyed doing the practical laboratories before the COVID pandemic.

It was clear from the students' comments that most of the students preferred face-to-face mode.

7.5.2.4 Discussion

The investigation of the effect of the delivery mode variable in section 7.5 showed that the face-to-face mode was associated with more positive emotions. The results are aligned with those of the study by Kemp and Grieve (2014), students find it easier to engage with the face-to-face course because they have opportunities to discuss and get feedback. Enjoyment was seen to be significantly higher for the students attending in face-to-face mode for all three weeks of term 3 2019. It is interesting that at the middle of the course the only emotion showing a significant difference between the two modes was enjoyment, while towards the end of the course all the positive emotions are higher while the negative emotions are lower in the face-to-face mode.

For a larger dataset with data from 2019 and 2020, the results again indicated that face-to-face mode generated more positive emotional engagement than both the blended mode and online COVID-19 modes.

The qualitative comments for face-to-face mode conducted in 2019 term 3 and 2020 term 1 included: "*Enjoyment, because i can see that the lecturers are trying their best to make the lectures more interesting*." and "..*Teacher and classmates are humorous, and we do our best to learn.*". As mentioned earlier in section 2.7, the blended mode is admired for its flexibility.

Research has shown that students' mental stress increased during the COVID-19 pandemic (Pedrosa et al, 2020). The transition to online mode of study due to COVID-19 pandemic affected students' emotions too, ".. *I have felt more anxiety in the transition to the online course material. lectures, I feel, are for learning from people who have a better understanding of the topic, to go into more depth with answering questions*..". The results in this Chapter indicate that, compared to the face-to-face and blended modes of teaching, positive emotions are significantly reduced in the online mode. Students' comments reflect the emotional impact on their learning experience, "*Anger, at times due to COVID-19 it was harder to learn because I find it easier face-to-face*" and "*I miss the experience for doing laboratory with a partner in a more advanced laboratory than doing it at home with nothing*.".

7.6 Summary

In conclusion, AEQ-Physics is a valid and reliable tool. It is conceptually sound and can measure the discrete and interrelated emotions as conceptualized by Pekrun et al (Pekrun et al, 2005a). The utility of the tool is presented in this Chapter while presenting comparison of students' emotions between two lecture streams and modes of teaching.

For the two lecture streams that were taught with same engagement elements such as predict-observe-explain and class discussions, it was discovered that one single engagement element, the ‘colorful historical story’, did not result in any significant difference of emotional engagement between the two lecture streams. For the two modes of teaching, face-to-face and blended, students had more positive emotions for the face-to-face mode and showed better emotional engagement.

I have compared students’ emotions for three different modes of teaching: face-to-face, blended, and online. The results of which indicate that face-to-face mode works best for students’ emotional engagement.

CHAPTER 8

Discussion, implications and conclusion

8.1 Introduction

In this Chapter, I present the motivation and summary of my research. I also present a discussion of the results, implications and future work, and limitations of my research.

8.2 Discussion

8.2.1 Summary of motivation and method for my research

Other researchers have shown that emotional engagement is required for students' continued interest and achievement in a subject (Pekrun, 2006; Kuh et al, 2008; Weiner, 2010). For the majority of students, positive emotions can be beneficial and negative emotions can be detrimental to academic learning (Pekrun et al, 2011). In subjects such as physics emotional engagement becomes even more important and yet such engagement is under researched. My study fills this gap by investigating the emotional engagement of students in a range of scenarios in introductory first-year physics at two research-intensive universities in Australia.

Previous research has suggested that the inclusion of color and history can have beneficial effects on students learning and engagement (Matthews, 1994; Stinner, 1995; Höttecke, 2012; Elliot, 2015). However, such strategies have not been widely adopted within physics. It has been suggested that this is because curriculum designers with traditional epistemological beliefs are reluctant to include such stories due to the lack of pedagogical knowledge and skills (Höttecke et al, 2010).

My research seeks to fill the gap by doing the following:

- Establish the need to tap into students' emotional engagement by adapting a survey tool to measure and compare students' emotions in physics practicals and courses.
- Enhance students' emotional engagement with carefully developed research-based stories that contain historical anecdotes and colorful pictures.
- Investigate whether delivery mode has an impact on students' emotional engagement.

In the paragraphs below I describe the method used for each of these points.

Firstly, to study students' emotional engagement, my research follows the conceptual framework of the control-value theory (Pekrun, 2006). I used quantitative and qualitative methods. For the quantitative methods, I adapted the Achievement Emotion Questionnaire (AEQ) to measure emotions in the laboratories. I validated the adapted tool, creating my tool called AEQ-PhysicsPrac. I used SPSS software to conduct exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) to validate the structure and patterns in students' emotions. Later, similar adaptation and validation processes followed for the tool to measure emotions for a whole course, AEQ-Physics. The emotions are deemed measurable and distinguishable with our surveys. For the qualitative methods, I investigated students emotions through open-ended survey responses, observations and interviews. The qualitative data were coded inductively and analysed thematically. Triangulating the qualitative and quantitative data provided reliable and valid measures of students' emotions and their emotional engagement.

Secondly, in order to enhance students' emotional engagement, I have carefully created interesting stories with historical anecdotes and real life applications of physics; colorful pictures accompany the stories. Research based 'colorful historical stories' were crafted for both the laboratory and the lecture components of a course, with somewhat different styles of presentation being used due to the nature of their delivery. In both environments, the stories were 'presented' without altering the content being taught. The 'colorful historical stories' were used in intervention-control style studies to investigate their influences on students' emotional engagement and, in one case, deployed in two courses for different cohorts.

Lastly, I investigated the impact of mode of studies on students' emotional engagement. This aspect focused on physics courses and includes data from cohorts which were affected by COVID-19.

8.2.2 Synopsis of the findings

The results of my study show that the adapted tools, called AEQ-PhysicsPrac and AEQ-Physics, are valid and reliable instruments for measuring students' emotions in first year undergraduate physics courses at the two universities examined. The tools provide measures of emotion which are discrete and interrelated as conceptualized by Pekrun et al (2005a). The surveys help instructors and course designers evaluate students' emotional engagement in different teaching and learning environments as well as compare emotion profiles of cohorts.

I crafted 'colorful historical stories' for a series of four experiments on electricity for a laboratory component of the intoductory physics course at The University of Sydney. These were implemented with two cohorts: the first cohort comprised of students who were more likely to major in physics whereas second were not likely to do so. The quantitative analysis showed that the emotional engagement is similar, the means of the six measured emotions were not statistically significantly different between the two cohorts. However, I found that for one cohort there were statistically significant correlations between the positive and negative emotions but this was not observed for the other cohort. This may be because the two cohorts are different in their predilection for physics and tutors used different teaching approaches for the cohorts. I also looked into qualitative responses and it was apparent that both the cohorts found the 'colorful historical stories' interesting, and that 'latch and hold interest' plays a role in emotional engagement in the laboratories.

I crafted 'colorful historical stories' for a series of fourteen lectures on Newtonian mechanics for an introductory course at the University of New South Wales. There were two lecture streams: both were taught with the same engagement elements such as predict-observe-explain and class discussions, except that the ‘colorful historical stories’ were used in one stream but not the other. I compared students’ emotional engagement between both the streams and discovered that one single engagement element, the ‘colorful historical story’, did not result in any significant difference of emotional engagement between them. For the same course, I also compared students’ emotions for the two modes of teaching, face-to-face and blended, and found that students were more positively engaged with the face-to-face mode.

8.2.3 Teaching during COVID-19

As my study at the University of New South Wales was conducted during year 2019 and 2020, I got an opportunity to study students’ emotions under three circumstances: Pre COVID-19, Looming COVID-19 and During COVID-19.

The introductory physics course that is generally offered in two modes, face-to-face and blended, to the students at the University of New South Wales, had to shift to online mode during the COVID-19 pandemic.

Opportunistically, I investigated students’ emotions for all three modes and found that, compared to the blended mode and online COVID-19 mode, the face-to-face mode generated the more positive emotional engagement. In qualitative comments students reported that the face-to-face mode provided them with an opportunity of peer discussion and lecturers’ instant feedback. Blended mode provided flexibility of learning, whereas the online COVID-19 mode increased their anxiety while negatively impacting their engagement.

8.3 Implications and future work

As with much work in physics education research, my novel study has implications for both research and teaching practice. These are discussed in the next two subsections.

8.3.1 Implications and future work for research

My study puts forward a case for further research on humanizing the first-year physics curriculum by incorporating ’colorful historical stories’ without impacting the content being taught. Such research is rare in the university context, but the journey needs to start somewhere. Thorough evaluation and research on alternatives for different contexts and for social inclusion is imperative. For example in my research, female role-models and everyday contexts were used. Researchers need to consider professional development and change management within their departments as a cornerstone for effective implementation. Also some students do not take kindly to 'colorful historical stories', hence, managing this discord is also needed. The science and craft of measuring effectiveness of interventions need to be developed as well. While I used the AEQ, other measures should also be explored to identify factors impacting emotional engagement of students other than found in this thesis. I have focused on emotional engagement, but also kept an eye on the various facets as a whole.

To strengthen the research basis for my suggestions for teaching practice, further adaptations and validation of the AEQ-PhysicsPrac and AEQ-Physics survey tool in different settings are needed. Equally important is the need to explore different types of 'colorful historical stories', implement them in a concerted effort and use measures of emotions to ascertain emotional engagement. The next big question would be to investigate whether emotional engagement impacts academic achievement and performance as well as persistence and retention. More qualitative analysis is also required to study in a deep manner the effect of the stories on students' emotions. The role of interest as a mediator as well as understanding the interest of diverse cohorts with respect to emtional engagement is under-researched and clearly needs further study.

I am currently incorporating story-based questions into formative quizzes for another introductory physics course at the University of New South Wales. Following the methodology, I used in this thesis, I plan to adapt and validate the AEQ for physics quizzes. I will measure and compare students' emotions during regular quizzes with questions containing the context of a 'colorful historical story'. I hope to publish the results in the near future.

In order to develop a more nuanced view of how to better emotionally engage students in the process, I would like to invite other researchers to join me in measuring students' emotions as well as in developing 'colorful historical stories' while the students are learning physics. It is my hope that this and like research will be adopted by the Physics Education Research (PER) community to investigate students' emotions.

8.3.2 Implications and future work for practice

My study puts forth a case for taking students' emotional engagement into account as part of their learning process in physics. I note that this involves large scale change in stance and approaches. It may be difficult for physics academics with fixed epistemological beliefs to embrace what my research has demonstrated. It took substantive effort on my part and that of my supervisors and other teaching and learning leaders to engage staff with my work. Even when they witnessed my strategies working, there was noticeable hesitancy. There needs to be persistent conversations and ongoing professional development around exploring diverse strategies for engaging students beyond reorganising and modifying 'content'.

I hope that this work assists academics to apply a research-based strategy to enhance emotional engagement. In this thesis, I show how to engage other academics and tutors in using research-based stories containing historical anecdotes and colorful pictures to enhance emotional engagement. I describe the process I followed to craft the 'colorful historical stories': this method can be followed by other practitioners to craft stories suitable to their own settings. I also present the stories created for the physics practicals and lectures along with the description of the theoretical underpinning for the same. These can be adapted according to practitioners' requirement and the level of the students to aid their feelings and engagement. In parallel, academics can be creative and produce their own styles of stories.

I wish to explore further in the field of role of emotional engagement in students' learning and I would like to invite practitioners to use my research in order to design learning resources for improved student engagement and to provide a better physics learning opportunity to students.

Another aspect to explore in the field is the inclusion of emotional engagement strategies in policy. I would like to invite practitioners to work with policy makers in order to better engage students in their physics learning and to keep them interested so that they continue further physics studies.

8.4 Limitations

Undoubtedly, there are limitations of this research that need to be mentioned as well. Firstly, both the large and complex dimension of human mind and experiences that affect students' emotional engagement and learning constrict any research. Factors that might impact students' engagement are their familiarity with the subject, the sophistication of their approach to learning (maturity), their expectations, their prior experience of similar learning tasks and probably their views about the epistemology of physics. This was apparent when I used colorful historical stories with the four experiments on electricity with two cohorts.

A second source of limitation comes from the data collection method. Since my research is on students' emotions, I used self-reports which may introduce biases. When the students reported their emotions in AEQ, the self-report tool used in my research, the reported feelings might be biased for each student, based on their interpretation and their stance on each item. Furthermore, bias may be introduced by my role as an 'observer as participant' (often referred to as a 'participant researcher'), when I observed the first-year physics laboratory classes.

A third limitation comes from the demographics of the samples used for this research. This study was conducted at The University of Sydney and the University of New South Wales, both of which are research-intensive metropolitan universities. If this research is adapted for other universities internationally, adequate modifications may be required in the research methodology and the interpretations of the results.

Finally, another limitation of this research is that it is conducted with first-year undergraduate students over a period of three years. More data needs to be collected and analysis conducted for samples collected from a greater variety of universities for different levels of students over a number of years in order to establish AEQ-PhysicsPrac and AEQ-Physics as thorough and valid survey tools to measure students' emotions with their physics studies.

8.5 Conclusion

In summary, this is a timely and novel study focusing on measuring, understanding and enhancing students' emotional engagement with the potential to broaden participation in physics.

This study demonstrates a potential instrument for further research in exploring undergraduate students' emotions towards physics. With the help of this instrument learning resources can be evaluated and redesigned for better student engagement. The adapted AEQ opens up the possibility of observing different profiles of emotions experienced by students for different learning situations. Since emotions can be measured and stories inserted, future studies can probe their influence on students' achievements.

Appendix A: Ethics and participant information forms

The University of Sydney ethics and participant information forms

Wednesday, 12 December 2018

Assoc Prof Manjula Sharma
Physics; Faculty of Science
Email: manjula.sharma@sydney.edu.au

Dear Manjula,

The University of Sydney Human Research Ethics Committee (HREC) has considered your application.

I am pleased to inform you that after consideration of your response, your project has been approved.

Details of the approval are as follows:

Project No.:	**2018/809**
Project Title:	**Measuring student engagement in first-year physics laboratories**
Authorised Personnel:	**Sharma Manjula; Kota Srividya Durga; Bhansali Aesha; Tzioumis Vicky;**
Approval Period:	**11/12/2018** to **11/12/2022**
First Annual Report Due:	**11/12/2019**

Documents Approved:

Date Uploaded	Version Number	Document Name
22/10/2018	Version 2	Bhansali survey - revised clean
22/10/2018	Version 2	Kota survey - revised clean
04/12/2018	Version 3	Participant Information Statement - revision 3 clean

Condition/s of Approval

- Research must be conducted according to the approved proposal.
- An annual progress report must be submitted to the Ethics Office on or before the anniversary of approval and on completion of the project.
- You must report as soon as practicable anything that might warrant review of ethical approval of the project including:
  - Serious or unexpected adverse events (which should be reported within 72 hours).
  - Unforeseen events that might affect continued ethical acceptability of the project.
- Any changes to the proposal must be approved prior to their implementation (except where an amendment is undertaken to eliminate *immediate* risk to participants).
- Personnel working on this project must be sufficiently qualified by education, training and experience for their role, or adequately supervised. Changes to personnel must be reported and approved.
- Personnel must disclose any actual or potential conflicts of interest, including any financial or other interest or affiliation, as relevant to this project.
- Data and primary materials must be retained and stored in accordance with the relevant legislation and University guidelines.

- Ethics approval is dependent upon ongoing compliance of the research with the *National Statement on Ethical Conduct in Human Research*, the *Australian Code for the Responsible Conduct of Research*, applicable legal requirements, and with University policies, procedures and governance requirements.

- The Ethics Office may conduct audits on approved projects.

- The Chief Investigator has ultimate responsibility for the conduct of the research and is responsible for ensuring all others involved will conduct the research in accordance with the above.

This letter constitutes ethical approval only.

Please contact the Ethics Office should you require further information or clarification.

Sincerely,

[redacted]

Associate Professor Rita Shackel
Chair
Human Research Ethics Committee (HREC 3)

The University of Sydney of Sydney HRECs are constituted and operate in accordance with the National Health and Medical Research Council's (NHMRC) National Statement on Ethical Conduct in Human Research (2007) and the NHMRC's Australian Code for the Responsible Conduct of Research (2007)

Discipline of Physics Education
School of Physics
Faculty of Science

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Student engagement in first year physics laboratories

PARTICIPANT INFORMATION STATEMENT

(1) What is this study about?

You are invited to take part in a research study about the integration of digital technologies, modelling, storytelling and whole class discussion with inquiry-based learning to improve student engagement. The study aims to understand how undergraduate physics students engage in laboratories and which features describe their engagement.

You have been invited to participate in this study because you are enrolled in a first-year Physics unit. This Participant Information Statement tells you about the research study. Knowing what is involved will help you decide if you want to take part in the research. Please read this sheet carefully and ask questions about anything that you don't understand or want to know more about.

Participation in this research study is voluntary.

By giving your consent to take part in this study you are telling us that you:
- ✓ Understand what you have read.
- ✓ Agree to take part in the research study as outlined below.
- ✓ Agree to the use of your personal information as described.

You will be given a copy of this Participant Information Statement to keep.

(2) Who is running the study?

The study is being carried out by the following researchers:
- Manjula Sharma (Professor, School of Physics, The University of Sydney)
- Srividya Durga Kota (Master's student, School of Physics, The University of Sydney)
- Aesha Bhansali (PhD student, School of Physics, The University of Sydney)

Srividya Durga Kota and Aesha Bhansali are conducting this study as the basis for the degree of Master of Philosophy and Doctor of Philosophy, respectively, at The University of Sydney. This will take place under the supervision of Professor Manjula Sharma.

(3) What will the study involve for me?

Your participation will involve answering survey questions about your experiences of the laboratory work you have completed. The types of questions that you will be asked include whether you found the experiment interesting, whether you think it helped you to develop laboratory and data interpretation skills, whether it is relevant to your studies.

(4) How much of my time will the study take?

This survey should only take 15 minutes to complete.

(5) Who can take part in the study?

This study is open to students enrolled in First year Physics courses.

(6) Do I have to be in the study? Can I withdraw from the study once I've started?

Being in this study is completely voluntary and you do not have to take part. Your decision whether to participate will not affect your current or future relationship with the researchers or anyone else at the University of Sydney.

Submitting your completed questionnaire is an indication of your consent to participate in the study. You can withdraw your responses if you change your mind about having them included in the study, up to the point that we have analysed and published the results.

(7) Are there any risks or costs associated with being in the study?

Aside from giving up your time, we do not expect that there will be any risks or costs associated with taking part in this study.

(8) Are there any benefits associated with being in the study?

Your feedback will help us to improve the labs and experiences of future classes. We cannot guarantee that you will receive any direct benefits from being in the study.

(9) What will happen to information about me that is collected during the study?

By providing your consent, you are agreeing to us collecting personal information about you for the purposes of this research study. Your information will only be used for the purposes outlined in this Participant Information Statement, unless you consent otherwise.

Your information will be stored securely and your identity/information will be kept strictly confidential, except as required by law. Study findings may be published, but you will **not** be individually identifiable in these publications.

(10) Can I tell other people about the study?

Yes, you are welcome to tell other people about the study.

(11) What if I would like further information about the study?

If you would like to know more at any stage during the study, please feel free to contact Professor Manjula Sharma manjula.sharma@sydney.edu.au

(12) Will I be told the results of the study?

You have a right to receive feedback about the overall results of this study. No specific feedback will be given to you individually, however, the results of the study may be published in refereed or non-refereed journals. Feedback will be available on the Sydney University Physics Education Research (SUPER) group website in the form of a one-page lay summary and a link to any published papers after the study is finished.

(13) What if I have a complaint or any concerns about the study?

Research involving humans in Australia is reviewed by an independent group of people called a Human Research Ethics Committee (HREC). The ethical aspects of this study have been approved by the HREC of the University of Sydney *[INSERT* protocol number once approval is obtained*].* As part of this process, we have agreed to carry out the study according to the *National Statement on Ethical Conduct in Human Research (2007).* This statement has been developed to protect people who agree to take part in research studies.

If you are concerned about the way this study is being conducted or you wish to make a complaint to someone independent from the study, please contact the university using the details outlined below. Please quote the study title and protocol number.

The Manager, Ethics Administration, University of Sydney:

- **Telephone:** +61 2 8627 8176
- **Email:** human.ethics@sydney.edu.au
- **Fax:** +61 2 8627 8177 (Facsimile)

This information sheet is for you to keep

University of New South Wales ethics and participant information forms

UNSW Human Research Ethics Application Form

More than Low Risk OR Low Risk Research Applications

1. Lay Summary & Aims (Maximum of 500 words)
Briefly provide a summary of the project in lay terminology (no more than 500 words). The project summary should include the following details: • Aims of the project • Importance of the study
Students' emotional engagement is one of the important factors to be considered in Physics Education Research. Emotions influence students' learning, motivation and achievement outcomes (Pekrun, 2017). No instruments are yet developed to measure emotions in Physics. Pekrun et al. have developed Achievement Emotion Questionnaire (AEQ). We have adapted it and validated AEQ-Physics (AEQ-Ph) for first year physics course. The measurements we will take are: • Survey students for Mechanics concept inventory test (FCI), Thermal concept survey (TCS), AEQ-Ph • Interviews students. The aims of the study are: • To develop a self-report measure of student emotions for the first year physics courses. • Check the impact of factors like the lecturer, and students' attendance to classes on students' emotional engagement. • To find how students' emotional engagement impacts their conceptual understanding of physics. This survey instrument will be helpful for assessing and analysing students' emotional engagement with undergraduate physics. Thus the relevant changes could be made to engage students better.

2. Background Literature Review – (Maximum of 500 words)
Provide an outline of the theoretical background for the research proposal with reference to relevant literature. • The background literature review should be "based on a thorough study of the current literature, as well as previous studies" (NS 1.1c) along with; • The potential significance of the study
Student engagement has been labelled the 'holy grail' of education (Sinatra, Hedy, & Lombardi, 2015) and has been conceptualized as: a) cognitive engagement - the mental energy students put in 2) emotional engagement - the positive emotional response students experience while learning 3) behavioural engagement - students' interaction with each other (Fredricks, Blumenfeld, & Paris, 2004) Specifically, students' emotional engagement is one of the important factors for academic success and continued learning. Emotions influence students' learning, motivation and achievement outcomes (Pekrun, 2017). Emotional engagement is presumed to be malleable through interventions and changing contexts (Fredricks, Blumenfeld, & Paris, 2004; Skinner & Pitzer, 2012). As part of this study we will investigate and compare the relationship between multiple predictor emotions of students' self-efficacy and cognitive load during an undergraduate first year physics course. *References:* Fredricks, J.A., Blumenfeld, P.C. and Paris, A.H. (2004). School engagement: Potential of the concept, state of the evidence. Review of Educational Research, 74 (1), 59–109. Gilbert, J. K. (2004). Models and modelling: Routes to more authentic science education. International Journal of Science and Mathematics Education, 2(2), 115–130. Nersessian, N. J. (2008). Mental modeling in conceptual change. In S. Vosniadou (Ed.) International handbook of research on conceptual change (pp. 391–416). London, UK: Routledge. Pekrun, R. (2017). Emotion and Achievement During Adolescence. Child Development Perspectives, Volume 11, 215–221. Rice, J. W., Thomas, S. M., & OToole, P. (2009). Tertiary science education in the 21st century. Sydney: Australian Learning and Teaching Council.

Sinatra, G.M., Hedy, B.C. and Lombardi D. (2015). The challenges of defining and measuring student engagement. Educational Psychologist, 50 (1), 1–13.

Skinner, E.A. and Pitzer, J.R. (2012). Developmental dynamics of student engagement, coping, and everyday resilience. In S.L. Christenson, A.L. Reschly, C. Wylie (Eds.), Handbook of research on student engagement (pp. 21–44). Springer, Boston.

3. Research Design and Methodology (Maximum 1 page)

Provide an outline of the research design, the study timeline and data collection methods.

We will survey first year undergraduate students attending Physics 1A courses (PHYS1121/1131 and 1141). We will be looking at whether there are differences in the emotional engagement of the students in different lecture streams and how this compares to the students who choose to take the lectures online. Information about their lecture stream and engagement with online lectures will be obtained from Moodle. We will also look for correlations between their emotional engagement and results in concept inventory tests.

The measurements we will take are:

- Mechanics concept inventory test (pre and post) FCI: online; bonus mark to motivate them to do it, usually over 50% do, the bonus mark will be awarded to any students who completes this survey, whether they agree to be part of the study or not (ie. The survey will be available to everyone, students can opt out of this study).
- Thermal concept survey TCS (pre and post): online; bonus mark to motivate them to do it, usually over 50% do, the bonus mark will be awarded to any students who completes this survey, whether they agree to be part of the study or not (ie. The survey will be available to everyone, students can opt out of this study).
- Emotional survey will be given during problem solving workshop in week 4 and week 9 (online but in class) this ensures we have their student number and so enrolment details. This survey will be optional but they will be given some class time to complete it.
- Focus groups with students

4. Clinical Trials involving the use of a medicine, device or placebo.

- Provide a description of the medicine, device or placebo that you intend to use in the research.
- Provide copies of the [Australian Register of Therapeutic Goods (ARTG)] product information or ARTG identifier number.
- Outline whether the medicine or device will be use as per the conditions set out in the ARTG Public Summary documentation.

NA

5. Sample Size (Maximum of 250 Words)

Outline the intended sample size for the project and justify how this will meet the aims of the study.

Sample size calculations tools can be found online at:

- http://powerandsamplesize.com/Calculators/ (quantitative)
- http://stat.ubc.ca/~rollin/stats/ssize/index.html (quantitative)
- http://eprints.ncrm.ac.uk/2273/4/how_many_interviews.pdf (qualitative)

Around 700 students are taking PHYS1121/1131/1141 in term 1. Out of which 147 students are currently taking the lectures online (web stream). In total around 2000 students over the year take the Physics 1A courses. This large sample size will allow us to identify if there is a correlation between emotional engagement and lecture stream.

6. Research Participants (Maximum of 500 words)

Describe the characteristics of the participants that you intend to recruit in the study (e.g. inclusion/exclusion criteria, sex, age range of participants).

All students enrolled in PHYS1121/1131/1141 will be invited to participate in the survey.

7. Recruitment of participants

Outline the methods that will be used to recruit participants to the study. The methods in this section should describe:

- What process(es) will be used to identify potential participants;
- How initial contact will be made with potential participants;

- How participants will be screened to ensure they meet the inclusion criteria.

The researchers will seek volunteers from the 2000 students who study Physics at a first year undergraduate level at UNSW, Sydney. The students will be asked, during the physics workshop sessions, to participate in a survey seeking to understand how students engage with the course work. It will be explicitly stated that this survey is voluntary and will not affect their grade. It is anticipated that the sample size will be around 2000 students each calendar year which will allow for the aims of the study to be achieved and is large enough for statistical analyses to be conducted.

8. Consent

Provide a detailed description of the consent process to include the following:

- The type of consent that will be sought (e.g. verbal/ written/ return of survey etc.), how and when you will provide consent materials to your potential participants and why this method of consent is appropriate for the participant population.
- How, when and to whom participants will indicate their consent and how any real or perceived coercion will be avoided during the consent process.

**if the project involves the use of data already collected and the participants have already provided their consent for this to happen, please attach a copy of the original consent form as evidence.
**if you are seeking a waiver of consent, please provide justification. (See the National Statement, Chapters 2.2 and 2.3 for more information).

Consent will be asked for in the survey

9. Reimbursement of Expenses or Incentives to Participate

Explain whether there will be any reimbursement of out-of-pocket expenses, financial incentive or other "reward" as a result of participation in the study.

No rewards given

10. Risks to participants

Describe the anticipated risks to the participants, including:

- Whether the benefits outweigh the risks to the participants;
- How will you manage or minimise the risks to participants.

No risks to participants

11. Privacy and Confidentiality

At this section the research team needs to describe how the data may be collected, stored or disclosed:

- Specify the format that the data will be collected in;
- Specify how individual identifiers will be removed (if applicable);

The data will be de-identified. Only the de-identified data will be in the thesis, journal paper and conference presentations.

Define how data collected will be stored

Data Type	Campus/Location	Building/Server Name	How is data stored securely	How is access restricted	Estimated date of data destruction
☐ **Hard Copies** (add additional rows for multiple locations)					
☒ **Electronic Copies** (add additional rows for multiple locations)	**Library**	**UNSW data Archives**			**Seven years after collection**
☐ **Audio/Visual** (add additional rows for multiple locations)					
☐ **Human Biospecimens (e.g. blood/tissue)** (add additional rows for multiple locations)					

12. Publications and Dissemination of Results

In this section detail how:

- The research results will be reported to the participants of the study;
- How the research results will be reported/ published;
- How participant confidentiality will be maintained in your reports and/or publications.

The research results will be published in the research journals, and researcher's PhD thesis.

PARTICIPANT INFORMATION STATEMENT AND CONSENT FORM

Exploring students' emotional engagement in first year physics
A. Prof. Elizabeth Angstmann

1. **What is the research study about?**
You are invited to take part in this research study. The research study aims to measure students' emotional engagement. You have been invited because because you are enrolled in one of the Physics 1A courses, and your contact details were obtained from from the course Moodle site.

2. **Who is conducting this research?**
The study is being carried out by the following researchers: Manjula Sharma (USyd), Elizabeth Angstrmnn (UNSW) and Aesha Bhansali (USyd).
Research Funder: This research is not funded.

3. **Inclusion/Exclusion Criteria**
Before you decide to participate in this research study, we need to ensure that it is ok for you to take part. The research study is looking recruit people who meet the following criteria:
    - Are enrolled in one of the Physics 1A courses.

4. **Do I have to take part in this research study?**
If you decide you want to take part in the research study, you will be asked to:
    - Read the information carefully (ask questions if necessary);
    - Sign and return the consent form if you decide to participate in the study;
    - Take a copy of this form with you to keep.

5. **What does participation in this research require, and are there any risks involved?**
There are no risks involved in this study. You can withdraw your participation at any time during the interview or filling out the survey.

Participation in focus group

- If you decide to take part in the research study, you will be asked to participate in a face to face focus group. You will be asked questions about how you felt about the physics lectures during the term. It should take approximately 10 minutes to complete.
To ensure we collect the responses accurately, we seek your permission to digitally record the interview using an audio tape. If you would like to participate but do not wish to be recorded, you will need to discuss the options for your participation with the research team.

If you decide to take part in the research study, the research team will ask you to answer few questions regarding emotions that you felt during physics lectures for the term. It should take approximately 10 minutes to complete the task.

There is no reimbursement to participants in this study.

If you experience discomfort or feelings of distress while participating in the research and you require support, you can stop participating at any time. You can also tell a member of the research and they will provide you with assistance or alternatively a list of support services and their contact details are provided below.

6. **What are the possible benefits to participation?**
We hope to use information we get from this research study to benefit of future students taking the Physics 1A courses and similar courses run elsewhere.

7. **What will happen to information about me?**

By signing the consent form you consent to the research team collecting and using information about you for the research study. Your data will be kept for a minimum 7 years after the project's completion. We will store information about you in an identifiable format on the UNSW Data Archive. Your information will only be used for this study into emotional engagement. All published data will be de-identified.

The information you provide is personal information for the purposes of the Privacy and Personal Information Protection Act 1998 (NSW). You have the right of access to personal information held about you by the University, the right to request correction and amendment of it, and the right to make a complaint about a breach of the Information Protection Principles as contained in the PPIP Act. Further information on how the University protects personal information is available in the **UNSW Privacy Management Plan**.

8. How and when will I find out what the results of the research study are?
The research team intend to publish and/ report the results of the research study in a variety of ways. All information published will be done in a way that will not identify you.
If you would like to receive a copy of the results you can let the research team know by including your details in the space provided in the consent form.

9. What if I want to withdraw from the research study?
If you do consent to participate, you may withdraw at any time. You can do so by completing the 'Withdrawal of Consent Form' which is provided at the end of this document. Alternatively you can ring the research team and tell them you no longer want to participate. Your decision not to participate or to withdraw from the study will not affect your relationship with UNSW Sydney and/or University of Sydney. If you decide to leave the research study, the researchers will not collect additional information from you. Any identifiable information about you will be withdrawn from the research project.

Focus group
If you decide to participate in the focus group, your comments along with other participants will be recorded during the group discussions. Because of the way in which the focus group discussions are recorded, the research team will not be able to withdraw or destroy individual participant responses.

10. What should I do if I have further questions about my involvement in the research study?
The person you may need to contact will depend on the nature of your query. If you require further information regarding this study or if you have any problems which may be related to your involvement in the study, you can contact the following member/s of the research team:

Research Team Contact Details

Name	Aesha Piyush Bhansali
Position	PhD Candidate
Telephone	
Email	abha0871@uni.sydney.edu.au

Name	Elizabeth Angstmann
Position	Associate Professor
Telephone	9385 4542

Email	e.angstmann@unsw.edu.au

What if I have a complaint or any concerns about the research study?
If you have a complaint regarding any aspect of the study or the way it is being conducted, please contact the UNSW Human Ethics Coordinator:

Complaints Contact

Position	UNSW Human Research Ethics Coordinator
Telephone	+ 61 2 9385 6222
Email	humanethics@unsw.edu.au
HC Reference Number	[INSERT HC reference number]

THE UNIVERSITY OF SYDNEY	UNSW SYDNEY

PARTICIPANT INFORMATION STATEMENT AND CONSENT FORM

Exploring students' emotional engagement in first year physics
A. Prof. Elizabeth Angstmann

Consent Form – Participant providing own consent

Declaration by the participant

☐ I understand I am being asked to provide consent to participate in this research study;
☐ I have read the Participant Information Sheet or someone has read it to me in a language that I understand;
☐ I understand the purposes, study tasks and risks of the research described in the study;
☐ I understand that the research team will audio record the interviews; I agree to be recorded for this purpose.
☐ I provide my consent for the information collected about me to be used for the purpose of this research study only.
☐ I have had an opportunity to ask questions and I am satisfied with the answers I have received;
☐ I freely agree to participate in this research study as described and understand that I am free to withdraw at any time during the study and withdrawal will not affect my relationship with any of the named organisations and/or research team members;
☐ I would like to receive a copy of the study results via email or post, I have provided my details below and ask that they be used for this purpose only;

Name: ______________________________________

Address: ____________________________________

Email Address: _______________________________

☐ I understand that I will be given a signed copy of this document to keep;

Participant Signature

Name of Participant (please print)	
Signature of Research Participant	
Date	

Declaration by Researcher*

☐ I have given a verbal explanation of the research study, its study activities and risks and I believe that the participant has understood that explanation.

Researcher Signature*

Name of Researcher (please print)	**Aesha Piyush Bhansali**
Signature of Researcher	[signature]
Date	**26/2/2019**

+An appropriately qualified member of the research team must provide the explanation of, and information concerning the research study.

Note: All parties signing the consent section must date their own signature.

Form for Withdrawal of Participation

THE UNIVERSITY OF SYDNEY	UNSW SYDNEY

PARTICIPANT INFORMATION STATEMENT AND CONSENT FORM

Exploring students' emotional engagement in first year physics
A. Prof. Elizabeth Angstmann

I wish to **WITHDRAW** my consent to participate in this research study described above and understand that such withdrawal **WILL NOT** affect my relationship with The University of New South Wales, University of Sydney. In withdrawing my consent I would like any information which I have provided for the purpose of this research study withdrawn. [I understand that the information collected about me during my participation in the focus group cannot be withdrawn given the nature of the focus group].

Participant Signature

Name of Participant (please print)	
Signature of Research Participant	
Date	

The section for Withdrawal of Participation should be forwarded to:

CI Name:	Manjula Devi Sharma
Email:	manjula.sharma@sydney.edu.au
Phone:	+61 2 9351 2051
Postal Address:	Rm No, 203 Physics Building No A28 | The University of Sydney | NSW | 2006 | Australia

THE UNIVERSITY OF SYDNEY
Department of Physics

UNSW SYDNEY

ONLINE PARTICIPANT INFORMATION STATEMENT

Exploring students' emotional engagement in first year physics
A. Prof. Elizabeth Angstmann

1. **What is the research study about?**
   You are invited to take part in this research study. The research study aims to measure students' emotional engagement. You have been invited because because you are enrolled in one of the Physics 1A courses, and your contact details were obtained from from the course Moodle site.

2. **Who is conducting this research?**
   The study is being carried out by the following researchers: The study is being carried out by the following researchers: Manjula Sharma, Elizabeth Angstmann and Aesha Bhansali, University of Sydney, University of New South Wales.
   Research Funder: This research is not funded.

3. **Inclusion/Exclusion Criteria**
   Before you decide to participate in this research study, we need to ensure that it is ok for you to take part. The research study is looking recruit people who meet the following criteria:
   - Are enrolled in one of the Physics 1A courses.

4. **Do I have to take part in this research study?**
   Participation in any research study is voluntary. If you do not want to take part, you do not have to.

   If you decide you want to take part in the research study, you will be asked to:
   - Read the information carefully (ask questions if necessary);
   - Complete the online questionnaire.

5. **What does participation in this research require, and are there any risks involved?**
   There are no risks involved in this study. You can withdraw your participation at any time during the interview or filling out the survey.

   If you decide to take part in the research study, we will ask you to complete an online questionnaire. The questionnaire will ask you questions about how you felt about the physics lectures during the term. It should take approximately 10 minutes to complete.

   If you experience discomfort or feelings of distress while participating in the research and you require support, you can stop participating at any time. You can also tell a member of the research and they will provide you with assistance or alternatively a list of support services and their contact details are provided below.

6. **What are the possible benefits to participation?**
   We hope to use information we get from this research study to benefit of future students taking the Physics 1A courses and similar courses run elsewhere.

7. **What will happen to information about me?**
   Submission of the online questionnaire is an indication of your consent. By clicking the 'I agree to participate' button you are providing your permission for the research team to collect and use information about you for the research study. Your data will be kept for a period of 5 years after the publication of the research results We will store information about you in an identifiable format on the UNSW Data Archive. Your information will only be used for this study into emotional engagement. All published data will be de-identified.

The information you provide is personal information for the purposes of the Privacy and Personal Information Protection Act 1998 (NSW). You have the right of access to personal information held about you by the University, the right to request correction and amendment of it, and the right to make a complaint about a breach of the Information Protection Principles as contained in the PPIP Act. Further information on how the University protects personal information is available in the **UNSW Privacy Management Plan**.

8. How and when will I find out what the results of the research study are?

The research team intend to publish and/ report the results of the research study in a variety of ways. All information published will be done in a way that will not identify you.
If you would like to receive a copy of the results you can let the research team know by adding your email or postal address within the consent form. We will only use these details to send you the results of the research.

9. What if I want to withdraw from the research study?

If you do consent to participate, you may withdraw at any time. You can do so by completing the 'Withdrawal of Consent Form' which is provided at the end of this document. Alternatively, you can ring the research team and tell them you no longer want to participate. If you decide to leave the research study, the researchers will destroy any information that has already been collected and no additional information will be collected from you. Your decision not to participate or to withdraw from the study, will not affect your relationship with UNSW Sydney and/or University of Sydney.

The information you provide is personal information for the purposes of the Privacy and Personal Information Protection Act 1998 (NSW). You have the right of access to personal information held about you by the University, the right to request correction and amendment of it, and the right to make a compliant about a breach of the Information Protection Principles as contained in the PPIP Act. Further information on how the University protects personal information is available in the **UNSW Privacy Management Plan**.

10. What should I do if I have further questions about my involvement in the research study?

The person you may need to contact will depend on the nature of your query. If you require further information regarding this study or if you have any problems which may be related to your involvement in the study, you can contact the following member/s of the research team:

Research Team Contact

Name	Aesha Piyush Bhansali
Position	PhD Candidate
Telephone	
Email	abha0871@uni.sydney.edu.au

Name	Elizabeth Angstmann
Position	Associate Professor
Telephone	9385 4542
Email	e.angstmann@unsw.edu.au

If at any stage during the study, you become distressed or require additional support from someone not involved in the research please call:

THE UNIVERSITY OF SYDNEY Department of Physics	UNSW SYDNEY

ONLINE PARTICIPANT INFORMATION STATEMENT

Exploring students' emotional engagement in first year physics
A. Prof. Elizabeth Angstmann

What if I have a complaint or any concerns about the research study?
If you have a complaint regarding any aspect of the study or the way it is being conducted, please contact the UNSW Human Ethics Coordinator:

Complaints Contact

Position	Human Research Ethics Coordinator
Telephone	+ 61 2 9385 6222
Email	humanethics@unsw.edu.au
HC Reference Number	

ONLINE PARTICIPANT INFORMATION STATEMENT

Exploring students' emotional engagement in first year physics
A. Prof. Elizabeth Angstmann

Consent Form – Participant providing own consent

Note: this will be completed online.

Declaration by the participant

- ☐ I understand I am being asked to provide consent to participate in this research study;
- ☐ I have read the Participant Information Sheet or it has been provided to me in a language that I understand;
- ☐ I provide my consent for the information collected about me to be used for the purpose of this research study only.
- ☐ I understand that if necessary I can ask questions and the research team will respond to my questions.
- ☐ I freely agree to participate in this research study as described and understand that I am free to withdraw at any time during the study and withdrawal will not affect my relationship with any of the named organisations and/or research team members;
- ☐ I would like to receive a copy of the study results via email or post, I have provided my details below and ask that they be used for this purpose only;
  Name: ___________________________________

  Address: _________________________________

  Email Address: ____________________________

- ☐ I understand that I can download a copy of this consent form from the moodle site.

Participant Details

Name of Participant (please type)	
Participant email address (if applicable)	
Date	

I agree, start questionnaire

Department of Physics

ONLINE PARTICIPANT INFORMATION STATEMENT

Exploring students' emotional engagement in first year physics
A. Prof. Elizabeth Angstmann

Form for Withdrawal of Participation

I wish to **WITHDRAW** my consent to participate in the research proposal described above and understand that such withdrawal **WILL NOT** affect my relationship with The University of New South Wales, University of Sydney. In withdrawing my consent I would like any information which I have provided for the purpose of this research study withdrawn.

Participant Name

Name of Participant (please type)	
Date	

Submit withdrawal of consent

FOCUS GROUP PROTOCOL
Introduction

- Upon entering the room – welcome participants
- Take participant names and check them off the registration list
- Ask participants to take a seat, write their first-name (or pseudonym) on index card at their seat and complete the consent form
- If demographic information has not been collected, ask participants to complete demographic questionnaire

Background

Good (morning/afternoon/evening) and welcome to our session.

[INTRODUCE SELF]
Thank you for taking the time to join our discussion. This focus group is about your experience at the physics lecture the University of New south wales. I want to talk to you about your emotional experiences or your emotions during the lecture. We are going to focus on how coming to university, attending a particular lecturer's class, learning with fellow students in the class affects your emotions and engagement. There are no right or wrong answers, because everyone experiences things differently. We are interested in the full range of experiences, so please feel free to share your point of view even if it differs from what others have said.

Discussion Group Rules

Before we begin, let me suggest some guidelines that will make our discussion more productive.

- Please speak up—but only one person should talk at a time. We're recording the session because we

don't want to miss any of your comments. If you have trouble hearing any of the comments, please let

the group know.

- In the discussion, we'll be on a first-name basis. In later reports no names will be attached to any comments. Your name will be kept confidential. We also ask that you respect the confidentiality of everyone here. Please do not repeat who said what when you leave the room. We've placed name cards on the table in front of you just to help us remember each other's names during the course of the discussion. You may feel free to use a pseudonym if you choose, please just ensure that it matches the name you entered on the demographic questionnaire.
- My role here is to ask questions and to listen. I won't be actively participating in the conversation, only guiding it. I want you to feel free to talk to the group

and not just to me. I'll be asking some specific questions. We are interested in your experiences, but because this is a research project, it is important that you link your comments back to the questions. I'll move the discussion from one question to the next to try to keep us on track so that we can finish by the time limit. If at any point you would prefer not to answer a question, please feel free to pass.

- Just so you know, the bathrooms are [point out directions]. Once we start, we will not be taking any breaks for the next 10-15 minutes. If you need to go to the bathroom or want to get up and get more to drink please feel free to take care of your needs.
- Sometimes, people in focus groups think of things they want to say after the discussion has moved on to other questions. If you would like to add to your comments after the group, we will be around to talk with you privately.
- Any questions before we begin?

Focus Group Questions

1. Let's begin with introductions. Please tell us your first name and your program of study.

2. (a) Now that we have all been introduced, we would like you to think broadly about your experience

here – about your classes, your lecturer, the physics topics, your learning experience at the lecture as a whole – and complete the following sentence. "My physics lecture experience during Physics__ is/has/feels ___________________" You can insert either one word or a phrase to complete the sentence, but the idea is to get as many different descriptors on paper as possible in 2 minutes. [DISTRIBUTE STICKY NOTES & WRITE QUESTION ON FLIPCHART/CHALKBOARD]

(b) Now we would like you to work together to group all of your words/phrases into categories by theme of different emotions like Pride, Enjoyment, Anger, Anxiety, and Hopelessness.
[MODERATOR COLLECTS STICKY NOTES KEEPING THEM ORGANIZED BY THEME]

3. Thinking back on your physics lectures how welcome did you feel?

4. Did you need advice regarding physics problems, concepts or your level of understanding – did do you get it?

5. Would you wish for better opportunities for student-faculty interaction. Do you share their perspective? Where, outside of classes, have some of your most positive interactions

with faculty occurred? Can you describe how you might like or expect to have interaction with faculty?

6. Did you lecturer use real life examples, demonstrations to make you better understand the concepts of Physics? How many ? Would you like more ?

7. To what extent do you feel that you and your success and the lecture experience are a high priority for the lecturer? Did they answer your questions during or after lectures? Did you find it comfortable to pose the questions before or after class?

8. How would you rate your interest and level of understanding required for the course. Does it impact your engagement in positive or negative way?

10. Do you think, the main purpose of the lecture was to prepare you for the exams? Or to learn the concepts of physics, see the beauty of Physics, and the application of Physics in real life .

11. [SUMMARIZE SESSION] We wanted to get lots of perspectives on the students' emotional engagement. Thinking about what we've talked about today, is there anything we didn't address that you thought we would talk about? Is there one thing you feel passionately that should be changed for better student engagement? Is there one thing you feel passionately that should be preserved?

Conclusion

- Thank participants for attending
- Allow space for any participants who would like to speak to you privately to do so.
- record any key themes that emerged from the discussion and any issues with the protocol or facilitation methods that should be resolved before the next focus group.
- Check the tape to ensure that the discussion was properly recorded.
- Collect tapes and any notes from the focus group, clearly label them with the date/time of the focus group, and move them to a secure location immediately (e.g. locked file cabinet).

Appendix B: Physics questionnaires

AEQ-PhysicsPrac Survey 1

THE UNIVERSITY OF SYDNEY

Put your answers on the right-hand side of this form. If you feel you cannot answer a particular question, just leave it and go onto the next question. Use a dark pen or pencil to select your answer to each question. Fill in circles completely like this ●	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. During this experiment, I was satisfied with my work.	○	○	○	○	○
2. For me this experiment was a challenge that was enjoyable.	○	○	○	○	○
3. I felt annoyed by this experiment.	○	○	○	○	○
4. I felt elated by my accomplishments during this experiment.	○	○	○	○	○
5. I got scared that I might do something wrong while doing this experiment.	○	○	○	○	○
6. I felt this experiment was exciting.	○	○	○	○	○
7. It was irritating that my efforts were not useful.	○	○	○	○	○
8. I took pride in being able to keep up with the tasks in this experiment.	○	○	○	○	○
9. I made important contributions during this experiment.	○	○	○	○	○
10. I felt nervous during this experiment.	○	○	○	○	○
11. I was glad that my efforts during the experiment paid off.	○	○	○	○	○
12. I enjoyed this experiment.	○	○	○	○	○
13. During this experiment I felt like giving up.	○	○	○	○	○
14. I can see the relevance of this experiment to my physics studies.	○	○	○	○	○
15. I resented doing this experiment.	○	○	○	○	○
16. I felt panicky during this experiment	○	○	○	○	○
17. I am happy that I could cope with this experiment.	○	○	○	○	○
18. I found this experiment dull.	○	○	○	○	○
19. I was bored during this experiment.	○	○	○	○	○
20. I found this to be an interesting experiment.	○	○	○	○	○
21. Completing this experiment has increased my understanding of physics.	○	○	○	○	○
22. During this experiment, I was so resigned that I felt that I had no	○	○	○	○	○

energy.	
23. The experiment provided me with the opportunity to take responsibility for my own learning.	○ ○ ○ ○ ○

FOR THE FOLLOWING QUESTION, USE THE SCALE INDICATED	**A**	**B**	**C**	**D**	**E**
24. Overall, as a learning experience, I would rate this experiment as: **A** = 'excellent' **B** = 'good' **C** = 'average **D** = 'poor' **E** = 'very poor'	○	○	○	○	○

On the scale below, please rate the mental effort you invested doing the experiment

Extremely low mental effort *1 2 3 4 5 6 7 8 9* *Extremely high mental effort*

Rate how confident you are doing the experiment

Least confident *1 2 3 4 5 6 7 8 9* *Most confident*

25. What aspects of the experiment did you find most enjoyable and interesting?

26. What did you think was the main lesson to be learnt from the experiment?

27. What did you think about the Lab notes of this experiment? Explain how it affected you.

28. Compare this experiment with other experiments in this course. How does it differ?

AEQ-PhysicsPrac Survey 2

This is a survey for all four electrical experiments this semester. **Please put your answers on the right-hand side of this form. If you feel you cannot answer a particular question, just leave it and go onto the next question.** Use a dark pen or pencil to select your answer to each question. Fill in circles completely like this ●	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. During these four experiments, I was satisfied with my work.	○	○	○	○	○
2. For me these four experiments were challenges that were enjoyable.	○	○	○	○	○
3. I felt annoyed by these four experiments.	○	○	○	○	○
4. I felt elated by my accomplishments during these four experiments.	○	○	○	○	○
5. I got scared that I might do something wrong while doing these four experiments.	○	○	○	○	○
6. I felt these four experiments were exciting.	○	○	○	○	○
7. It was irritating that my efforts were not useful during these four experiments.	○	○	○	○	○
8. I took pride in being able to keep up with the tasks in these four experiments.	○	○	○	○	○
9. I made important contributions during these four experiments.	○	○	○	○	○
10. I felt nervous during these experiments.	○	○	○	○	○
11. I was glad that my efforts during these four experiments paid off.	○	○	○	○	○
12. I enjoyed these four experiments.	○	○	○	○	○
13. During these four experiments I felt like giving up.	○	○	○	○	○
14. I can see the relevance of these four experiments to my physics studies.	○	○	○	○	○
15. I resented doing these four experiments.	○	○	○	○	○
16. I felt panicky during these four experiments.	○	○	○	○	○
17. I am happy that I could cope with these four experiments.	○	○	○	○	○
18. I found these four experiments dull.	○	○	○	○	○
19. I was bored during these four experiments.	○	○	○	○	○
20. I found these four experiments to be interesting.	○	○	○	○	○
21. Completing this experiment has increased my understanding of physics.	○	○	○	○	○
22. During this experiment, I was so resigned that I felt that I had no energy.	○	○	○	○	○
23. The experiment provided me with the opportunity to take responsibility for my own learning.	○	○	○	○	○

FOR THE FOLLOWING QUESTION, USE THE SCALE INDICATED	**A**	**B**	**C**	**D**	**E**
24. Overall, as a learning experience, I would rate these four experiments as: **A** = 'excellent' **B** = 'good' **C** = 'average **D** = 'poor' **E** = 'very poor'	○	○	○	○	○

On the scale below, please rate the mental effort you invested doing these four experiments

Extremely low mental effort 1 2 3 4 5 6 7 8 9 *Extremely high mental effort*

Rate how confident you were while doing these four experiments

Least confident 1 2 3 4 5 6 7 8 9 *Most confident*

25. The four experiments had little colorful historical stories in the Introductions. Did you have a quick look or read through them? What did you feel? Circle the relevant emotions and explain.

Enjoyment

Pride

Anger

Anxiety

Boredom

Hopelessness

26. Did the stories motivate you to positively engage with the experiments? Explain.

27. Would you like such short colorful historical stories to be added to your labnotes?

28. Any other comments?

Thanks a lot for your time ☺

AEQ-Physics Survey

Do you give permission for this data to be used for the research? Yes O No O

Put your answers on the right-hand side of this form. If you feel you cannot answer a particular question, just leave it and go onto the next question. Use a dark pen or pencil to select your answer to each question. Fill in circles completely like this ●	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. During this Physics course, I was satisfied with my work.	O	O	O	O	O
2. For me this Physics course is a challenge that is enjoyable.	O	O	O	O	O
3. I felt annoyed by this Physics course.	O	O	O	O	O
4. I felt elated by my accomplishments during this Physics course.	O	O	O	O	O
5. I felt frustrated during this Physics course.	O	O	O	O	O
6. I got scared that I might do something wrong during this Physics course.	O	O	O	O	O
7. I felt uneasy during this Physics course.	O	O	O	O	O
8. I felt this Physics course was exciting.	O	O	O	O	O
9. During this Physics course, I felt hopeless.	O	O	O	O	O
10. I found this Physics course pointless.	O	O	O	O	O
11. It was irritating that my efforts were not useful in this Physics course.	O	O	O	O	O
12. I took pride in being able to keep up with the tasks in this Physics course.	O	O	O	O	O
13. I got restless during this Physics course.	O	O	O	O	O
14. I made important contributions during this Physics course.	O	O	O	O	O
15. I got tempted to walk out of this Physics course.	O	O	O	O	O
16. I felt nervous during this Physics course.	O	O	O	O	O
17. I was glad that my efforts during this Physics course paid off.	O	O	O	O	O
18. I enjoyed this Physics course.	O	O	O	O	O
19. During this Physics course I felt like giving up.	O	O	O	O	O
20. I can see the relevance of the historical context to my physics studies.	O	O	O	O	O
21. I resented doing this Physics course.	O	O	O	O	O
22. I felt panicky during this Physics course.	O	O	O	O	O
23. I am happy that I could cope with this Physics course.	O	O	O	O	O
24. I found this Physics course dull.	O	O	O	O	O
25. I was bored during this Physics course.	O	O	O	O	O

26. I found this Physics course to be interesting.	O O O O O
27. Completing this Physics course has increased my understanding of physics.	O O O O O
28. During this Physics course, I was so resigned that I felt I had no energy.	O O O O O
29. The colorful historical story was a really good way to introduce the physics concept.	O O O O O

30. What aspects of the course did you find most enjoyable and interesting?

31. What do you think about the lectures of this course? How did they affect you?

Choose the relevant emotion that you felt from the list below and explain.

Enjoyment
Pride
Anger
Anxiety
Hopelessness
Boredom

32. Do you think the lectures were engaging? Did you find it helpful for your concept development?

33. Compare this course with the other courses. How does it differ?

Thanks a lot for your time ☺

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