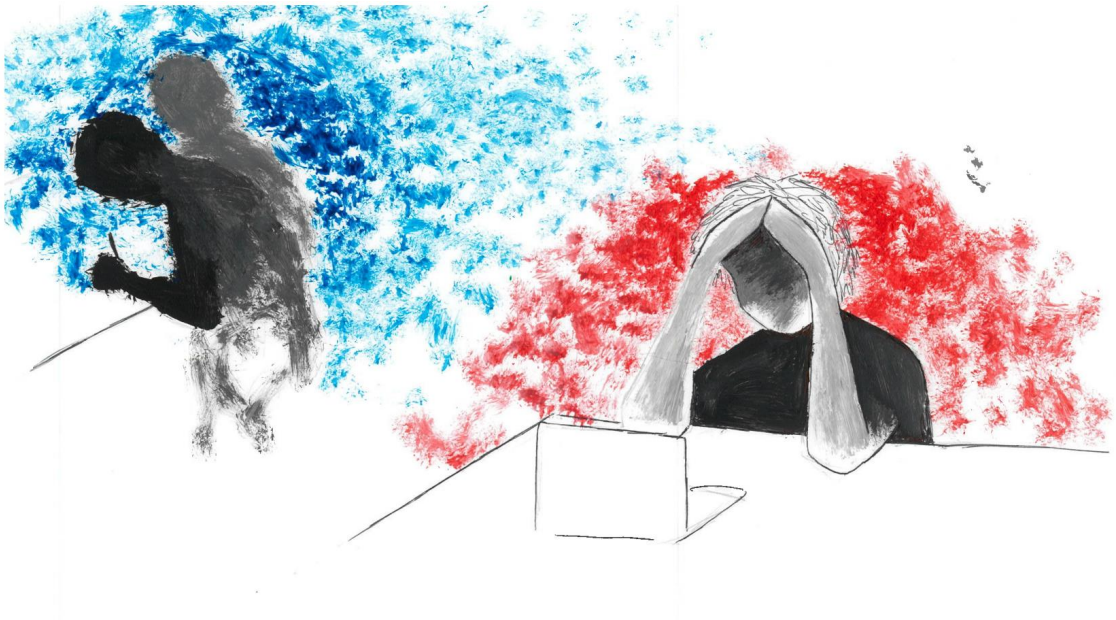
Online vs. in-person: The student experience of tutorials in engineering



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Thank you to:

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Cover image: a painting by Helen (pseudonym) showing her frustration when working in an in-person tutorial, distracted by the sounds of others.

Abstract

What can we learn from the great experiment of converting to online learning during lockdown? What is the student experience of online vs. in-person? What can we learn about each mode, and what does this perspective help us to see more generally?

To answer these questions I focussed on 'tutorials' — small, unstructured lessons — in undergraduate engineering. Preliminary research with a survey (n=1610) and focus groups found a strong preference for in-person tutorials but without a clear explanation.

Through arts-based focus groups, where eight students expressed their experience through drawing, painting, and sculpture, I gained deeper insight. I found similar overall preferences but by identifying 'achievement emotions' I found a more nuanced picture of the experience.

Students valued social support in-person but could get distracted. They valued the flexibility online but were often frustrated. Overall preferences depended on the personal weighting of these pros and cons, emphasising the importance of diversity and inclusion in our teaching. Some students were struggling in both modes.

Using a reflexive thematic analysis I identified deeper themes that transcend the online vs. in-person dichotomy. Students perceived engineering knowledge as objective, without a personal or tacit component in the sense of Polanyi. This epistemic view, and the lack of feedback they receive, contributed to students' constant sense of not being 'up-to-date'. They were therefore often averse to incongruity and confusion. This aversion is a key barrier to developing an engineering 'mindset'. I conclude with recommendations on monitoring the emotional experience of students, providing more feedback, and re-balancing our culture. Knowledge is essential; but ways of thinking are the hallmark of an engineer.

Contents

CHAPTER 1

Introduction

We have lived through a great experiment in education where we abruptly converted our learning and teaching activities into the online mode — and back again. I want to ask what we can learn from that experiment.

I want to ask the students what their experience has been like. How does it *feel* to study online as opposed to in-person? To manage the scope of my research I will focus on *tutorials* in particular — small group unstructured lessons that I will define in more detail later.

The problem I struggle with in this dissertation is that although I *want* to ask the students about their experience in tutorials, I found that I *can't* ask them. The problem is not that they do not know — of course they know — but they cannot *tell*. Their experience is obvious to them, but their knowledge is *tacit*. So I will present a methodology of, and results from, asking students to produce a piece of art to express their experience.

In enquiring about the student experience my interest goes beyond the methodological aspect of tacit knowledge — the problem of asking questions that cannot be answered directly. I also explore the role of tacit knowledge in the discipline itself — in my case, engineering. A practising engineer operates in a heavily implicit manner. But what about the raw, underlying theories that we teach undergraduates? I will argue that they have a strong tacit component too, both in their form when already learned; but also, importantly and even more so, during the process of learning.

By enquiring about what engineering knowledge *is*, and how tacit knowledge is learned, I build a picture of knowledge and learning that is both counter to widely held philosophical beliefs yet somehow also obvious and intuitive to any practising engineer. It is not a picture of explicit rules and methods; nor is it a picture of implicit 'rules and methods' as such; it is a picture of a mindset, a way of thinking, a way of seeing. It is a way of *being*; an ontology.

Engineers know this. Academics know this. But we struggle to adapt our teaching to be true to what we know. My method will be to empathise with the students through their art. I will draw on theories of tacit knowledge and learning; emotion in learning; and reflection-in-action; I will try to at least help frame the problem of what and how we should teach. I will frame the problem as:

> How can we foster a culture of mastery and an internal conversation in the

learner that thrives on incongruity and is driven to explore and discover?

I will recommend some concrete actions but it is important not to see in my diagnosis a problem that needs a direct solution. We do not need a completely new curriculum or a revolution in how we operate. Rather, we need to refresh our own internal, guiding voice that informs our solutions to the many smaller practical problems of teaching.

I want us to pay attention to *problems* and not *methods*. To embrace *divergence* and not *convergence*. Of course mastery of methods is needed; but the context in which students experience this mastery is important; the context must be a reflective, critical one.

As children we live and breathe divergent problems; our reality is incongruous. We're fine with that and we make our way, learning and growing. The problem at university (and perhaps at school too) is not how to *teach students* to develop a healthier mindset, but to teach ourselves how to teach without inhibiting the natural explorers who enter our system and put such a profound trust in us.

1.1 Context

The Mechanical Engineering degree programme at Imperial is illustrated in Figure 1.1 and my focus is on the first two years of the programme where the majority of the programme runs in standard modules. In autumn and spring terms each module comprises weekly lectures and bi-weekly tutorials. In summer term final exams take place.

Tutorial sessions in this context are groups of up to 22 together for 50 minutes and dedicated to a particular module. One or more tutors are in the room and the session is typically unstructured. The tutors can be academics of any level, or graduate teaching assistants (typically PhD students). A detailed description of tutorials is given in the Literature Review.

It is notable in Figure 1.1 that the bottom two lines are mostly grey, meaning 'core' academic subjects that are theory-dominated; there is a small but significant pink component denoting 'design', which is more applied. In years 1 and 2 the theory and application are essentially separated; then in years 3 and 4 they are integrated in the large projects where students confront genuinely open problems. An existing concern that my colleagues and I have is whether and how it is feasible to learn theory separately from practice, and to subsequently — up to two years later — successfully apply that theory to an open problem.

Against the background of that general question, in recent years the teaching *mode* has varied dramatically. The UK was in some form of lockdown or restrictions from March 2020 to summer 2021. The broad effect on the Mechanical Engineering Department at Imperial, as with many others, was that one entire academic year took place remotely (see Table 1.1). This dissertation is timed to capitalise on this once-in-a-lifetime 'experiment' by engaging with students to explore how remote learning has given them new perspectives on what happens during a class session — specifically in a 'tutorial'.

Pre-2020	In-person
2019/20	In-person*
2020/21	Remote**
2021/22	In-person^{+}

* Summer revision sessions and exams were remote.
** Small numbers of students in-person in November 2020.
$+$ Remote-only from mid-December to late-January.

Table 1.1: Learning mode in recent years — Imperial Mechanical Engineering Department.

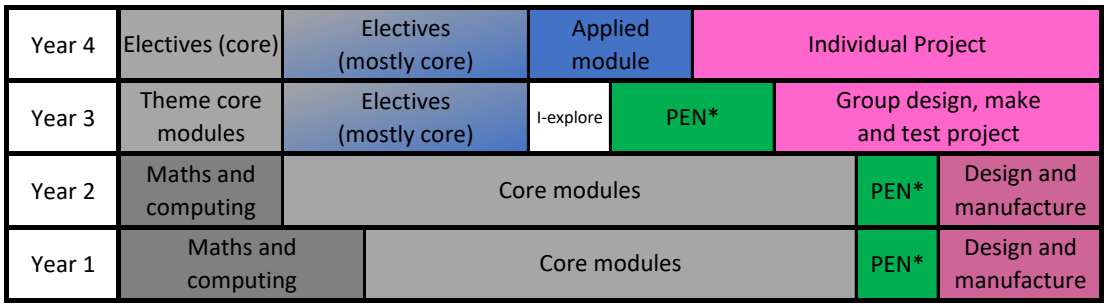


Figure 1.1: An overview of the mechanical engineering degree. Grey is theory, green ('PEN') is practical, pink is design, blue is elective. This dissertation is about the 'tutorials' in the grey modules in Years 1 and 2.

The question is to what extent online tutorials can play the role of in-person tutorials; how they might be superior, and how they might be inferior. Further, perhaps the dramatic change in mode provides us with a new perspective to inform our broader interest in how to deliver tutorials.

The research question we had, even for some years before remote learning was enforced, was: what happens in our tutorials? What is good that we do not necessarily know about; and what could be better? The abrupt change to remote learning, and equally sudden return to in-person, makes the contrast very clear in students' minds and allows us to get more insight from our discussions with them about what happens in tutorials. The motivation of this dissertation is to expand significantly on the following, which is currently our best record of our practice:

> "students are expected to attend, work though problems individually or with help from other students, and consult the tutor when they need help. The tutor may occasionally address a common problem ad hoc by discussion with the whole group."
>
> — Department of Mechanical Engineering (2017, p.49).

1.2 Preliminary research

I began my research into the online vs. in-person question from a practical point of view, as I advised my department during summer 2021 on how to organise the return — or partial return — to in-person learning the following academic year. I organised a survey and focus groups to investigate student preferences. The primary thrust of this research was to inform operational decisions in the short term, however the survey and focus groups were also pre-approved by the Imperial Education Ethics Review Process for use in research. In this Section I present the findings of this preliminary, very practically oriented research and I show how this shaped the deeper research question that I focus on in the remainder of the dissertation.

Survey of student preferences after lockdown

An anonymous survey was run in 6 departments within the Faculty of Engineering generating a total of 1,610 responses between June and September 2021. Technical details of the survey, including the process followed

and the response rates, are in Appendix A.1. Results were highly uniform across the six departments that were probed. Here I will share some key results from the survey, and will focus on the Mechanical Engineering Department where I am familiar with the programme, students, and culture. In this population there were 481 responses, of which 380 answered all 25 questions, giving a response rate of over 50%.

The first finding was that tutorials, i.e. unstructured lessons, were perceived as the least important aspect of learning compared to other lesson types. The second finding was that in-person activities, i.e. attending campus, is important. Most students (86%) wanted to attend campus at least 3 days per week, with over half wanting to attend at least 4 days per week.

The preference for in-person attendance did not manifest equally across different lesson types. Self-declared attendance (because we do not have a more reliable measure) is illustrated in Fig. 1.2 where attendance at lectures was only marginally affected by moving online; whereas tutorial attendance was halved. This result suggests that specifically in tutorials, something desirable is happening in the classroom that is not happening online.

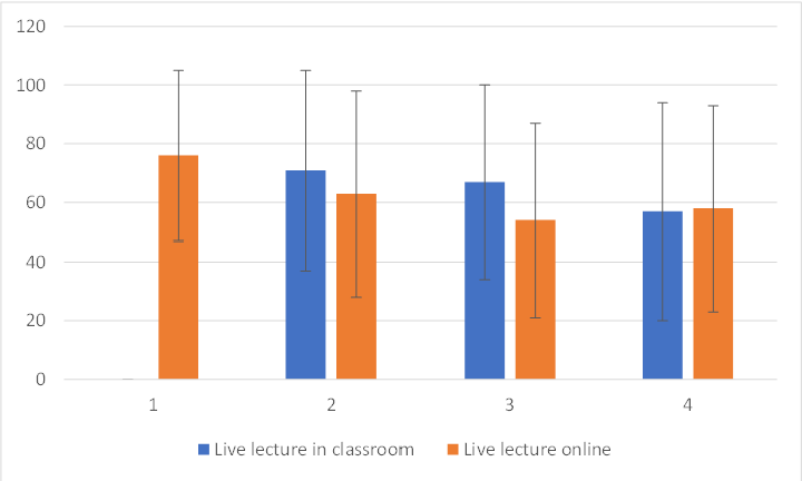
Asking students about their preference between online and in-person for different types of sessions yielded the response in Fig. 1.3. In particular, academic tutorials are clearly perceived as more effective in-person: over 60% strongly disagree that they are better online, while only 19% agree to any extent that they are better online. Preferences for lectures are less clear, with a spread of views slightly leaning towards in-person.

The survey used here was also designed to obtain insight into these preferences. We probed attendance decisions further and found that many factors affect decisions to attend — see Fig. 1.4. The survey also asked specifically what the value of in-person teaching is using a list of suggested reasons that were based on my informal conversations with students. The results are in Fig. 1.5 from which the remarkable conclusion is that the in-person experience is *complex*. There are multiple, independent and strong reasons for students to attend in-person activities. The conclusion from this survey was that in-person tutorials are preferred overall, but that our understanding of the student experience was limited.

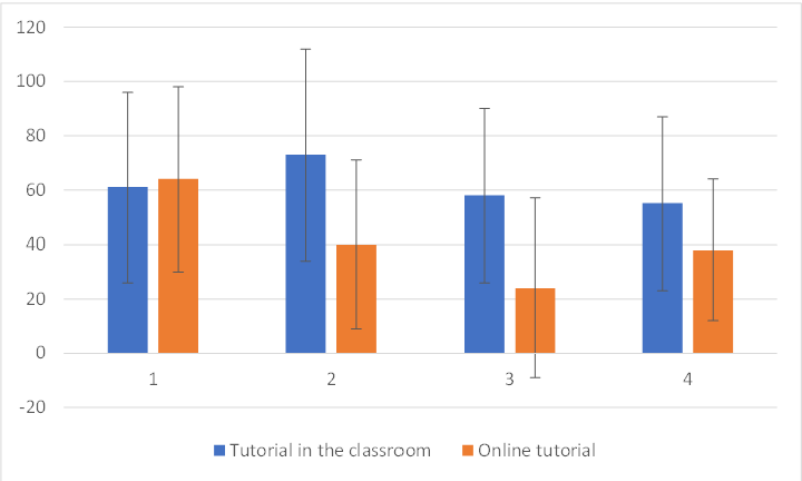
Focus groups

To complement the survey and as part of the same work I ran two focus groups with students to ask them about their experience of tutorials and to contrast in-person vs online. Some more detailed evidence is provided in Appendix A.3, from which some key themes were identified. The online experience was characterised by a 'transactional' paradigm, where students queue for a chance to ask a question, then ask and receive their answer, and then attention moves on. This was coupled with a self-consciousness asking in front of other listeners; and often a lack of opportunity to even ask questions — leading to more assertive behaviour as the year of lockdown progressed.

In contrast, the in-person experience was characterised by a 'relation-



(a) Lectures.



(b) Tutorials.

Figure 1.2: Self-declared attendance (percentage), comparing in-person and online (the first year cohort had not been offered any in-person lectures, and only a few in-person lectures). Coloured bars shown population mean; error bars represent population standard deviation.

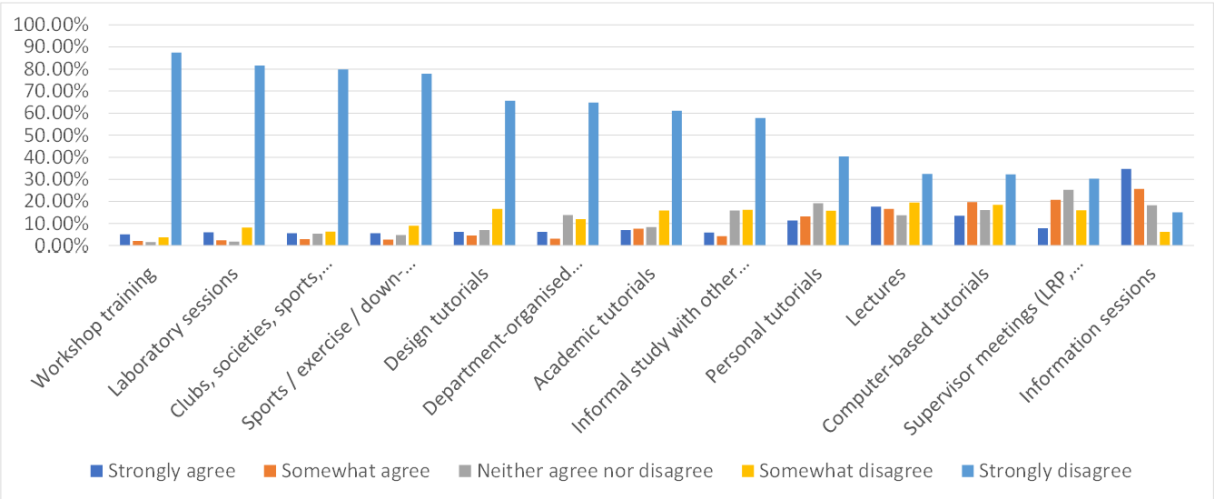


Figure 1.3: "Even when in-person is an option, the following sessions would be better online." These results are for Mechanical Engineering (n=375) but were almost identical across the faculty (n=1200).

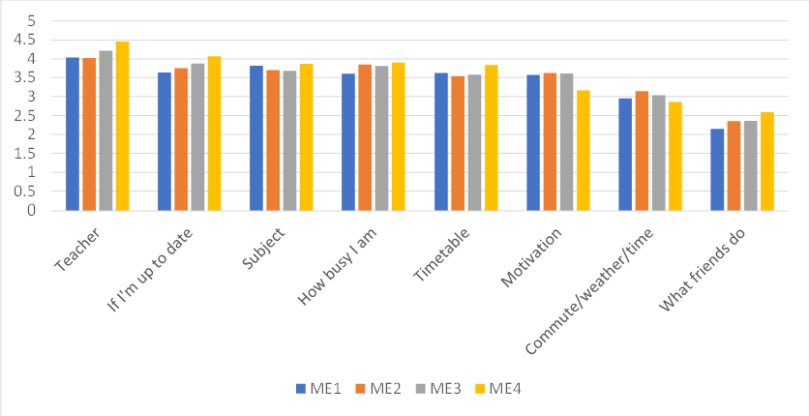


Figure 1.4: "What factors affect your preferences for the format, and your attendance, of lectures and tutorials?" The colours represent year groups. A Likert scale with five levels was answered, and these were weighted linearly from 1 to 5 to get a weighted average displayed here. Note that this question covers both lectures and tutorials. This was a compromise to make the survey shorter, but hides the distinction between the two types of lesson. It probably reflects attendance at lectures.

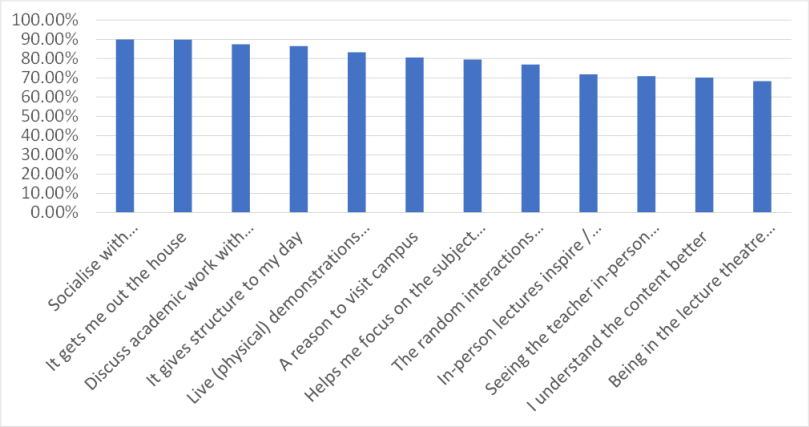


Figure 1.5: "What value do you get from in-person classes (lectures and tutorials) if you attend them?" Responses for all Mech Eng students (n=377). A 5-point Likert scale was used and the chart shows the percentage who either agreed or strongly agreed. Disagreement or strong disagreement was generally below 10%. To reduce the survey length this question addressed lectures and tutorials together, so does not distinguish them (or any other type of session).

ship' between the tutor and tutees that developed over time. The online experience inhibits this relationship building, and there is therefore a barrier to learning opportunities that are less transactional.

Summary and conclusions from preliminary research

The survey showed a strong preference for in-person activities, in particular for tutorials. The reasons for attending in-person were many and complex so required focus groups to look deeper at the issue. The focus groups uncovered some hints, in particular on the ability to build relationships in-person. The importance of the relationship between students and between a student and the tutor was something that the focus groups highlighted, but did not explain.

I seemed to reach an impasse as I looked beyond the relatively shallow conclusions that I have listed. For example, students stated both that all 'work output' could be achieved online; yet something else — the ineffable — was valuable in the classroom. The students sensed something was happening, but could not articulate it. This led me to direct my energies, in reading and in designing further data collection, toward *tacit* knowledge.

The questions that arose from this preliminary research was:

> why is a relationship between students, and between a student and their tutor, important? How does this relationship develop and what are its benefits?

The basis of this dissertation is therefore an enquiry into *implicit* or *tacit*[1] learning, and tacit knowledge. Is there something implicit being learned that is more effective in-person than online? Or is it simply a question of quality of communication of explicit knowledge; or perhaps simply that student well-being and comfort are better in-person, hence their preference?

[1] The words *implicit* and *tacit* can be considered essentially synonymous in that both refer to something hidden.

1.3 Background on applied mathematical problems

In order to convey my research in this dissertation, which is about Engineering Education, I would like to explain some underlying concepts. This explanation is aimed primarily at the reader not intimately familiar with Engineering Education. I will present two concepts: firstly a basic mathematical idea, accessible to anyone, to illustrate issues of tacit vs. formalised knowledge and how reflection-in-action works; secondly I will present exemplar learning material from my own teaching and explain how it relates to the epistemology and ontology that I will review in the Literature Review.

Example knowledge

We all 'know' that,

$$2 \times 3 = 6.$$

This is an example of formalised knowledge written using symbols. The reader will likely 'say' in their head 'two times three equals six'. Comprehension of the statements requires knowledge of the symbols that are used:

cardinal numbers ($2, 3, 6$ in this case), equality, and multiplication. There is a tree of knowledge that stems from these symbols: multiplication follows certain rules, such as being commutable; in turn commutability is one of a set of properties of binary operators; and so on.

The reader *does* know what 'commutability' is — where numbers can swap positions — but may not know the word. So the reader's underlying knowledge may be *tacit* as opposed to formalised. Using formalised knowledge can therefore cause confusion. At this point we are not judgemental about confusion — it may be good or bad, and that point is central to this dissertation.

The example of multiplying two numbers has illustrated formalised and tacit knowledge, and how the former relies on the latter. I will review these concepts in more detail in the literature review.

Toy problem

Consider the following problem, which has a deliberately obvious answer but is a model of what more complex problems are like.

> An engineer needs to connect a conduit between two tanks to supply steam. Quantify the number of bolts needed, given that there are three flanges and each flange requires two bolts.

The solution to the problem appears to be that six bolts are required, and this can be justified by the expression $2 \times 3 = 6$.

Then a colleague brings to the engineer's attention that for steam applications the minimum number of bolts depends on the steam pressure, and provides a calculation for this case which concludes

> 2.4 bolts per flange are required for this application.

The engineer updates their calculation but is confused because they now have the following:

$$\underbrace{2.4}_{\text{Bolts per flange}} \times \underbrace{3}_{\text{No. of flanges.}} = \underbrace{?}_{\text{Total no. of bolts}}$$

Suppose — remembering that this is a toy problem — that the engineer *didn't know* how to multiply non-integer quantities; or didn't know how to round numbers. What should they do?

An engineer needs to be equipped to *find out* the answer by questioning their own knowledge and finding out what they need to do. A good engineer will do that out of *habit*.

In this example the engineer needs to learn to multiply decimals. The answer is then 7.2 bolts — but this doesn't make sense. The engineer will be *confused*.[2] In this particular application, the number of bolts per flange should actually be an integer (a 'whole' number) so multiplying decimals isn't necessary. The engineer should probably round *up* from 2.4 to 3 in this calculation, just to be safe, and conclude that $3 \times 3 = 9$ bolts. How do we teach that the engineer should know *that*?!

To be clear, the question is not how to teach 3×3. The question is, how to teach someone to know that 3×3 is the relevant calculation in this particular case? This seems obvious to the reader, but there is

[2] Remember, this is a toy problem — we must pretend, for a moment, that we are also confused.

an analogy from this toy problem to real, everyday engineering problems. The analogy is that the engineer will *not know* what to do, and will need to decide. The difference is that the engineer's knowledge will be at a more advanced stage — but they still experience the same issue of being confused by the relation between the present, unfamiliar problem, and their existing knowledge and experience.

Broadly speaking, my experience with students is that, following very good exam results in the first two years, they are still not able at the beginning of their third year to integrate the theory that they learned in the previous years; it almost feels like they are starting again. They can follow learned procedures in isolation, but they can't critically evaluate them and innovate with them in a different context.

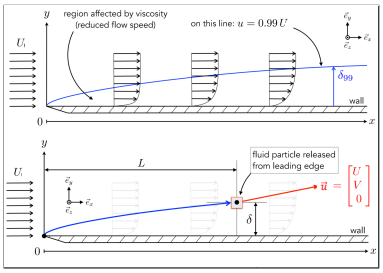
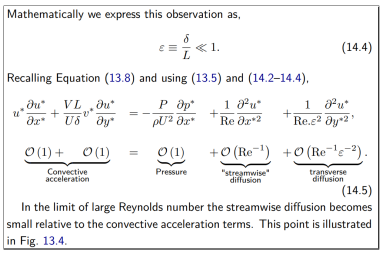


Figure 1.6: Graphic communication in my lecture notes.


Mathematically we express this observation as,

$$\varepsilon \equiv \frac{\delta}{L} \ll 1. \tag{14.4}$$

Recalling Equation (13.8) and using (13.5) and (14.2–14.4),

$$u^*\frac{\partial u^*}{\partial x^*} + \frac{VL}{U\delta}v^*\frac{\partial u^*}{\partial y^*} = -\frac{P}{\rho U^2}\frac{\partial p^*}{\partial x^*} + \frac{1}{\mathrm{Re}}\frac{\partial^2 u^*}{\partial x^{*2}} + \frac{1}{\mathrm{Re}\,\varepsilon^2}\frac{\partial^2 u^*}{\partial y^{*2}},$$

$$\underbrace{\mathcal{O}(1) + \mathcal{O}(1)}_{\text{Convective acceleration}} = \underbrace{\mathcal{O}(1)}_{\text{Pressure}} + \underbrace{\mathcal{O}\left(\mathrm{Re}^{-1}\right)}_{\text{"streamwise" diffusion}} + \underbrace{\mathcal{O}\left(\mathrm{Re}^{-1}\varepsilon^{-2}\right)}_{\text{transverse diffusion}}. \tag{14.5}$$

In the limit of large Reynolds number the streamwise diffusion becomes small relative to the convective acceleration terms. This point is illustrated in Fig. 13.4.

Figure 1.7: Symbolic language in my lecture notes.

In the $y-$momentum equation used to study boundary layers (Eqns. 14.7), show that for high Reynolds numbers and zero streamwise pressure gradient ($\partial p/\partial x = 0$) the equation reduces to $p \approx p_0$ where p_0 is a constant.

Figure 1.8: An example homework problem inviting the student to familiarise themselves with the material and to develop experience using new methods of analysis.

Example learning material

Some actual learning material from my teaching with second year Mechanical Engineering students is displayed in Figs. 1.6–1.8. The material is notable for its heavy use of symbolic and graphic communication. The material appears to be very formal, giving the impression of impersonal, objective knowledge. This impression masks the tacit component of what we teach.

To relate the toy problem to a real problem, suppose a student has studied the technique in Fig. 1.7 called 'order of magnitude analysis'; in this technique the 'scale' of each term in the equation is indicated by a 'big O' and then a quantity in parentheses, for example $\mathcal{O}(1)$. This is an advanced technique that the reader is unlikely to understand but is common in engineering; it is analogous to the technique, in the toy problem, of 'multiplying integers'.

If the student graduates and in their first job is asked to find the 'order of magnitude' of a term in new, previously unencountered equation, what will they do? They could

(a) Think they do not know and avoid the problem (analogous to not selecting a number of bolts in the toy problem — not really an acceptable action);

(b) Apply the method they know, not realising that it's not applicable (analogous to selecting a non integer number of bolts);

(c) Understand the fundamentals of the method in question, and reflect on what is different about the problem in hand; learn what is necessary to apply the method to the current problem (analogous to selecting three bolts).

To carry out option (c) — the correct option — the student will need to be constantly reflecting during their studies, both to have an adequate grasp of the fundamentals of the method in question, and to have developed the habit of thinking like an engineer.

1.4 Overview of the dissertation

The dissertation is structured as follows. In Chapter 2 I present a literature review driven by an interest in engineering epistemology, and its 'unsaid' or tacit component. I draw heavily on Polanyi's *Personal Knowledge* and tacit knowing, and on Vincenti's Engineering Epistemology. This builds a picture of engineering knowledge as having a strong and unavoidable tacit component. I then review the learning process itself which I argue is personal and with a strong tacit component. I use Schön's reflection-in-action model to idealise the mindset that engineers need to adapt.

To anticipate findings about the student experience, given the personal nature of learning that I articulate, I review research on emotion in learning, with a particular focus on Pekrun's control-value theory of achievement emotions, and more recent work on epistemic emotions, in particular confusion.

In Chapter 3 I present a methodology describing how I worked with students to produce a piece of art to express their experience. I describe the context of other related research, namely arts-based research. I describe some of the necessary detail on how I executed the method, and then I critique my method and highlight its strengths and limitations.

In the Results chapter I present the art work of eight students, which comprises four drawings, five paintings, and two sculptures. I identify basic preferences and achievement emotions for each student.

In the Discussion chapter I synthesise my findings in five themes: emotions behind the preferences; diversity and inclusivity; perceptions of knowledge; the role of confusion; reflection-in-action.

I conclude the dissertation with an overall summary, practical recommendations, and personal reflections.

CHAPTER 2

Literature review

This literature review is motivated by the conclusions of my preliminary research, namely that there is something *ineffable* in what students learn, i.e. there is some *tacit* knowledge; and that there is something implicit about the way this knowledge is *learned* — the learning process is not evident to the learner.

The aim of the literature review is to articulate the research question:

> What is the student experience of in-person vs online tutorials, and what is the role of tacit knowledge in this process?

2.1 Epistemology

In the mid-20th century science, and by association knowledge, was widely perceived to be objective and impersonal — separate from humanity. Michael Polanyi, himself and eminent scientist, disrupted this view with his book *Personal Knowledge* (Polanyi, 1958). Polanyi's title was deliberately provocative, using a phrase perceived as contradictory at the time. Polanyi asserted that science is driven by knowledge personal to the scientist. This personal knowledge was *tacit*, i.e. silent. It was 'inarticulate' and unformalised.

Polanyi asserted that tacit knowledge is the norm in all sentient beings, including animals and baby humans. In adult humans some knowledge can be made explicit, or 'articulate' or formalised, through the use of language. Language here is a broad concept covering the use of symbols, including 'writing, mathematics, graphs and maps, diagrams and pictures' (Polanyi, 1958, p.78). Articulate, formalised knowledge is a subset of all knowledge, and must emerge, originally, from its tacit form. In other words all knowledge begins as tacit, and some but never all of it becomes explicit. Formalised knowledge can be seen as the tip of the iceberg, with the tacit portion the greater part, and the basis of the formal part.

Formal knowledge uses symbols, but the meaning of the symbols is only known through their definitions (otherwise the symbols themselves are meaningless); a certain amount of tacit knowledge is necessary to understand the meaning of the symbols — hence the assertion that the formal relies on the tacit. This line of thinking extends to pure mathematics and Gödel's incompleteness theorem (Gödel, 1931)[1], which proves that no formal system is complete, i.e. any expression that proves the

[1] See Hofstadter (1979) or https://youtu.be/HeQX2HjkcNo for an informal guide.

completeness of a system must itself require definitions from outside of that formal system (Polanyi, 1958, p.94).

Ultimately tacit knowledge is required to understand the definitions that underlie formalised knowledge; and in fact attempts to over-formalise systems of knowledge render them impractical. The important conclusion from an educational point of view is that all formal knowledge rests on tacit knowledge. I will consider separately, later in the review, the *process* by which tacit knowledge is *acquired* as this is a process of discovery that I separate from the knowledge itself.

Polanyi's work on tacit knowledge originated with his reflections on science and scientific knowledge. His work is therefore applicable and very relevant to the subject I teach, which has much in common with the physical sciences. Nevertheless we should ask to what extent Engineering Knowledge differs from Science. Vincenti (1990), in a historical account of aeronautical engineering knowledge in the 20th century, used the prototypical example of dynamic control of an aircraft to distinguish Engineering epistemology from applied science;

> "it called for a great deal more than simply the application of scientific knowledge and principles. It required a complex interaction of intellectual and experiential elements."
>
> — Vincenti (1990, p.4)

Vincenti (1990) stresses distinctions between engineering and scientific knowledge throughout his account; and indeed there are differences in substance — there is knowledge in engineering that is not used in science, and vice-versa. One key distinction is that in science, knowledge is the output; whereas in engineering artefacts are the primary output while knowledge is also generated as a by product. It is perhaps more subtle, then, how engineers build on previous achievements as it is not a simple chain of knowledge.

Vincenti nevertheless builds a picture of engineering knowledge that has much in common with Polanyi's picture. Vincenti, referring to engineering, describes cumulative knowledge, produced within a community as part of a larger problem solving activity (Vincenti, 1990, p.289 n.44–45). This is the same concept as Polayni's 'Superior knowledge' (Polanyi, 1958, p.374), which refers to the coherent body of knowledge of the scientific — and broader societal — community, very little of which is known by one individual (Vincenti, 1990, p.52,73,135). Just as one mathematician trusts another to know their own specialism and can only converse based on common definitions at their interface, so an engineer does, for example rely on a manufacturer to know how to machine something to the tolerance that they claim. Science and engineering knowledge, then, bear much in common with the more recent articulation of 'Communities of practice' (Wenger, 1998).

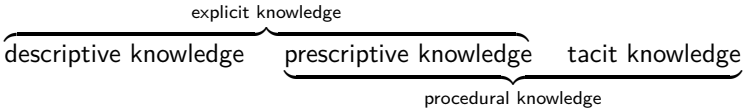
Given the brief review of the similarities and differences of knowledge in science and engineering, how applicable is the concept of tacit knowledge? It appears to be *even more* applicable to engineering. As Polanyi (1958, p.328) defines it, 'contriving' must necessarily involve tacit knowledge and cannot be made impersonal. Vincenti agrees and provides more detail from the everyday life of an engineer through historical case studies. To give

one example from aircraft manufacturing,

> "Although much could be learned about forming dimples or upsetting flush rivets from books or word of mouth, complete mastery required hands-on experience. All the acquired knowledge in matters of this kind is not susceptible of codification or communication."
>
> —Vincenti (1990, p.194)

Does Vincenti's point mean that engineering education cannot be codified? We could argue against that assertion on the basis that most of the content of an engineering degree is theory which is closer to science than it is to such 'hands-on' practice that Vincenti describes. However, this argument fails in two ways; firstly Polanyi has made clear how science itself is built on tacit knowledge; and secondly, the tacit knowledge required even to appreciate engineering theory requires an appreciation of life as an engineer. This latter point is perhaps contentious but my research in this dissertation will hopefully contribute to that debate.

Vincenti (1990, p.198) proposes a schema of engineering knowledge as follows



Vincenti's schema makes clear that tacit knowledge plays a role in engineering, and echoes this in his case studies

> "the continual effort in engineering [is] to replace "acts of insight" (unteachable) by "acts of skill" (capable of being taught)."
>
> —Vincenti (1990, p.168)

The tacit component in Vincenti's schema is in the procedural element of the job. He describes a continuing effort to codify insight into prescriptive procedures that can be made explicit. Again, we could argue that the 'hands-on' and procedural parts of engineering are not part of the undergraduate curriculum and we therefore are safe to conceive of our curriculum as mostly or wholly formalised knowledge. However, this argument would overlook the role of 'thinking' as a procedure in engineering. Indeed, this is Vincenti's overarching argument in his definition of engineering epistemology — it is a way of thinking (see Vincenti, 1990, Ch.4), a way of *being*. Thinking and being can never be codified; they are tacit, they are learned socially or personally, and they are the essence of the engineer.

So far I have discussed tacit knowledge in science and engineering, and the continuing endeavour to codify, or formalise this knowledge. Formalised knowledge is powerful for its abstractness and for structuring thinking. In Engineering Education we endeavour to help students develop advanced formalised knowledge. What this review argues is that formalised knowledge has limits and rests on tacit knowledge. There will always be a tacit component in the undergraduate curriculum. What exactly is this tacit knowledge? Naturally, it is hard to directly articulate! From my review I have identified tacit knowledge in science and mathematics, which is the tacit definitions and assumptions that we use to

construct formalised knowledge. In engineering it is the ineffable 'how we think'.

2.2 The learning process

Polanyi and Vincenti both pay special attention to the generation of knowledge in science and engineering respectively. Scientists discover and engineers invent, design, implement or operate. From an education point of view, however, we must take an interest not only in knowledge when fully formed, and its generation for the first time; but also in the development of knowledge within the learner who was not the original discoverer.

Our own roots at Imperial are in Armstrong's pedagogy of the discoverer: 'methods which involve their finding out instead of being merely told about things' (Armstrong, 1910, p.236). Students must themselves discover — 'old results for new men' (or women). The 'discovery' process for the learner hints at a path of learning close to that of the original discoverer. Historically this approach has not been maintained.

As STEM education 'drifted' towards a more theory-heavy curriculum over the 20th century (Harwood 2010; Crawley et al. 2014, p.231), the practical experience of students themselves has reduced. We are now at a state where students arrive at university with negligible practical experience and are immediately exposed to the formal structure of engineering theory. Nathan (2012) diagnoses this approach as 'Formalisms first', arguing that educationally we put the cart before the horse, teaching symbols before teaching the meaning that they represent. They have 'nothing to abstract' and the formlisms lack meaning.

Nathan (2012) reviews the literature on learning in relation to formalised language, including some remarkable experiments. For example, it has been repeatedly shown that students of mathematics are more able to pass tests that are informally posed than those that use formalised language. Berry (1997) reviews literature on *implicit learning* which shows, for example, that people can learn systems of grammar without knowing what the system is (or even that we have learned it). Results of these experiments suggest that learning is not as simple as transmitting explicit concepts; and in fact that they may be unhelpful in early stages of learning a particular subject. Tacit knowledge must come first.

Polanyi describes the process of acquiring tacit knowledge as 'indwelling' (Polanyi, 1967, p.17). Indwelling involves 'interiorisation', which is an act of empathy where we 'identify ourselves with the teaching'. In Polanyi's view, which contrasts with dualism common in the West since Descartes, the body is the primary instrument of understanding. As our understanding of distal parts of our body become tacit, so we can progress to extend our understanding to what lies beyond our body, and interiorise it in the same way.

> "The task of inducing an intelligent contemplation of music and dramatic art aims likewise at enabling a person to surrender himself to works of art. This is neither to observe nor to handle them, but to live in them."
>
> —Polanyi (1958, p.208)

An essential part of acquiring tacit knowledge is to recognise the per-

formance of a person in the act of skill. For example, in studying a game of chess we must 'enter into the mind' of the player; we need not observe the inner workings of their mind, nor must they themselves even know their mind (Polanyi, 1967, p.30) .

The path to knowledge, then, seems very different to the formalised version of the knowledge itself. Nathan argues that

> "In education, we need to identify and implement curricula and instruction that are not merely true to the disciplines from which they come, but also developmentally "true" to new learners who are engaging with the ideas and discourse practices of a new field."
>
> —Nathan (2012, p.136)

This leads to the opinion that

> "Developing one's intellectual abilities exclusively on stripped-down formalisms without exposure to perceptually rich stimuli robs learners of opportunities to learn how to recognize deep structure and filter out irrelevancies."
>
> —Nathan (2012, p.137)

So far I have only referred to formal education but we can also learn from the literature on 'professional' or non-formal education. Schön (1983) reviewed how a range of professionals, including engineers, work and learn; and the role of their education. Schön describes the transformation of formal education in post-WWII America as becoming more science and less art, until the art was altogether gone. He calls the broader philosophy under which this transition happened the 'Technical Rational'. In the Technical Rational philosophy all problems can by solved using scientific knowledge and methods.

In the second half of the 20th century this led to a crisis in confidence in professionals who could not 'describe or account for the artful competence which practitioners sometimes reveal in what they do' (Schön, 1983, p.19). Argyris and Schon (1974, p.174) highlighted the incongruity between 'espoused theories' (theories professionals claim to apply) and 'theories-in-use'.

Schön (1983) argues against the Technical Rational philosophy, which assumes repeatable work in the professions and that the emphasis is in solving problems, rather than on framing problems. The reality of these jobs is a great deal of variability, uncertainty, and 'messiness'. Schön draws on Polanyi and points out the heavily implicit nature of knowledge and decision making in professional jobs. When we learn implicitly, we become adept at noticing changes from the norm, rather than by knowing the norm — which itself remains tacit. For example you can see changes in facial expressions but you do not know how to describe the face itself (or how you knew its expression had changed).

Polanyi (1958), Schön (1983) and Nathan (2012) all argue against a formal and scientific view of the knowledge used in engineering and in fact argue that it is a job where tacit knowledge is the predecessor — chronologically — to formal knowledge.

Schön (1983) argues for a different view of the professional called reflection-in-action. In this view the professional reflects during the job

when stimulated by the uniqueness of a situation. It requires consideration of how known methods may apply, what is new, and how to act.

Schön's insight into the professions extends back to formal education because formalised knowledge is only useful in practice if it is interiorised by the practitioner and ready to be used reflectively.

Reflection is a widely studied topic in education, for example the literature is reviewed by Moon (2013), who defines the process as making an observation (what happened), analysing it (why it happened), and making a judgement (it was good/bad). Gibbs (1988) has a more practical approach, which a toolkit by the University of Edinburgh (2022) summarises as a 6-point process: describe the experience, feelings and thoughts about the experience, evaluate the experience (good and bad), analyse to make sense of the situation, conclude about what you learned and could have done differently, plan actions for the future.

The distinction in Schön's concept is that the reflection should happen during the event. This is reflection-*in*-action, not just *on* action after it happened. For Schön our knowledge is *in* our action (Schön, 1983, p.49). Just as with daily life, our doing is our knowing; we have no separate knowledge of what we are doing. We do not think and then act — it happens together.

We are continually in a conversation with our work, asking questions, hearing answers, trying experiments, accommodating results. Positive and negative results are not success or failure, but relevant information (Schön, 1983, p.59).

The practionioner *frames* the problem through this process, repeatedly reframing and "open to the discovery of incongruent phenomena" (Schön, 1983, p.268).

To summarise Section 2.2 on the learning process, developing tacit knowledge is described by Polanyi as a personal process involving *indwelling* and interiorisation, rather than directly absorbing formalised knowledge. Nathan argues that indeed directly exposing a learner to formlised knowledge is not appropriate. Schön argues that professionals practice reflection-in-action, a habit that I will argue should be the goal of our education.

Given the personal nature of knowledge, the social nature of sharing it, and the requirement to learn to be reflective-in-action, the learning process is an emotional process. By this argument emotions are important to any discussion of the student experience of tutorials.

2.3 Achievement emotions

Awareness of the importance of emotion in cognitive development is growing due to the influence of modern neuroscience (Sousa, 2010). For example Immordino-Yang and Damasio (2007) compiled evidence that learning is underpinned by emotion; and this research is ongoing.

While neuroscience highlights the importance of emotion, we are still largely in the phase of using psychology to develop a practical understanding of emotion in education.

Pekrun (2006) articulates a control-value theory where total outcome

Object focus	Appraisals: Value	Appraisals: Control	Emotion	Tutorial context	Code
Outcome/ prospective	Positive (success)	High	Anticipatory joy	'I'm looking forward to learning'	P+1
		Medium	Hope	'I hope I will be able to learn'	P+2
		Low	Hopelessness	'I can't influence how much I will learn'	P+3
	Negative (failure)	High	Anticipatory relief	'I will solve my problems'	P–1
		Medium	Anxiety	'I worry if I'll have problems'	P–2
		Low	Hopelessness	'I won't solve my problems'	P–3
Outcome/ retrospective	Positive (success)	Irrelevant	Joy	'It went well'	R+1
		Self	Pride	'I did well'	R+2
		Other	Gratitude	'I appreciate their help'	R+3
	Negative (failure)	Irrelevant	Sadness	'It went badly'	R–1
		Self	Shame	'I couldn't focus'	R–2
		Other	Anger	'They distracted me'	R–3
Activity	Positive	High	Enjoyment	'It was fun'	A+
	Negative	High	Anger	'It was a pain'	A–
	P've/N've	Low	Frustration	'I did/didn't understand'	AX
	None	High/Low	Boredom	'It was boring/a waste of time'	A0

Table 2.1: Achievement emotions, adapted from Pekrun (2006, p.320) by adding two columns. Firstly to put that work in context for this research, secondly to add a code for ease of reference later. For the code the first character P/R/A is for propective/retrospective/activity; followed by +,–,X,0 for positive, negative, both, neither respectively; and numbers are 3 categories.

expectancies are a combination of situation-outcome and action-outcome expectancies, meaning the probability that either the situation or one's actions, respectively, will cause an achievement.

For example if the tutorial itself is seen as likely to cause learning, then a student will be motivated to attend by their situation-outcome expectancies; alternatively the tutorial may be a distraction and therefore produce low situation-outcome expectancies. I will show how this perception, and its dependence on mode (online vs. in-person), varies dramatically between students.

The mechanism behind perceived outcome expectancies is assumed to be emotional. Pekrun has developed a theory of 'achievement emotions' defined as 'emotions tied directly to achievement activities or achievement outcomes' (Pekrun, 2006, p.317).

Pekrun summarised achievement emotions in a table which is reproduced here in Table 2.1 with two additional columns: one to give simplified example of a student's point of view about a tutorial, to highlight the type of response I am interested in; and a column with a code for each emotion.

Pekrun noted that students may make an *appraisal* of their situation as an antecedent to experiencing an emotion, but that the appraisal is not essential nor is it necessarily conscious (Pekrun, 2006, p.324); likewise the student may not be aware of the emotions themselves, for example they may be habitualised. These *tacit* emotions are therefore difficult to detect — for example, asking a student about it may not be adequate.

Pekrun (2006) acknowledges that perceptions and emotional experience are a strong function of achievement goals, beliefs about control and value, and social and cultural factors including the environment. This

acknowledgements implies that (a) we would expect a range of results amongst our student group, and (b) the causes are complex and unlikely to be established by a simple piece of research.

There is also a complex relation between achievement emotions and positive outcomes for learning, achievement, and life satisfaction. This is because positive/negative emotions do not always lead to positive/negative outcomes respectively (Pekrun, 2006, p.326); for example, negative emotions can galvanise action. Students are highly motivated by exams, and not necessarily because they see it as an opportunity to achieve (anticipatory joy, P+1; hope, P+2); but typically because of anticipatory relief (P–1) or anxiety (P–2). It is not necessarily our aim, therefore, to maximise the positive or minimise the negative aspects of achievement emotions.

The habitual aspect of tutorials is also important. They are regular events and there is a feedback loop. The emotional experience of students in a tutorial *in general* is the result of a tuning process in the initial weeks of term where expectations are set. There are many parameters outside the scope of the normal tutorial arrangements that could affect the way tutorials are ultimately experienced by students. This includes aspects within our control as teachers, such as assessment, deadlines, staff training, expectations; but also outside our control such as lockdowns, cultural trends, other departments and universities.

The control-value theory of Pekrun (2006; 2007) is about achievement emotions with application to education, but not fundamentally built around educational goals. It incorporates the concept of *appraisals* but not reflection more broadly. It does not distinguish a learning goal from another type of goal; and there is no conception of knowledge or learning inherent in the theory.

2.4 Confusion

Schön's reflection-in-action theory, and theories of tacit knowledge and implicit learning, revolve around noticing differences from the norm and how we respond to them. An emotional response to "discrepant, contradictory information generating cognitive incongruity" is called an 'Epistemic emotion' (Vogl et al., 2020, p.626).

Epistemic emotions are central to learning and in fact they feature in Imperial's graduate attributes to 'Approach challenges with curiosity, critical thinking and creativity'.

Typologies for incongruities that lead to epistemic emotions, such has comprehensibility, familiarity, etc. have been suggested by Kagan (2009) and Silvia (2010).Confusion is an epistemic emotion that I will focus on in this dissertation and is reviewed by D'Mello and Graesser (2014).

Vogl et al. (2020) performed large scale, quantitative experiments on epistemic emotions to systematically identify their antecedents and their outcomes. Their method involved trivia questions and they found a strong link between high-confidence errors — when the student is confident in their knowledge but gets feedback that they are incorrect — and epistemic emotions.

Vogl et al. (2020) found that confusion was sometimes but not always

an antecedent of exploratory behaviour. They theorise that participants' varying beliefs in the likelihood of resolving their confusion govern their likelihood to explore.

Evidence for the role of confusion in learning is especially strong when the level of required learning is 'deep', "especially when the learner needs to bridge the gap between an existing (and usually faulty) mental model and an ideal conceptual model" (D'Mello and Graesser, 2014, p.301).

2.5 Tutorials

In this section I define what a tutorial is both in Imperial and more broadly. This serves both to define the subject of the dissertation but also to explore other institutional cultures to provide a broader context to the research I present.

A 'tutor', from the Latin *tutore*, is a guardian or custodian. It comes from the verb to watch but includes an active component, to look out for, to take responsibility for. The tutor is the guardian of education. A tutorial is when the student and tutor meet. A tutorial defies a more precise definition and is used with different meanings in education. In modern universities with large cohorts, a tutorial usually means a class size smaller than the whole cohort. Exactly how small, and exactly what happens, varies by institution.

Most famously, and of relevance to my research, Oxbridge have run tutorials for centuries — albeit with varying levels of quality assurance. The modern Oxbridge tutorial was revitalised in mid-19th century (Argles 1964, p.45; Ahmed 2017, p.16). In a briefing to Oxford students Probert Smith (2008) clearly distinguishes tutorials from lectures:

Lectures are optional; not interactive; not personal; the end is predetermined; material is covered in a first pass.

Tutorials are compulsory. They are private; individual; the end is not pre-determined beforehand. Participation makes it meaningful. "tutorials are much more than an examples class with the primary aim of providing solutions. They offer the chance to progress from a surface understanding to a deeper knowledge". "The tutor's job is to ask the questions, stimulate the discussion, and provide the guidance to help you to deepen both conceptual understanding and analytical technique."(Probert Smith, 2008, p.66)

The tutorial is for early years of undergraduate study, after which it "transmogrifies into project supervision" (Probert Smith, 2008, p.62) — a description that also covers progression at Imperial, in Mechanical Engineering at least. Probert Smith summarises the value of the tutorial as seen by students:

- "Making me work all year, not just for examinations: self-motivation can be hard to maintain over very long periods.
- Sorting out problems as they arise: essential in subjects which build up on earlier material, and reducing the problem of poor motivation which results from getting stuck with a problem at an early stage."

— Probert Smith (2008, p.65)

Sarkar (2017) reviews the Cambridge 'supervision' system, analogous to the Oxford tutorials. Sarkar gives the definition "The supervision provides structure and individualised feedback for high quality self-study." (Sarkar, 2017, p.9). The structure directs study to 'create deeper understanding'. The emphasis on self-study is because of the work required before the supervision; the incentive of the session mirrors the same emphasis by Probert Smith (2008, p.65).

Sarkar also gives an alternative definition as teaching 'how to think'. This definition is alternative as opposed to principal firstly because it may not be clear to students what it means to learn how to think; and secondly because self-study is, anyway, a pre-requisite to learning how to think — the student must be familiar with the material first. So, in a way, the teaching how to think is an *implicit* part of the process.

Sarkar is quite clear that the supervision itself is a sequence of questions posed *by* the supervisor *to* the student.

It is notable that according to Probert Smith (2008, p.65) the students point specifically to benefits of motivation to work, and 'sorting out problems'. These are two from a longer list of benefits; the students I have asked at Imperial are also sensitive, in particular, to these two topics. I will show in this dissertation that students at Imperial also see motivation as important — but in our context as we do *not* require or check their work, we see the opposite effect, i.e. students are demotivated. Students at Imperial also express the same benefits of 'sorting out problems', which I take to mean they are already aware of the problem before they arrive at the tutorial, and they arrive with questions.

What the Oxford students haven't expressed here — and I do not know how aware they are of the benefit, but Probert Smith (2008, p.66) and Sarkar (2017) clearly see it — is the stimulation when the tutor asks the student a question (as opposed to vice-versa). This is a key distinction. I will show in this dissertation that students are very sensitive to such an event; it can be very powerful, but in fact it is rarely welcome. One of my key findings in this dissertation will be that such a challenging stimulus is rarely welcome, and that this is explained by students being too far behind with their other work.

Practically speaking, Imperial tutorials follow the same generally accepted principles of a small class, non-predetermined outcome, and a relatively informal atmosphere. There are, however, two principal differences between Imperial and Oxbridge. Firstly, class sizes are much larger at Imperial, around 20 rather than two or three (contact is more frequent, so this is not necessarily an economic difference); secondly there is no collegiate system wherein students are tutored by someone in a 'College' to which they belong and is distinct from academic departments. The result is that the beautiful description above by Probert Smith is not the reality at Imperial. Whether or not it is the aspiration I do not know — I do not have a history of the tutorial at Imperial. Gay (2007) provides a detailed history of Imperial but not to the level of detail of tutorial arrangements.

Within my own department I do not have history beyond the Taught

Institution	Tutorial focus	Source
Cambridge	1–3 students; test your ideas; develop your thinking.	Uni website
Hull	Small; active; test your ideas	Uni website
UNSW Sydney	Small; informal; discuss; clarify; test ideas; improve thinking skills	Uni website
USC (South. California)	Small (15-25); informal discussion	Uni website
McMaster	Walkthrough; clarify; delve deeper	Uni website
Buckingham	High level of support	Uni website
HE Academy	Flexibility; interaction; Reflexivity and Engagement.	Mills and Alexander (2013)

Table 2.2: Representative emphasises on the nature and purpose of a tutorial. References to 'Uni website' are hyperlinks (in PDF version), last accessed 21/05/22. For further references see Balwant and Doon (2021, Table 1).

Courses Handbook (Department of Mechanical Engineering, 2017) that I quoted on p. 9. Last updated in 2017 but with content from up to ten years earlier, it says that class sizes are 16 (note they have grown to 22 now) the description in the handbook matches very well the culture I have encountered from 2018 onwards in the department.

Other universities around the world follow a pattern somewhere between Oxbridge and Imperial. Table 2.2 provides some representative examples that I have found; a more complete review is given by Balwant and Doon (2021). To summarise this survey of other institutions: explicit emphasis on developing thinking skills in tutorials is rare; expecting specific work to be done in advance is common (roughly half of institutions); 'small' class sizes (but typically 10+) and informal structure are the norm everywhere.

Beyond undergraduate teaching, a web-based tutorial for learning a method in computing is a very common tool; such tutorials are typically a 'walkthrough' of how to do something, with added commentary. The association of an online tutorial with computing walkthroughs has spilled over into online academic courses ('MOOCs'[2]), and this has fed back into in-person activities. For example, M.I.T. lists tutorials in mechanical engineering including using software and using machining tools (M.I.T., 2020).

[2] Massive Open Online Course'.

The review of tutorials here has been brief. It is limited to a basic review of the Oxbridge and Imperial systems, and an incomplete comparison to some Anglo-Saxon institutions. It is not a critique of tutorials, which would inevitably spill into a broader educational literature review, for example on active learning, flipped classrooms, staff-student power dynamics, and so on.

I have not compared to other systems such as France or Germany; or institutions in emerging economies. Balwant and Doon (2021) provide a list of alternatives based on a scoping review of 48 journal papers chosen from 1500+ originally found in their search. The aim of the review here has only been to define what a tutorial is, and the various ways in which it can be executed. Thus I have provided a context in which to present my research about student experiences of tutorials at Imperial.

To summarise this review of tutorials, the Oxbridge system mandates tutorials with very small groups. The sessions require work to be completed in advance. Students benefit from the motivation to work in ad-

vance, and the chance to ask questions. The tutorials follow a Socratic method of teachers questioning the students, and when run successfully carry the deeper meaning of developing ways of thinking in students and taking academic risks. Most other institutions have a diluted version of this tutorial system.

2.6 Summary

Engineering knowledge has a strong tacit component. The path to learning involves interiorising tacit knowledge first; developing a mode of thinking and being which, once developed in the learner is later well represented by, and applied using, formalised knowledge. Whether this is a one-off process, or a cycle of exchanges between the forms, does not seem to be well understood.

This process of learning appears to involve a significant element of reflection. Reflection is stimulated by novelty or differences from the norm, and is effective when it leads to new, generally constructive, actions. When knowledge is the goal, reflection should lead to exploration.

Reflection is a personal process that we increasingly conceive of as governed by emotions, specifically achievement emotions (listed in Table 2.1) and epistemic emotions (for example surprise, curiosity, and confusion). Reflection, and in turn exploration, seems to be prompted by epistemic emotions, which themselves are triggered by encountering high confidence errors, i.e. feedback that high confidence knowledge or beliefs are inaccurate.

The context of my research is firstly an interest in the role, and the student experience of, tutorials; secondly, following the recent lockdown and introduction of online tutorials, I have a timely interest in the contrast between in-person and online tutorials. Based on the literature review I have presented here, my focus is specifically on:

- achievement and/or epistemic emotions in tutorials, which may be habitualised and implicit
- tacit knowledge, indwelling, and implicit learning in tutorials

The research problem is to establish evidence — or lack thereof — to inform these two lines of enquiry. In other words, to build a picture of the emotional experience in tutorials.

CHAPTER 3

Methodology

This Chapter presents and critiques the method I used to collect data to answer the research question

> What is the student experience of in-person vs online tutorials, and what is the role of tacit knowledge in this process?

The research challenge with studying tacit knowledge and habitualised emotions is that they are not articulate. It is the 'something' else that students can't describe. The Chapter begins with a review of techniques to solve this 'research problem', reviewing scientific techniques and concluding on using an arts-based method where students produce art.

I then describe the practicalities of the methods including arrangements, ethics, and benefits to students. I also briefly present some verification work where I used pure conversation at the beginning of the focus groups and replicated my findings from my preliminary research — validating the need for the method ultimately employed.

The remainder of the chapter is concerned with a critical discussion of the analytical methods employed to process the data, and the theoretical framework of both the data collection and the analysis.

3.1 Selecting a data collection technique

To identify internal experiences one option is to use modern scientific methods such as monitoring facial expressions, body motion, brain measurements such as electroencephalography (EEG), and brain imaging such as functional magnetic resonance imaging (fMRI) or positron emission tomography (PET). All of these techniques require specialist and expensive techniques were outside the scope of my research.

The next consideration as a technique was to look at the state of the art in psychology and the approach of asking participants about their experience. To what extent can research participants be expected to effectively describe their inner experiences? Hurlburt and Schwitzgebel (2011) discussed in depth the practical problem of asking people to describe their inner experiences. In their 'proponent meets skeptic' approach, a psychologist, Hurlburt, who had spent 20 years developing a techniquel to train participants to accurately describe their inner experiences discusses the merits of this approach with his 'critical friend', Schwitzgebel, a philosopher who asserts that such an achievement is not possible. Hurlburt's

careful technique — which has been subject to decades of peer review, see references in Hurlburt and Schwitzgebel (2011) — is acknowledged by Schwitzgebel to work reasonably well under a very limited set of circumstances.

Hurlburt's technique involves firstly training participants before participating; subsequently they carry a pen and paper with them and whenever a random buzzer buzzes — for example one that they are carrying in their pocket — they immediately write down exactly what is in their mind at that time. Hurlburt is rigorous in establishing exactly what it means to have something 'in one's mind' to be written down. This rigour is why Schwitzgebel does not completely disregard the method. However, it is clear that this approach only works at a given moment in time. It is not a method to be used in hindsight.

I considered using Hurlburt's approach in my research, as the truest way to probe student experiences. The practical implications of using such a method are quite extreme, and the level of investments from participants is significant. Given that I am not expert in that technique, it seemed unlikely that I would obtain high quality results.

There are methods in psychology that use computing and linguistics to decode implicit communications in language. For example Graesser et al. (2004) have developed a tool ('Coh-Metrix') to analyse language and make associations with psychology and in particular emotion. Linguistic analysis, such as 'cohesion', can be related to emotions through additional research; for example Graesser et al. (2004) showed that sentences lacking connectives are linked to confusion. Within the scope of an MEd project it was not feasible to pursue this approach on a deep technical level because of the level of investment needed in the technique.

By process of elimination I have rejected techniques of hard science; Hurlburt's approach of participants describing their inner experiences; and computational analysis of linguistics. It was also clear from my preliminary research that interviews reach a limit when the knowledge is tacit in the student.

Eraut (2007) reviewed research on learning from others in the work place, where the emphasis was on tacit knowledge. From a methodological point of view they concluded that 'the elicitation of tacit knowledge remained very difficult and appeared to require a more interactive approach to data collection.' (Eraut, 2007, p.405).

The method I employed was to ask students to produce a work of art that expresses their experience of tutorials. This approach builds on the same concepts that I discussed in the Literature Review, i.e. tacit knowledge and its communication through indwelling and interiorisation.

3.2 Practical considerations

Focus group arrangements

Students were invited to a one-hour session where they worked in a group, with me, to express themselves through art while I also recorded our conversations in the room. The emphasis in my approach was on the *process*

rather than the output. The works of art that resulted can be used as artefacts to refer to when discussing this process, and to help the reader connect to the subjects; the artefacts do not in themselves necessarily represent a formalisation of the knowledge though. The 'results' of this experiment are, in fact, not concrete and are open to interpretation, just as a work of art is.

Students were offered to use a range of means of expression in advance. In total nine students took part. Each student attended one of three focus groups. The expressions of art were all either graphical (painting or drawing), or sculpture using Plasticine and/or Lego. All students chose their mode of expression.

Ethics

There was a risk, categorised as low, that I could cause harm to participants, specifically through my position of power as their teacher. This risk was considered both as an actual risk that I may cause harm or unethical actions; but also the risk of *perception*.

The principle controls I used to reduce these risks were firstly to declare the process in written form to any potential participants and to make clear that it was optional and voluntary and was in no way connected to the curriculum or any academic credit. Secondly, the recruitment was conducted by other staff and I avoided any coercion, perceived or otherwise, of students to participate. Finally, an incentive in the form of a voucher was provided, partly to help recruitment but also to avoid any sense of an alternative, potentially unethical, reward.

The risk management process I proposed was evaluated anonymously by the Imperial College London Education Ethics Review Process in advance of performing the research and was approved. In taking part in the process students were promised anonymity; they also agreed in advance to the use of their transcripts and art in the public domain.

Benefits to students

The research enquires about student experiences during and after lockdown which was a difficult period for most people, including our students. The session therefore took on a therapeutic aspect to it that the students appreciated. 'Art therapy' is a well known activity although the primary goal in art therapy is healing and reconciling, whereas in my case that is a happy consequence rather than the main goal. The benefits were:

- Facilitates reflection, including on one's tacit knowledge and habitualised emotions
- Benefits to general well-being through reconciliation of past experience
- As a group activity it can help build bonds, enhancing the community and a sense of belonging

Validation of choice

I began the arts-based sessions with an ice-breaking conversation about tutorials, with no art involved. These initial conversations replicated the outcomes of earlier focus groups — see Appendix A.4 for details.

While there is some benefit to validating the insights I gained in preliminary research, it also leads to the conclusion that further focus groups in the traditional format are not likely to lead to new and deeper insight. The reason is because the insight I am looking for is tacit. Initial discussions in the new focus groups also repeated this very point; again, the more reflective students were aware that it is hard to articulate: "I don't know how to explain. It's just like easier in-person".

The replication of results from earlier focus groups justified the choice to include art generation as a primary activity during the focus group, to gain deeper insight.

3.3 Critical appraisal

This section provides context for the method I used; my positionality; and my approach to thematic analysis.

Arts-based research

'Arts-based research' refers to any research in which art is an essential component. Often it revolves around a creative expression with no "clear final outcome. Focus [is] on exploration, understanding and meaning making" (Savin-Baden and Howell Major, 2013, p.289).

Savin-Baden and Howell Major group arts-based research into three categories: inquiry based on art itself; the representation of findings by art; and inquiring into the response of an audience to a work of art. My approach is closest to the first of these categories although it is distinct in that the 'artists' are the participants, and they are not otherwise known as artists. I am not inquiring into the artistic process, but rather using the process of producing art as an instrument to help me connect with the participants.

It is recognised that arts-based research can be used "to initially bypass the need for verbal expression" (Greenwood, 2019), which is the same rationale that I have here. It seems unconventional, however, for the participants themselves to be the artists. For example

> "While the researchers in this study were the primary artists, it would also be interesting to explore the potential for participants to individually generate artworks that are then the starting point for interviews about the research topic."
>
> —Morris and Paris (2022)

My approach was to "generate or inductively develop a theory or pattern of meanings" from the art of the participants, which is a hallmark of social constructivism (Savin-Baden and Howell Major, 2013, p.63). The students were familiar to me, and I took part in the session with them, hence this was a constructionist philosophical stance (Savin-Baden and Howell Major,

2013, p.62). This approach views knowledge as constructed through the process of shared experiences. In this sense, 'knowledge' of tutorials only exists in the shared consciousness of the students (and myself). So if there is no tutorial there is no truth; and if there are multiple attendees, then there are multiple truths. With shared discussions, we can establish a shared truth.

Position

As a teacher, and conductor of the research that led to the question being addressed here, I conducted the focus groups from a starting position that was informed by my experience with students, the preliminary survey and focus groups, and a literature review.

It seemed clear to me that in-person teaching is valuable to students. More specifically, I adopted the position that engineering knowledge has a strong tacit component. I suspected that the preference for in-person tutorials was to facilitate learning this tacit component.

My position brings a bias with it that is inherent in qualitative research. As Braun, Clarke and colleagues put it,

> "The researcher is a storyteller, actively engaged in interpreting data through the lens of their own cultural membership and social positionings, their theoretical assumptions and ideological commitments, as well as their scholarly knowledge."
>
> —Braun et al. (2019, p.848)

Thematic analysis

I processed the recorded conversations into individual narratives for each student. Their contributions came at different points in time in the focus groups, interwoven with each other. By separating the narratives I could focus on each individual and triangulate their art, our conversation, and my preliminary research.

I have included the individual stories in Appendix B. Reading those stories is the best way to find an emotional connection to the students. There is only space in the Results section for a very brief version.

By studying the individual narratives, I identified both semantic and latent themes. The semantic themes were *a priori* determined as Pekrun's achievement emotions (Table 2.1). This 'TA codebook' approach involved combing each narrative for evidence of achievement emotions and labelling them; I could then collect these codes in a table to see a bigger picture of the student experience. Because these results are semantic (i.e. shallow and directly observable in the data), I will present them in the Results section.

The coded/semantic results I present are limited to individual stories that I extracted (Appendix B). Other parts of the raw conversations contain further data that could be processed at a later date.

As an example of evidence of an achievement emotion, a student, *Maria* (pseudonym) drew herself studying online; she struggled to express her experience despite having a clear memory of it. Through drawing it, and then discussing with me, she eventually said

Me: "So you remember it clearly do you?"
Maria: "I remember the feeling, I'm just thinking how could I ...?"
[express/articulate it]
[pause for a few seconds]
Me: "I guess it's probably lots of things"
Maria: "Yeah. Like. It's confusion. It's getting angry at yourself for not understanding. Frustration. 'What am I doing here?'"

In this example Maria has directly expressed confusion, anger, and frustration, the latter two of which are in Pekrun's table.

Other examples were less obvious. For example Maria expressed the positive experience she has in-person, and there was a clear sense of joy in her voice, her description, and — with the conversation as a guide — her drawing. So I inferred 'joy' with high confidence. Appendix B provides more detail on the coding of emotions.

To identify deeper, latent, themes, I used a reflexive thematic analysis. This process followed the six steps identified by (Braun and Clarke, 2006; Braun et al., 2019; Braun and Clarke, 2021): familiarise with the data, generate initial codes, search for themes, review themes, define and name themes, produce the report. This process was a time consuming one as the art was not something I was trained to interpret. It took deep reflection for me to identify themes; I have used those themes to structure the Discussion section.

CHAPTER 4

Results

In this Chapter I present the works of art that students produced in my focus groups. The focus groups were social, but the works of art were essentially created individually and each one tells a student's story.

The works of art are presented as full page items both to match their original form and to be viewed without visual interference. The full works of art are placed on page numbers listed in Table 4.1. All names are pseudonyms to protect the identify of the students. Nine students took part, of whom eight contributed to art used here. Two pieces of art (a sculpture of a desk, and a basic sketch) were excluded for brevity.

The order of the presentation is from the clearest preference of in-person over online, to the least clear. The motivation for this order will be clearer in Section 4.2 where I tabulate acheivement emotions in the same order.

Artist	Context	Page
Maria	Online	p. 36
Maria	In-person	p. 37
Simon & Jay	Composite	p. 39
James	Concrete	p. 45
James	Abstract	p. 46
Helen	In-person	p. 48
Helen	Online	p. 49
Amy	Online	p. 42
Amy	In-person	p. 43
David	in-person	p. 41
George	General	p. 50

Table 4.1: List of 11 works of art reproduced, the originators (pseudonyms), the mode expressed, and the page number.

4.1 Art works by the students

Maria produced two pencil drawings, starting with the online experience (p. 36, and annotated in Fig. 4.1) and then the classroom (p. 37 and an annotated in Fig. 4.2). Maria had a very clear preference of in-person vs. online. While drawing her online experience we had a conversation (replicated on p.33). After drawing, Maria tells the story of how she came to make her disingenuous comment:

> Maria: "I can't really figure it out ... they're just talking ... I'm like 'Yeh I got it thanks'"

In-person, in contrast, she was passionate about the connection she feels in the room,

> Maria: "I work better when I talk to someone. It doesn't disrupt me."

The arrow in her second drawing indicates

> Maria: [the content] "just goes into my head"
> [Pause]
> Maria: "it's just going in my brain"

Maria


Maria

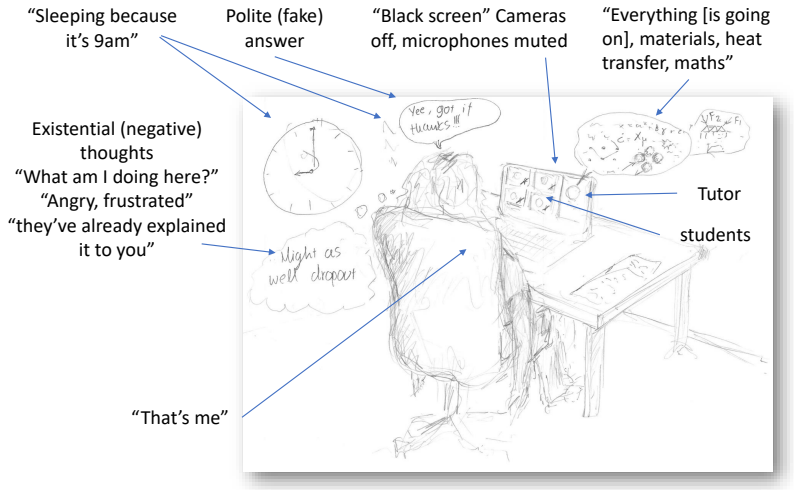


Figure 4.1: Maria's pencil drawing of an online tutorial, with my annotations.

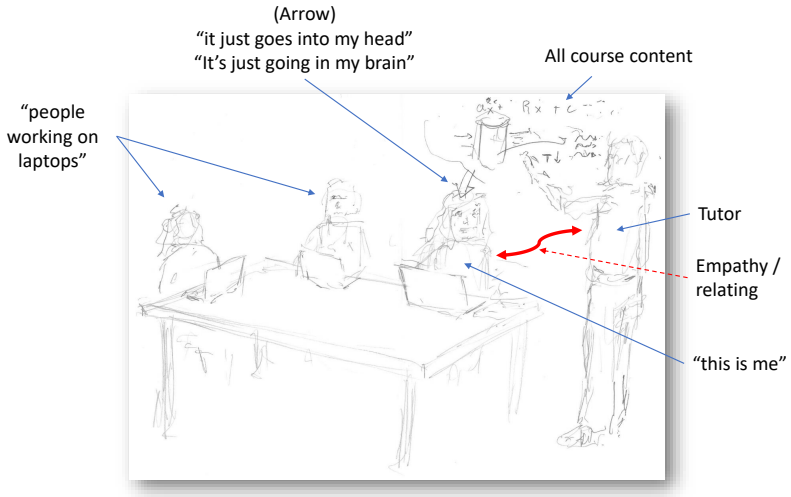


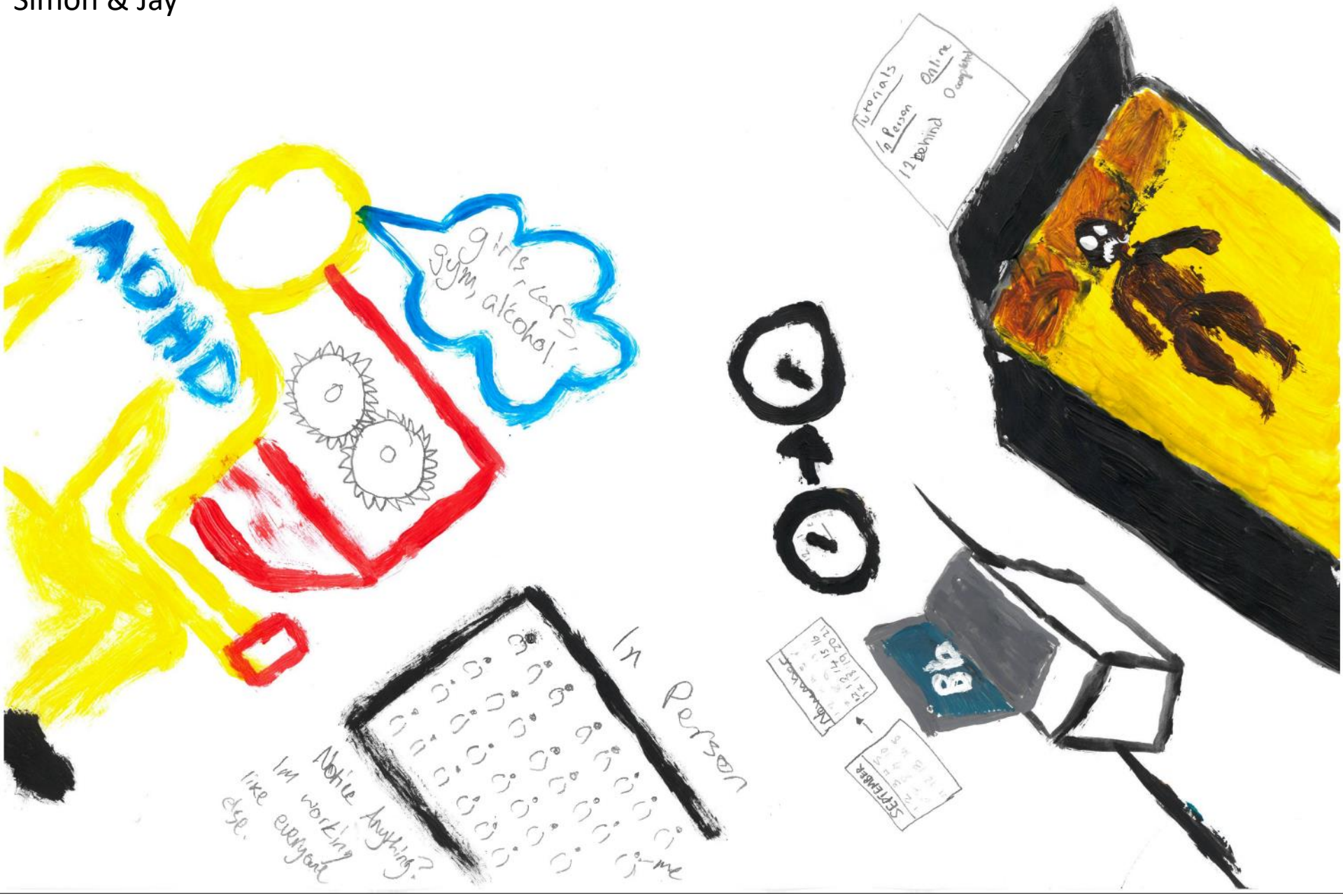
Figure 4.2: Maria's pencil drawing of an in-person tutorial, with my annotations.

Simon and Jay painted together on one sheet, reproduced on p. 39. Simon (left) painted himself at home distracted; and in the lecture theatre working. Simon strongly prefers in-person to online. He was diagnosed with ADHD at school and is easily distracted hence the thought bubble in his painting when working at home on his laptop; but he is an extravert and the company of others in work helps him work. Simon was entirely positive about in-person, for the motivation to work and for the social contact.

As an example of his motivation,

> Simon: "In the main hall, because being around people that are working, it makes me kind of feel like I should be working."

Simon & Jay


ADHD
girls
gym, alcohol
In Person
Notice anything?
Im working like everyone else.
Tutorials
In Person
Online
12 behind
0 completed
Big
SEPTEMBER

Jay painted himself at home and sad; he prefers in-person. He lost contact with his studies when online and fell behind. His sadness is evident in his painting. His ability to study is expressed in drawing: in-person he was '12 behind'; online he completed zero.

> Me: "So what's drawn you to [painting] the online scenario?"
> Jay: "Because [it brings back] the most powerful emotions, I think."
> Me: "And what does it look like?"
> Jay: "Anger, frustration. Impatience."

David created a Plasticine sculpture, of which a photograph is on p. 41 and an annotated version in Figure 4.3. As indicated two stick figures are present — himself, and the lecturer. A wall near David mostly blocks the view; "this is my brain" says David, referring to the wall. Small holes let some knowledge through, but it is mostly blocked. "Online, it would just be a solid wall". David prefers in-person to online.

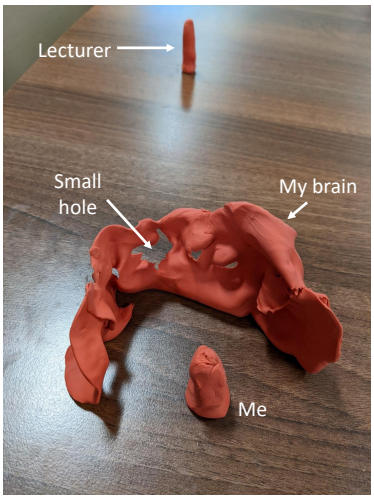


Figure 4.3: David's sculpture

Amy painted with acrylic colours. Amy's first expression is reproduced on p. 42 and it's her bedroom. Amy gets distracted at home.

> Amy: "When at home, there's so many distractions that it doesn't feel like I should be like in a tutorial, it feels like, oh, it's kind of optional. I could do something else."

Amy's second painting — reproduced on p. 43 — represents the tutorial room. It's a positive experience.

> Amy: "I think this has a lot more structure. So like I walk in there. And I see OK I need to do this. Well, *there* [points at the online painting — p. 42] I'm like looking around."

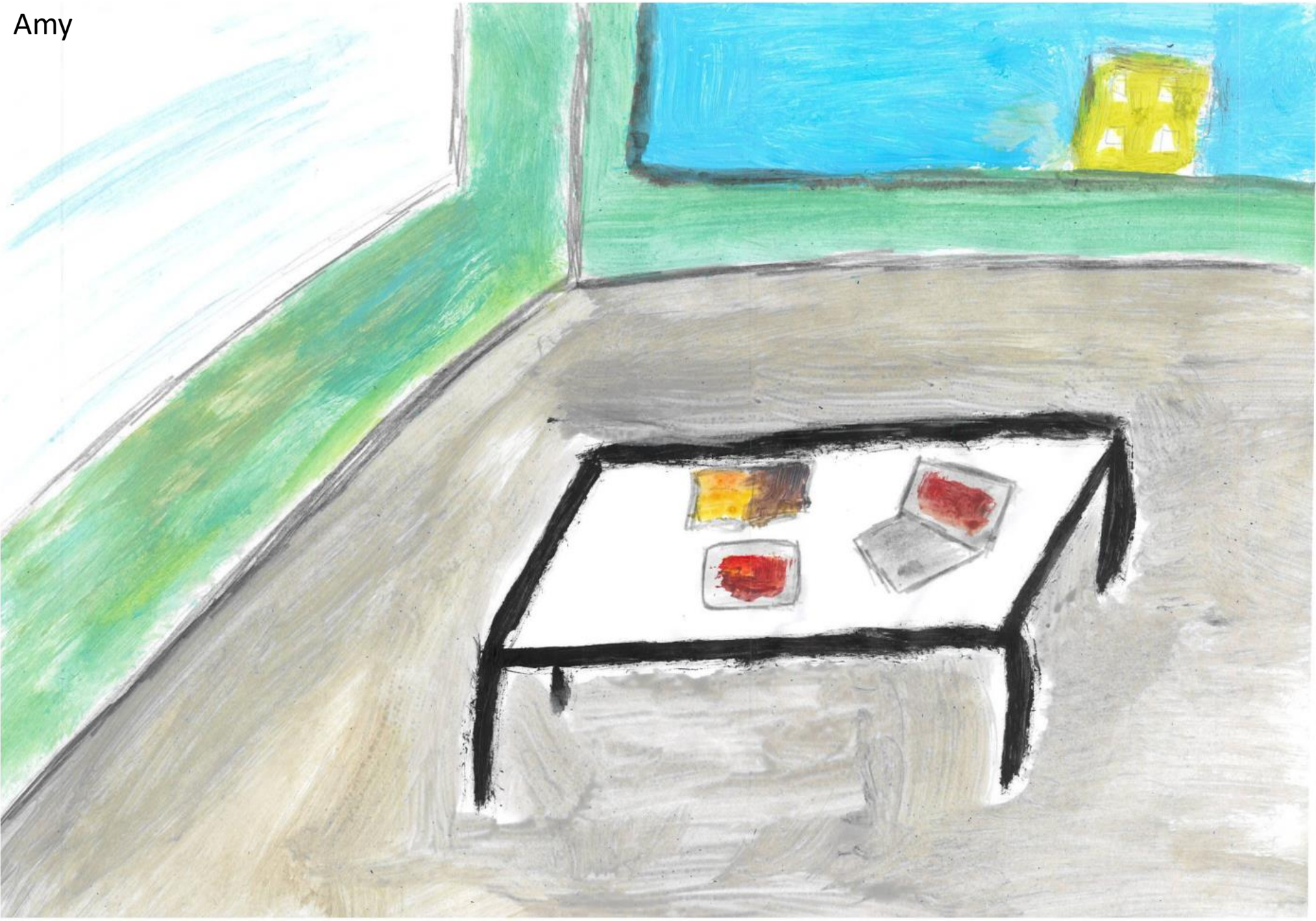
Through discussion, Amy reflects.

> Amy: "I like clinics a lot where I can just go ask my question."
> ['Clinic' is a drop-in session to ask questions]
> Amy: "I want more structure, but at the same time I don't want more structure because it's stressful."


David


Amy

Amy



James James drew at the same time as Maria. His first sheet is reproduced on p. 45 and is a concrete representation of both his online and in-person experience. James produced a second piece of work which was abstract and is reproduced on p. 46. Again it represents both his online and in-person experience.

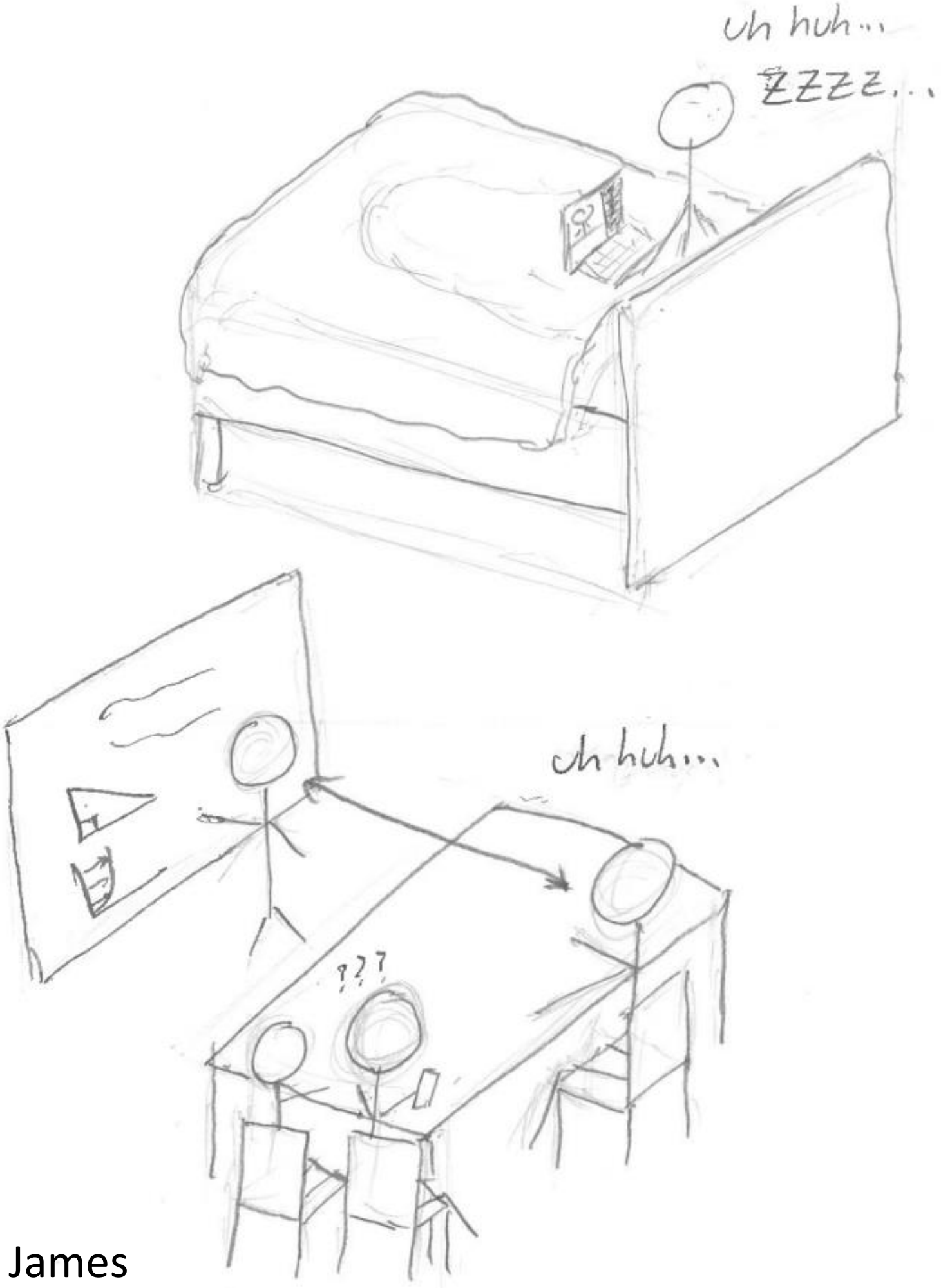
James is the first student in this sequence not to have a clear preference between online and in-person. Online he was more productive.

James valued the 'accessibility' of the online mode. This is not an achievement emotion so does not appear in the collated table, but it was a benefit to the online mode.

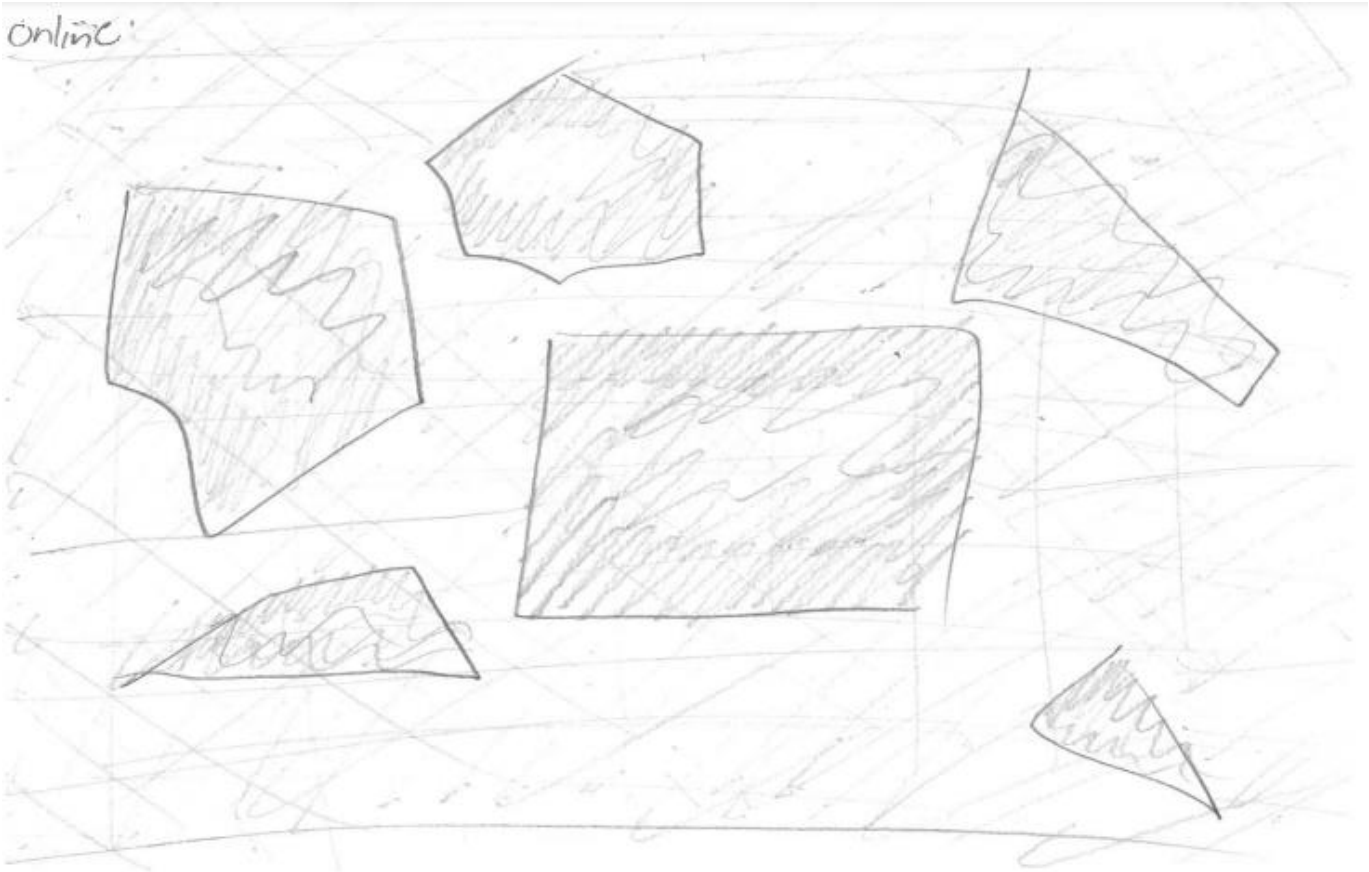
In his concrete sketches James indicates boredom through his liminal state of "kind of paying attention, kind of sleeping". This state is interrupted, for better or worse, when in-person,

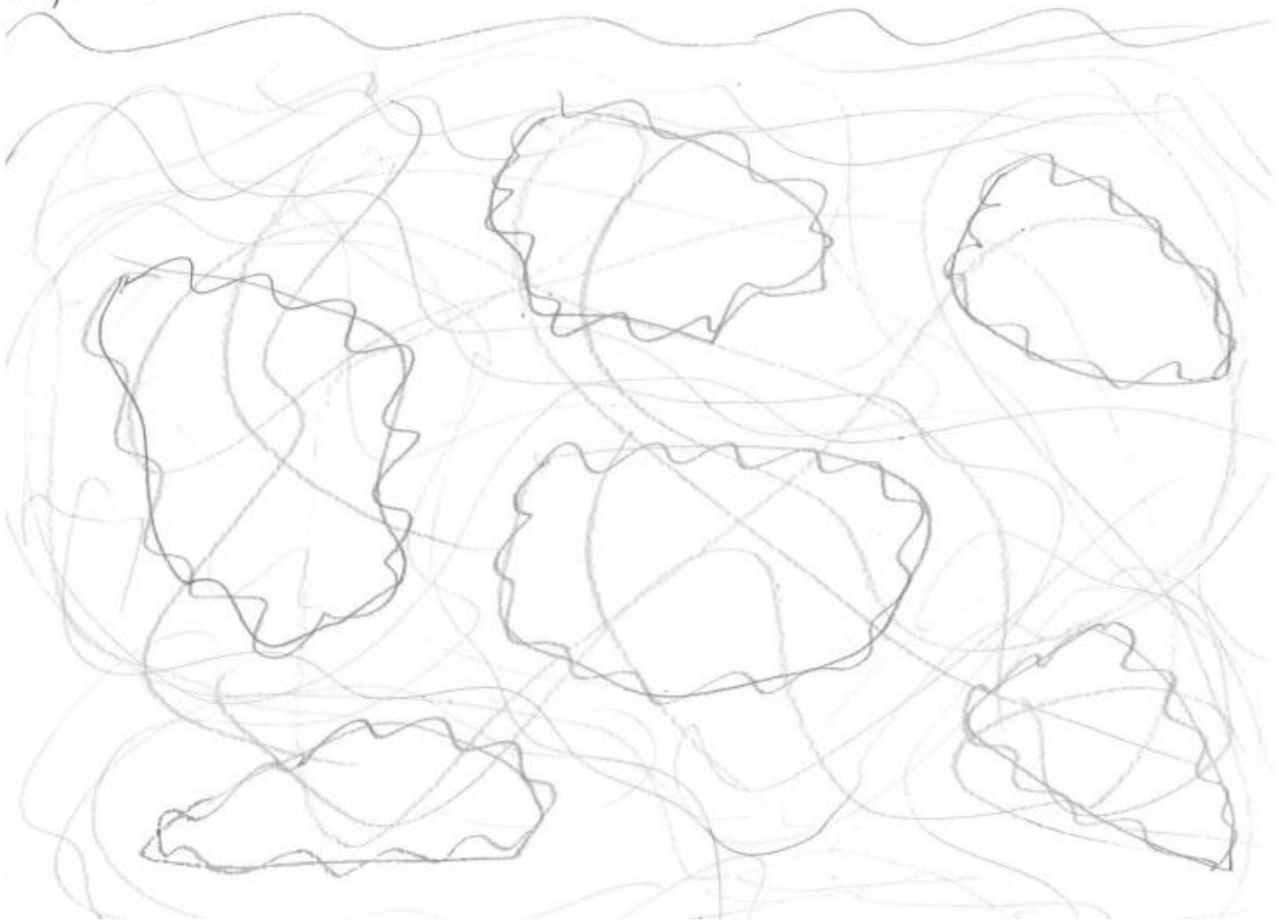
> James: "We just start talking and not working. [...] I like seeing people, but that doesn't help me with work."

In-person the socialising helped his wellbeing, but also distracted him from work; he would also often come unprepared.



James





James

Helen used colour acrylic paints and her first painting, of her in-person experience, is on p. 48.

> Helen: "The red is, that's my working. And then the blue is, so I find it really annoying in tutorials when people are talking about [inaudible] and I'm just trying to get on with my work and I just want to be on my own somewhere."

Helen's second painting is about the online experience and is reproduced on p. 49.

> Helen: "So at home, in contrast I have all this space that's my own, but it's harder to concentrate [...]."
> Me: "[And] what's the red outside?"
> Helen: "So, like often when I spend a day at home, I look up at 5 o'clock and the sun's already set and I've already missed the whole day, you know, and I may have been working, but I don't feel like I've done anything that day."

Helen goes on to describe the roughest days, with long lectures late in the evening.

> Helen: "Oh my God. It was dark and I've done nothing but sit in a chair. That was the day I really slept through a lot of lectures. I'd put them on and fall asleep *like that* [points to painting]."
> Me: "So are you sleeping there?"
> Helen: "It's ambiguous."

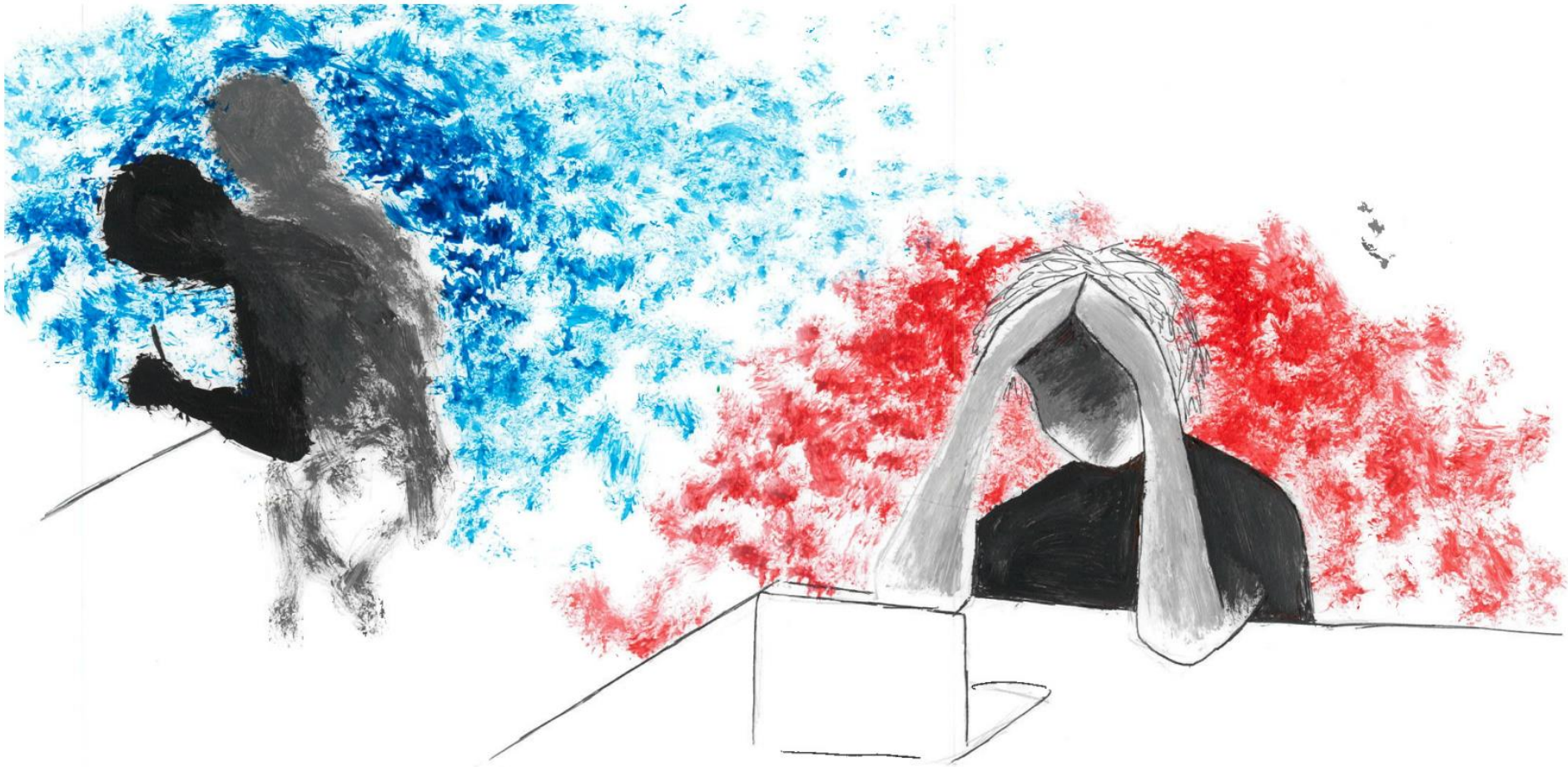
Helen is in a liminal zone, not studying, not sleeping; or both. It echoes James' description (p. 44, 'kind of sleeping, kind of listening').

Helen doesn't like either mode of learning and preferably finds a different place to study.

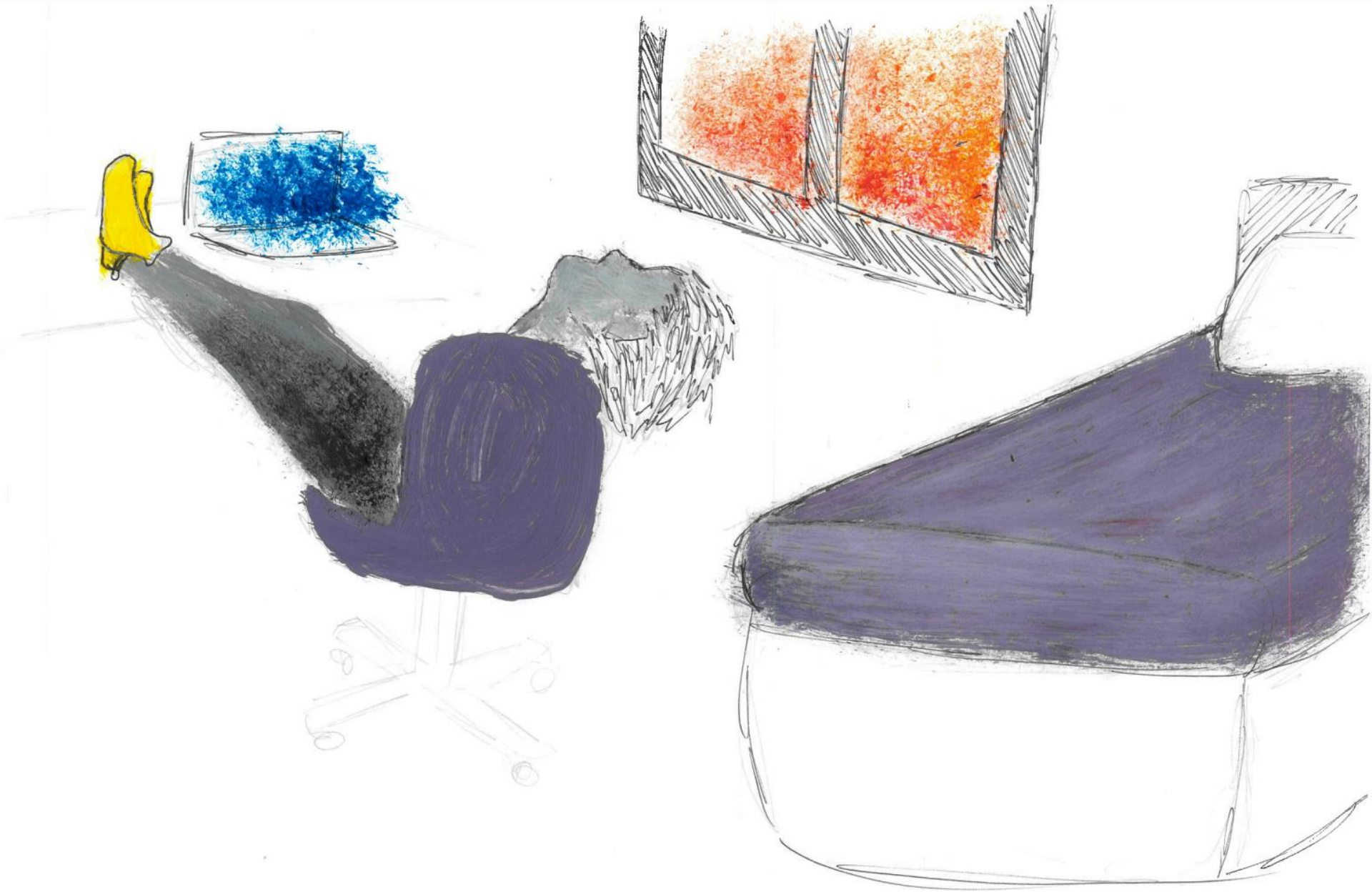
George created a sculpture from Lego and Plasticine. A photo is reproduced on p. 50. George has ADHD and experiences hyperstimulation in any learning mode. George's sculpture represents his brain (Lego) on fire (Plasticine).

> Me: "So tell us about the brain. You've got this structure of Lego"
> George: "Yeah, so it's a brain and the brain is on fire basically, which is pretty much how I feel in any kind of tutorial."
> Me: "OK."
> George: "Or to be honest, most lectures as well whether it's in person or online. [...] the contrast between being online and being in person would be where in person I feel trapped, whereas online I feel like I can separate myself or uhm, even leave much more easily."
> Me: "Yes, it's the autonomy."
> George: "So I mean, I guess I guess the visual representation of that would be either the brain just being on fire and then online I can sort of leave and stick my head in a, you know, in a swimming pool or whatever to cool it off. But then in person it's it's not only on fire, but it's also like trapped in a box so all the heat is just staying in and and getting worse."

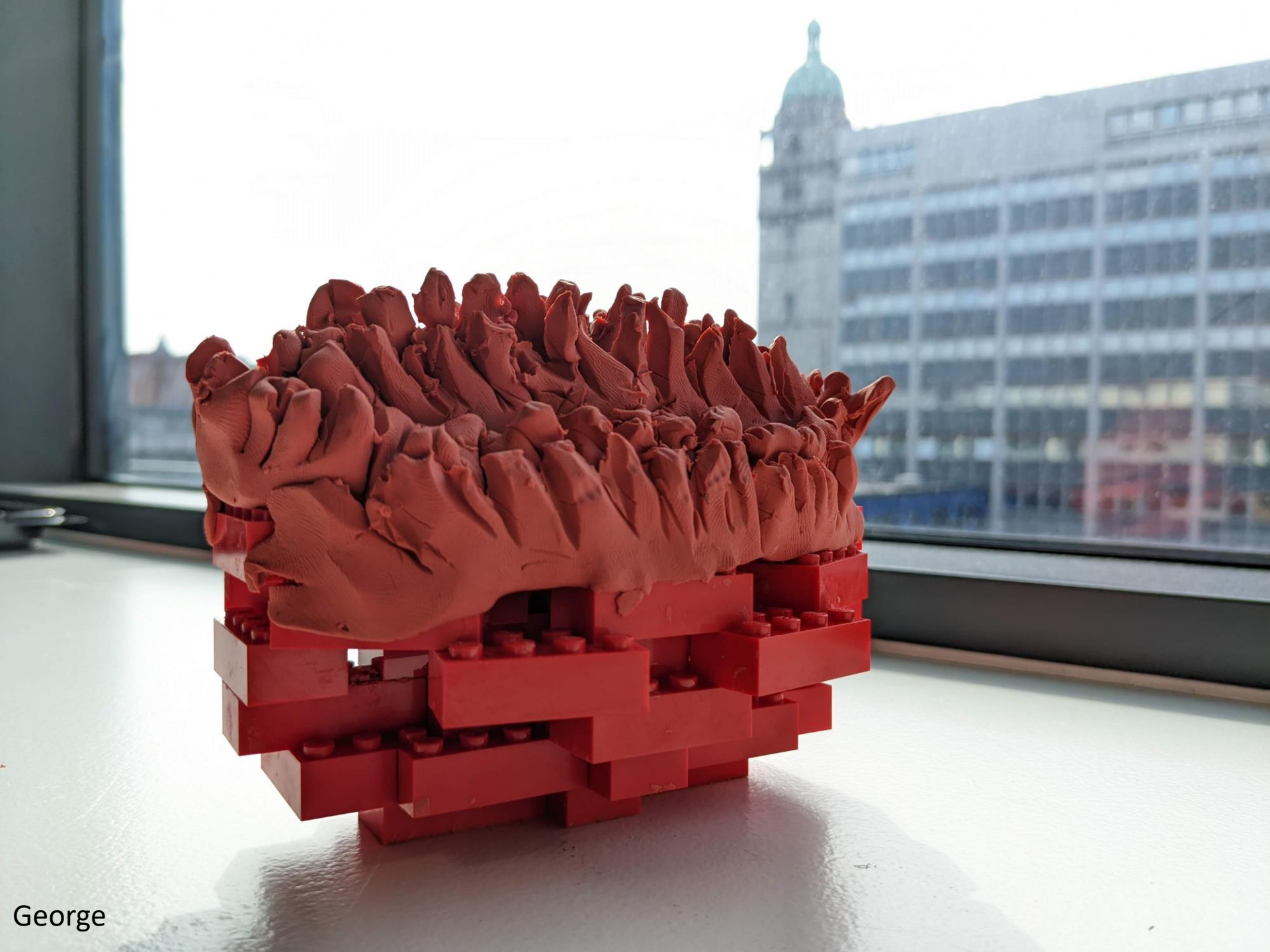
George has also had positive experiences in-person, depending on the group he is with. The online mode provides a respite from the intensities of in-person, giving him the freedom to study as he likes. But he can too easily disconnect and drop-off the radar. So overall he has mixed views about online vs. in-person, with pros and cons to each.



Helen



Helen



George

4.2 Achievement emotions

The previous Section reproduced the art works that students created and provided some brief comments by students on their art. A more detailed description is provided in Appendix B. In that appendix I identify specific achievement emotions from Pekrun's table (see Table 2.1) that each student experienced. I have compiled those findings in Table 4.2. The order (left-to-right) is the same as the previous Section, and goes from most positive to most negative about in-person.

Everything identified in the table is based on evidence given in the Appendix. Some of the evidence is direct, while other parts are inferential but with high confidence and a traceable justification and attribution. The process was that I first curated a narrative of each student, and subsequently identified their emotions. The filtering process to curate a narrative was based on coherence and keeping the stories relatively brief. For this reason, the raw data (transcripts) likely contains more evidence of emotions that has not been included here.

			Online								In-person								
			Maria	Simon	Jay	David	Amy	James	Helen	George	Maria	Simon	Jay	David	Amy	James	Helen	George	
Outcome	Prospective	P + 1									+	+		+					Joy
		P + 2													+				Hope
		P + 3												+					Hopeless
		P - 1												-	X		-		Relief
		P - 2												-	X		-		Anxiety
		P - 3	-		-					-				-	-		-	-	Hopeless
	Retrospective	R + 1									+	+		+	+				Joy
		R + 2												+					Pride
		R + 3												+				+	Gratitude
		R - 1			-				-					-			-		Sadness
		R - 2			-				-										Shame
		R - 3	-		-									-	-		-		Anger
Activity		A +									+	+		+		+		+	Enjoyment
		A -	-		-									-	-		-		Anger
		A X	-		-		+			-				-	-	-	-	-	Frustration
		A 0		-			-	-	-										Boredom
Overall			-	-	-		-	0	-	0	+	+	+	+	+	0	-	0	

Positive (+) Negative (-) Both (X) Neutral (0)

Table 4.2: Achievement emotions identified in the student stories, using Pekrun's table (see Table 2.1).

Overall attitudes towards in-person vs. online are summarised in the bottom row of Table 4.2. Overall five students explicitly preferred in-person to online (Maria, Simon, Jay, David, Amy). James and George were neutral on both in-person and online, i.e. there are pros and cons to both; this means that they do attend online by choice, but they do experience problems online; they do also attend in-person with positive

outcomes, but there are also negatives to in-person. Helen was negative about both modes. Overall these responses are inline with the statistical results I obtained in my preliminary research.

When interpreting Table 4.2 it is important to note that negative emotions are not necessarily bad. This is why, despite each row having an explicitly positive or negative meaning, I have also coded each cell as positive or negative or both. This is most relevant to Amy and David who expressed the positive aspects of negative prospective emotions, such as anticipatory relief. Otherwise positive emotions correlated with positive experiences/outcomes; and likewise negatives.

CHAPTER 5

Discussion

This Chapter analyses the results from arts-based focus groups that were presented in the previous Chapter. The starting point for analysis here is that the preliminary survey, described in the Introduction, showed a strong preference for in-person tutorials, but could not distinguish between the complex reasons for these preferences.

The arts-based focus groups identified the same trend of preferences for in-person tutorials, indicated on the bottom row in Table 4.2. There is also broad agreement in recent literature with the diagnosis of in-person preference (e.g. Nguyen et al., 2021; Nishimwe et al., 2022; Price Banks and Vergez, 2022). The triangulation of data on overall preferences provides basic confidence in the arts-based research method to provide results that are a good indication of how some of our students feel. The sample of eight, from a population of 200, it is not expected to be statistically representative and the research is still qualitative in its nature.

In this Chapter I use five themes to analyse the results of the arts-based focus groups. The order of these themes is from the highest confidence but most semantic analysis of the results, moving gradually to rely more on inference but also analysing deeper (latent) issues.

I begin with a review of the emotions that are behind the well-established preferences and then discuss the diversity of personal needs that students have. My deeper analyses are on student perceptions of knowledge and the role of confusion. Finally I present a solution-orientated discussion of the Socratic method and its role in developing reflection-in-action in students.

As a reminder, the research question is

> What is the student experience of in-person vs online tutorials, and what is the role of tacit knowledge in this process?

5.1 Joy and frustration are behind the preferences

The arts-based focus groups I have presented provided a deeper insight into the personal experience of each student. I could identify the emotions behind their preferences and found that in many cases, although a student 'preferred' in-person on balance, it was not a wholly positive or constructive experience. Overall preferences seemed to derive from a cost/benefit trade-off that I have tabulated in Table 5.1.

	Pros	Cons
In-person	Social support (Enjoyment, gratitude, flow)	Distraction, poor use of time (Frustration)
Online	Access, focus, flexibility. (Relief)	Disengaging, lonely. (Frustration, anger, boredom, hopelessness)

Table 5.1: Pros and cons of in-person and online modes. Associated emotions in parentheses. The relative weighting of pros and cons is personal and also depends on group dynamics within a particular tutorial.

Benefits of in-person In my arts-based focus groups all students appreciated the benefit of receiving help from peers to resolve small matters of confusion in in-person tutorials. It's a strong positive effect, but it's a fragile balance to achieve.

> Daivd: "some of them it's just sit down silent. Get work done. And then the numbers in those tutorials just slowly dropped off."

Although the benefit is positive, it is not always present and there is an aspect of randomness about group allocation.

Almost everyone — except perhaps George — also appreciated the general well-being aspect of socialising in tutorials. Emotionally, the positive aspects of in-person tutorials are experienced during the activity as enjoyment. After the activity they experience joy and gratitude. These are the pros of in-person tutorials in Table 5.1, to be traded off against the cons.

(a) Helen

(b) James

Figure 5.1: Students in the room.

Drawbacks of in-person Distraction by peers when in-person was the main drawback but it was moderated by personality. Maria and Simon felt *more* motivated and focused in the presense of their peers. James and Helen expressed frustration at the distraction that peers created (Fig 5.1). James traded this lack of 'productivity' off against the benefits to his well-being from socialising. Helen did not see such a trade off so was only negative about in-person tutorials. George had an incompatible group in one case, but in another group he achieved flow. Overall the relative effect of the drawbacks of in-person study varied greatly among the students.

Drawbacks of online The strongest emotional response was the drawbacks of online tutorials. None of the benefits of in-person (enjoyment, joy, hope, gratitude) was duplicated through online learning — at least, not in my focus groups. Perhaps unsurprisingly, students who valued social interaction the most, suffered the most when using the online mode. They failed to connect to their peers and to communicate with tutors. This led to frustration and anger, and eventually to boredom and hopelessness (e.g. Jay in Fig 5.2).

Figure 5.2: Jay studying remotely: Anger, frustration. Impatience. What am I doing?

Benefits of online The benefits to working online were expressed as a lack of negative effects. The lack of distractions allowed focus (although some students were more distracted at home); the lack of need to travel enhanced accessibility; and the ease with which students can disengage

provides flexibility.

Not all of the perceived benefits of working online necessarily served the students' interests. For example, the ease with which one can disengage is perceived as positive by a student if the lesson is not engaging; or if the student is not prepared; or if the student is not motivated. However, while the ability to 'switch off' is convenient in the short term, the need to switch off can be a symptom of a deeper problem; to which the online mode is not a solution.

There was nevertheless one arresting example of the benefits of online learning, which was George's ability to put his 'burning brain' in a 'swimming pool', i.e. to escape the hyperstimulation. I have even met students outside a lecture theatre saying they're looking for somewhere quiet to watch the lecture — live, online, in the same building. The dilemma for us as teachers is how we can meet the contrasting needs of different students. Some need an imperative to attend and engage; others need the flexibility. I will return to the theme of individuality in Section 5.2.

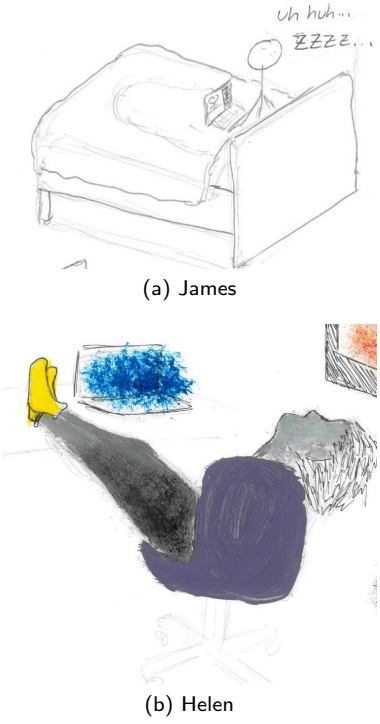
The analysis so far has made valuable use of Pekrun's table as an instrument in identifying emotions. All of the 18 achievement emotions listed by Pekrun were detected. Some were more common that others, partly due to actual prevalence but partly due to cultural issues, for example students were likely reluctant to express pride to their teacher or peers in the focus groups. The broad lack of 'hope', which was only expressed by Amy (and only then rather implicitly) is likely connected to the extensive hopelessness that I detected.

Pekrun's table was useful but not a complete list of student emotions. It seemed well suited to the in-person experience, but only partially suitable to describe online experiences.

My focus groups also identified emotions that are not in Pekrun's table. Some key emotions, or affective states, that students expressed about both online and in-person, but were not directly available from Pekrun's table were:

- Distraction. I mapped this onto frustration (AX).
- The liminal zone, partly sleeping, partly listening (Fig. 5.3). I mapped this onto Boredom (A0).
- Flow. Similar to, but distinct from, enjoyment (A+). cf. George in design week (p. 97).
- Motivation and focus. Difficult to map onto Pekrun. cf. Amy's response to the classroom.
- Epistemic emotions, especially confusion. (see Section 5.4)

We could add these extra emotions, or affective sates, to the list that we consider relevant in any future work. With the successful use of Pekrun's table that I have demonstrated here, and the additional states that I have detected, we could consider carrying out a large scale survey to probe



(a) James

(b) Helen

Figure 5.3: The liminal zone.

the student experience in tutorials. This would provide validation of the results provided here, which are only for a small sample. If it were a regular survey, it would serve to evaluate any interventions that we try to implement.

The emotional state of a student is not just important from a well-being perspective. Modern neuroscience shows how our emotional state governs how we filter sensory intake with the reticular activating system (RAS).

> "During fear, sadness, or anger ...the reflective, cognitive brain (prefrontal cortex) does not receive the sensory input of important items, such as the content of the day's lesson"
>
> —Willis (2010, p.50)

The students recognised this effect. David's 'Gaudi wall' in his brain is a graphic example of the filters we experience. We need to create an environment where each student is in an emotional state that promotes learning. The results summarised in this Section give a new level of granularity on the emotions that students experience; it provides us with a vocabulary to use in any future inquiry into emotions in tutorials.

5.2 Students have individual needs

Student art work has enabled me to tell personal stories. The viewer connects with the student on an emotional level and gains insight into habitualised, tacit experiences. This effect has also been articulated by other researchers, for example

> [arts-based research is used] "to capture and express ambiguities, liminalities, and complexities, to collaborate in the refining of ideas, to transform audience perceptions"
>
> —Greenwood (2019)

Regarding transforming audience perceptions, there is a profound individuality to each student's art. Even when student preferences or character traits appear to be similar, their art is unique and conveys important differences in their personal experience. Statistical approaches and direct interviews/focus groups do not detect such a depth of individuality in the cohort.

To highlight the uniqueness of all students, despite any attempt to categorise them, consider the stark contrast between Simon and George. Both students have ADHD and on paper have many other similarities. But they have polar opposite preferences, stemming from dramatically different personal dispositions.

Although Simon and George offer the most arresting example of diversity because their ADHD categorisation leads to presumptions of similarity, in fact this example is just a window into a broader issue.

For example Helen and James both find themselves in a liminal zone between sleep and study when online; but their response to distraction in-person is different.

In another example, Simon and Amy both get distracted at home and prefer in-person; but for Simon it is the social element in-person that works for him, while for Amy it is the ambience and simplicity of the room.

As teachers who care about our students we recognise this individuality and the challenges it poses. It is an important, but not a new, problem:

> "we are not all cast in one fixed mould and cannot all be made alike; educational rules must necessarily be made infinitely elastic and educational success can only be achieved by the elastic administration of rules."
>
> — Armstrong (1910, p.2)

What is new in the research I present here is the artistic expressions of the students. This format bypasses any analytical response or prejudices in the viewer and helps them connect on an emotional level. This tacit knowledge of the student conveyed through the art is in contrast to a formalised expression using agreed language. The emotional connection brings home the importance of a full consideration of equality, diversity, inclusivity, and belonging in our teaching.

A report by the Higher Education Academy (HEA) distinguishes four dimensions of diversity in students: educational (background), dispositional, circumstantial, and cultural (Thomas, 2010, p.5). The research here contributes to a qualitative understanding of dispositional diversity.

The stories I have uncovered here show a rich dispositional diversity in a group of students where it would be tempting to group them by common categories such as gender, ethnicity, academic achievement, and neurotype. The artistic approach used here has resisted such categorisation and shown that that it is not relevant to personal preference in learning. It reminds us all that equality, diversity and inclusion is not about minorities. It is not a question of spending large resources on a small number of people with special needs. Diversity is about the unique contribution that we can all make if we are accommodated in a way that caters to our personal needs. While extreme cases of minorities may be the ones that catch our attention, in fact all students have unique needs.

The response of educational institutions to the dispositional diversity of students can, according to the HEA report, consider four dimensions: management, curriculum 'content', pedagogy, and assessment and feedback. I will respond to the last three of these four points as I continue my discussion.

A relatively recent and popular response to the need for inclusivity is 'Universal Design for Learning' (UDL) promoted by Rose and Meyer (2002, 2006). There is a significant literature on UDL, including a meta-study showing positive results (Capp, 2017). The positive results of the meta-study are unsurprising due to the natural publication bias in education — the greater propensity to publish positive outcomes. Capp (2017) also acknowledges that there is a lack of cases with both pre- and post-methodology-change tests.

It is questionable, anyway, what such studies should really test. According to the arguments I will develop in this Chapter, traditional knowledge-oriented learning outcomes are not necessarily what we should be assessing. However, I will recommend that my colleagues and I look into the UDL literature further as there may be practical approaches that we can learn from.

5.3 Students do not perceive personal knowledge

My position when I conducted the arts-based focus groups was informed by my preliminary research where I detected student expressions of 'something else' happening in-person. I thought that the preference for in-person tutorials might be due to the better communication of tacit knowledge.

Student perceptions of knowledge were not expressed directly — perhaps because students rarely reflect on the nature of engineering knowledge — so it required inference to detect their perceptions.

James expressed his perception of knowledge in two ways, both of which suggested that knowledge, or 'content' as students refer to it, is formalised and objective in its nature. Firstly, with his concrete drawings (p. 45) he had the same verbal expression ('uh huh') in both online and in-person modes.

> James: "'uh huh' in both cases means I'm getting the same content; in the bed I'm just asleep."

James' comment suggests that the 'content' does not depend on the mode of learning.

In his abstract drawings (Fig. 5.4), James drew six shapes that persisted in both modes of tutorial. James was non-committal in his explanations of the drawing,

> James: "The shading of the shapes may indicate something. Not entirely sure what, but it is something yeah."

I learned more by asking if he had a preference over the two modes,

> James: "I would appreciate no lines going through my shapes, so maybe the top."
> Me: "OK, so that's like, interruptions?"
> [James is not direct in his answer]
> Me: [on the contrast] "Is this anything to do with the academic content, or is it entirely unrelated?"
> James: "The academic content is the same. I guess that would be why the general shapes are kind of similar".
> Me: "There's six in both cases. That could represent academic content."
> James: "I guess so. I don't know what I drew."

There is ambiguity in James' expressions. But he is clear that the content is invariant to the learning mode. His responses to my questions, focussing on the content, suggest that the content 'is' the knowledge.

Maria also provides some insight. She expressed the knowledge in her drawing explicitly as lists of formulas that either did or didn't 'go in' to her brain depending on the mode (Fig. 5.5). It would be harder to draw the tacit component, so it is arguable whether Maria really perceives the formalised version as the entire curriculum; but her expressions are suggestive that she perceives the knowledge as formalised and objective.

One of the reasons for not having more evidence on perceptions of knowledge is because the students focussed so heavily on their own struggles; on their self-efficacy or 'action-control'. This emphasis was justified by George

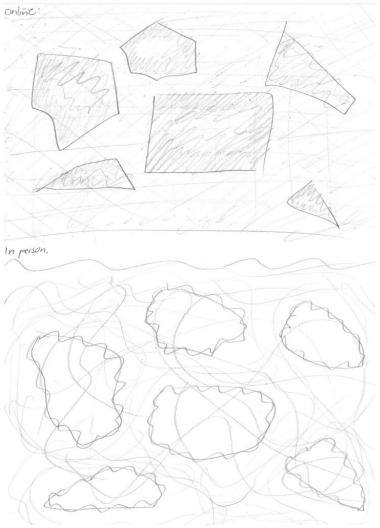
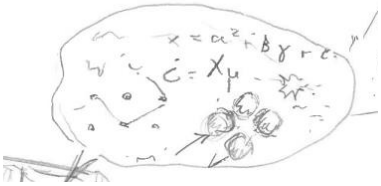
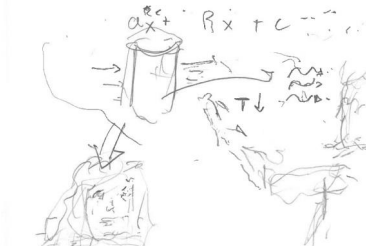


Figure 5.4: James' abstract drawing. Top: online. Bottom: in-person.



(Online)



(In-person)

Figure 5.5: Maria's representations of the curriculum.

> George: "I think part of the reason for that is because it's the thing that we feel like is in our control"

The fact that the knowledge is not perceived as controllable is more evidence of a perception of formalised, objective knowledge.

There was no sense in any of the artistic expressions or conversations that the knowledge itself may have a personal nature or that there is something personal to learn from the tutor.

Does this mean there is no tacit knowledge learned in the classroom? No. For example, Maria clearly connected with the tutor in-person. "I just can visualize it more when it's in person, like someone just talking to you." She is picking up a lot of tacit knowledge in the classroom. But in terms of her perceptions, she didn't give any hint of perceiving the knowledge as personal.

In contrast to my expectations, then, I could not find evidence of students learning something more tacit from the tutor. This issue transcends the online vs. in-person question and asks a deeper question about the education we provide.

Such a focus on the explicit tools that engineers need has some justification. Working knowledge is important. Schön calls this the 'stuff' of inquiry.

> "Skills in the manipulation of media, languages and repertoires are essential."
>
> — Schön (1983, p.271).

Practising is important. Ericsson, Krampe, and Tesch-Römer (1993) articulated the role of 'delibrate practice'. It is hard work. Student expressions of this struggle remind me of how hard it is just to get all the work done. This is the unavoidable truth of learning a discipline and we must not forget this struggle as teachers.

There is something more to our education, however. Underlying all of the curriculum, syllabus, learning outcomes, theories, equations, homework problems, and deliberate practice, is a deeper idea that there is such a thing as an engineering 'attitude'; a way of thinking and being. I will use Schön's term 'reflection-in-action'.

Essentially, in addition to practising the methods necessary to be an engineer, students also need to practice *being* an engineer. I made this point in the literature review and I have listed some conceptual ideas in Table 5.2 to highlight the distinction

Knowing	vs.	Thinking
What	vs.	How
Knowledge	vs.	Mindset
Methods	vs.	Problems
Convergent	vs.	Divergent
Formalised	vs.	Tacit
Deficit	vs.	Development
Action-control	vs.	Attitude-control
Failure	vs.	Learning
Transaction	vs.	Reflection
Product	vs.	Process
Epistemology	vs.	Ontology
Homogeneous	vs.	Diverse
Prescription	vs.	Choice
Outcomes	vs.	Attributes

Table 5.2 Different emphases in education.

A good education is a balance of both sides of Table 5.2. Intimacy with the left hand side — formalised, knowledge-orientated ideas — is necessary to become an engineer; but that is all in service of the right hand side, which is the essence of what we really want students to develop. Students in my focus groups and my broader practice are heavily focussed on the formalised description of their education, i.e. on the 'curriculum'.

The literal meaning of 'curriculum' is the full course of the student experience. Smith (1996) describes an evolution of interpretations of curriculum from knowledge oriented (transmission), to learning outcomes (product), to personal development (process), to social purpose (praxis).

The students, and most of our stakeholders, seem to view the curricu-

lum as a product, which is represented by the left hand side of Table 5.2. My view of education, grounded in the epistemology that I discussed in the literature review, is represented by the right hand side of Table 5.2.

The foregoing tension that I have identified has led me to challenge my own assumptions. I have, until now, implicitly assumed that curriculum is above pedagogy in a hierarchy of education. In other words, first we choose *what* to teach and then we optimise *how* to teach it.

What I realise now is that the how *is* the what. The pedagogy *is* the curriculum. The knowledge is not central. The process is central. The tacit knowledge of how to think is what we really want students to learn. This is problem solving (as opposed to technique mimicry), and even better, problem *framing*.

Problem-orientated education is common, for example the literature is rich with references to 'active learning' (e.g. Michael, 2006; Prince, 2004) and problem-based learning (PBL, e.g. Savery, 2015). However there is still an implicit assumption in that literature that curriculum begets pedagogy; they are changing pedagogy and/or changing the curriculum, but it is still knowledge-orientated. Problem-based learning is used to achieve better learning outcomes, not to change the goal of the learning.

The 'Conceive Design Implement Operate' (CDIO) approach of M.I.T., that has been used in 100 other institutions, recognises that knowledge is just one component of an engineer (Crawley et al., 2014). Their syllabus and supporting literature does make hints, especially in their 'Contemporary challenges' (Crawley et al., 2014, p. 249), at the need to define the attributes of an engineer, such as to frame problems and to adapt knowledge to new problems.

The concept of 'habits of mind' as a goal of education began with studies of mathematicians (Cuoco, Goldenberg, and Mark, 1996) and is epitomised by (Lockhart, 2009; Nathan, 2012). It was extended to scientists (e.g. Gauld, 2005), and has more recently been applied to engineers (Lucas, Hanson, and Claxton, 2014). The latter study surveyed expert engineers and articulated the habits of mind of an engineer:

- Systems thinking
- Adapting
- Problem-finding
- Creative problem-solving
- Visualising
- Improving

These habits of mind of an engineer are compatible with all of the following: part 2 of the CDIO syllabus v2.0 (Crawley et al., 2014, p.19); the concepts I listed on the right hand side of Table 5.2; the Imperial Graduate Attributes; and with the theory of reflection-in-action articulated by Schön (1983), which in turn draws heavily on tacit knowledge as articulated by Polanyi (1958) and identified in engineering by Vincenti (1990).

Aligning pedagogy with the attitude, habits, and mindset of the relevant profession is called 'signature pedagogy'; in our case the concept is that the pedagogy should mirror the engineering mindset (Shulman, 2005).

To summarise this Section, I was looking for student perceptions of tacit, personal knowledge in engineering but could only find evidence that they perceive engineering knowledge as formalised and objective; knowledge — as opposed to attitudes, mindset, and 'thinking' — is central to their efforts. This perception is not compatible with an engineering 'signature pedagogy' that aims to develop reflection-in-action. In the next section I will explore the implications of student perceptions of knowledge.

5.4 Confusion needs resolving

Engineering students study complex theories. The content is often confusing. In the focus groups students painted a picture, literally and metaphorically, of a constant battle with confusion. Direct expressions of confusion[1] are rare but confusion can be inferred from other expressions (D'Mello and Graesser, 2014, p.294). I often inferred confusion from student expressions and confirmed my interpretation with them. For example 'when you feel confused, is that a negative feeling or a positive feeling?'.

[1] E.g. Maria's comment that I used as an example on p. 33 in the methodology

> David: "I don't mind being confused. I just mind being confused and knowing that I'm not going to be unconfused later."

The prospects of resolution have a big impact on students' experience of confusion. Working remotely made confusions harder to resolve; working in a collaborative atmosphere raises the chance of resolution.

Confusion arises due to an incongruity (D'Mello and Graesser, 2014). Incongruities can arise in a lecture, or when studying either in a tutorial or elsewhere. The daily confusion that students experience is often on a small scale, i.e. not meeting the 'transformative' definition of a 'threshold concept' (Meyer and Land, 2006; Meyer, 2008)

D'Mello and Graesser (2014, p.299) developed a model of states that they have detected when experiencing confusion. The model is illustrated in Figure 5.6 and shows that confusion is a state of 'disequilibrium' which can be either resolved or, if not, it leads to frustration; and eventually boredom and disengagement. This model encapsulates the experience students expressed to me in the focus groups.

In theories of confusion, individuals can regulate their state with strategies that modify the context (select a different situation, or modify the situation) or regulate the response (D'Mello and Graesser, 2014). As an example of modifying the context, a student may choose to attend, or not attend a tutorial, and indeed they chose not to attend online tutorials — as illustrated in the preliminary survey.

Confusion is an important part of learning — it is not something we wish to avoid. However, the model of D'Mello and Graesser (2014) and David's comment both emphasise the importance of timely resolution to confusion to avoid the risk of disengagement. In other words, students need feedback. Disengagement is a symptom of a lack of feedback.

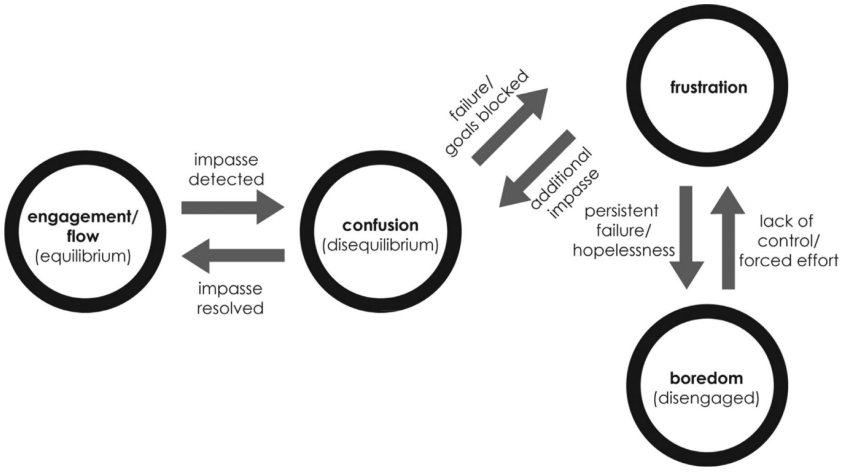


Figure 5.6: A model of states and changes of state around confusion, reproduced from D'Mello and Graesser (2014, p.299).

Confusion is a background hum in our students' lives. It cannot all be resolved by questions-and-answers in tutorials. The combination of the constant confusion and a perception of knowledge as objective and invariant leads students to develop a 'deficit' model of knowledge.

The deficit model based on objective knowledge leads to the 'problematisation' of confusion; i.e. confusion is viewed in a negative way. The student goes to a peer or tutor with a 'question', the currency of learning, and the tutor exchanges it for an answer. The deficit is partly alleviated. And the process continues. One can never fully catch-up; one can only ever hope to avoid slipping further behind.

If a student disengages then they become *behind*. In their own words, they are no-longer 'up-to-date'. Whether or not the cause is an unresolved confusion, or disorganisation or lack of effort, in reality the state that most students experience is not up-to-date. It doesn't take many disengaging events before students are so far behind that they are never likely to catch up. My own work with an online homework system (Johnson, Lock, and Ramsden, 2020) shows that the vast majority (about 75%) of students are at least one week behind in the subject that I teach. The students maintain their work at the rate required, even catching up slightly over the Christmas holidays, but their day-to-day experience is of not being up-to-date.

Helen provides an example of how this feels as the sun goes down, after a day of online learning (see art on p.49),

"I've been trying to work all day, but I've just not got anything done"

It is a sense of shame and it is demotivating. Alternatively maybe the student feels frustration and anger like Maria and James described online. In both types of responses there is a sense of failure. A 'deficit' mentality develops. 'I am behind'. 'I'm not up-to-date'. Confusion doesn't have to be a negative experience, but for our students it usually is. This is why the students express hopelessness.

To summarise this section, confusion is part of the daily experience for students. Their view of knowledge as formalised and objective leads them to see confusion as being resolved through asking questions. When

this process fails their 'deficit' model of knowledge means they are 'behind' — not 'up-to-date'. This constant feeling of being behind leads to hopelessness.

Although the students view knowledge as central to their studies and being 'up-to-date' as the main goal, there are alternative approaches to avoid this problem; that is the focus of the next Section.

5.5 We need to promote reflection-in-action

The concept of being up-to-date is symptomatic of an over emphasis on the left-hand-side of Table 5.2. If we measure ourselves by the 'what' not the 'how'; if our goal is to know; if we want to tick a box of a list of formalised knowledge and methods; then we can measure our status and identify a *deficit*. The deficit in knowledge means we are not 'up-to-date' if we have unchecked boxes. If there is any confusion, it is a barrier that must be overcome, lest we fall behind. Confusion is negative in this paradigm.

The alternative is to focus on the how; on thinking; on mindset; on approach to problems. These are tacit concepts, captured by Schön's reflection-in-action model. You can't be 'up-to-date' or behind with this approach. Confusion is a positive, welcome part of the experience embraced as stimulation to reflect-in-action; it is an opportunity to develop. Tutors are people to relate to; to share the journey with; to connect to. We aspire to attributes and not outcomes.

Some students are not open to this type of stimulation in tutorials.

> Me: "There isn't much sense of your tutor asking *you* questions. [...] Like 'what if we didn't make that assumption in this particular problem or question? What would happen then?'"
> David: "Sometimes the prompting to think could make it less engaging. [...] I've got no clue whats happening. I'm just tuning out"
> Helen: "That's because the answer isn't part of the course. I don't care, right?"

David is expressing that if he is already confused, then questioning him will cause more confusion and he will disengage. Helen even goes so far as to say that such an activity is outside the scope of the course — confirming that stimulation to reflect-in-action is not what some students consider to ever be within expectations.

Some students are, however, open to stimulation to reflect-in-action; to challenge their knowledge, embrace confusion, and develop a healthy mindset. To illustrate this point, consider my tutorial arrangements where I provide a choice of activity in parallel rooms: unstructured Q&A with a tutor in one or, in the other room, a structured tutorial that is more stimulating.

> Me: "Which ones do you go to?
> Jay: "I'm like I've gone to the structured tutorial a few times, but I've also gone to the non-structured tutorials, depending on how up-to-date I was. So if like I feel alright with this topic but I want to learn a bit more about it [...] I just go straight to the structured tutorial. OK, but if I'm a bit behind I'd rather focus on finishing everything before making sure I know that some of the ..."

> Simon: [interrupts] "I prefer doing one by one [tutorial sheets in order] and not kind of jumping around."
> Jay: "yeah exactly."

Here Jay and Simon articulate their openness to incongruity — but with the critical caveat that they must be up-to-date first.

This caveat was identified by Vogl et al. (2020): epistemic emotions (surprise, curiosity, confusion) only arise if the incongruity is in *high confidence* knowledge. To our students, this translates to being 'up-to-date'. If a student is not up-to-date then they are not confident in their knowledge because they are aware of their own lack of knowledge according to the standard that we set.

The problem at Imperial seems to me to be:

- Students see knowledge as a central goal and as objective in nature
- Lack of feedback leads to gradually becoming chronically 'behind' in knowledge accrual
- Being behind causes a lack of confidence
- They are not open to stimulating questions because it causes extra, unwelcome confusion
- They avoid chances to develop reflection-in-action
- They will only be open to stimulation, confusion, and reflection-in-action if they feel up-to-date

The above framing of the problem has two critical points: firstly, students need more feedback. Secondly, reflection-in-action and an engineering mindset will only be successfully learned when students recognise this as the goal and practice it regularly. The second point depends on the first point because quality feedback to increase confidence, motivation, and positive emotional states is a pre-requisite. The second point is then a question of culture and values.

The first problem, of feedback, probably raises, in most people's mind, the idea of marking homework. That would be a very labour intensive solution and may not even succeed. We need to explore exactly what feedback would be adequate to keep students moving.

The Oxbridge tutorial system provides a useful reference point. They require students to complete their work before attending, and set the expectation that students will be challenged. This ensures that there will be some high confidence knowledge, solving the 'up-to-date' problem.

On the second point, following Schön's argument, we could define the purpose of a tutorial as a means of inducing the process of reflection-in-action. In which case it would need to involve stimulation by incongruity, and a conversation involving divergent thinking.

The Oxbridge tutorial[2] seems to inherently nurture reflection-in-action in the sense of Schön. Through a trusted relationship between student and tutor, the tutor asks challenging questions. These questions create the uniqueness of the situation; the student is stimulated by a change from the (tacit) norm, and must reflect on their knowledge.

[2] 'Supervisions' at Cambridge.

The Imperial model that my students describe seems to be a more knowledge-deficit orientated paradigm that is less reflective regardless of the mode (online vs. in-person). The questions are primarily from the student to the tutor, so within the norms already accepted by the student. The question is posed as an explicit problem and the discussion revolves around formalised knowledge, for example 'why do we use the such-and-such method', or 'why is this assumption applicable?'.

The Oxbridge system creates an environment where the 'Socratic method' of tutor questioning student is feasible. The questioning *is* the feedback. Brownhill (2006) reviews the Socratic method in two forms. The 'non-autocratic' approach by Socrates himself, is "not so much concerned with the immediate task in hand but with an attitude to life itself" (p.72). The autocratic approach, which Plato idealised is where "the teacher has knowledge, students are manipulated so that they will look at the world through the teacher's epistemological spectacles.". The Oxbridge system uses a combination of the non-autocractic and autocratic Socratic methods. This is how students emerge saying they learned 'how to think'.

It may be unwise to suggest that the Oxbridge system should necessarily be implemented at Imperial as a solution to this problem. Firstly, it is not a practical solution as we lack the Collegiate system and the cultural inheritance. Secondly, the system is not without its problems. Ashwin (2005) reviews the variation in student experiences; Bradbury (2012) criticises the superficial nature of Oxbridge tutorials; it generates a dependence and does not empower students to manage their own studies as we do. Quality control is also very difficult with such a personalised tutorial system. Moore (1968) provides a more in-depth analysis.

We should look for our own solution at Imperial that respects our culture and heritage; and is built in the modern context of high student numbers, intense stakeholder management[3], the diversity of student dispositions, the heterogeneous culture of our intake, and the possibilities of modern technology.

[3] Teaching Excellence Framework (TEF), The Quality Assurance Agency for Higher Education (QAA), Office for Students (OfS), National Student Survey (NSS), unions, league tables.

The Socratic method has always had a place in education, including the ancient Greeks, the Oxbridge tutorials, Armstrong's method of discovery, and Vygotsky's ZPD (zone of proximal development). These are all methods to push a learner into a zone of confusion, but ensuring that the confusion can be resolved so that it is a productive learning experience. We need to find our own way to do that.

Willis (2010) reflects on how effective computer games are at making challenges compelling. The game "does not give prizes, money, or even pats on the back, yet it remains compelling" (p.49). There are conditions in which students will be motivated to study and to embrace confusion. It requires the right emotional response, and for challenges to be tuned to the level and timing that works for the student.

We should aim to create a positive working environment and culture that will stimulate a positive emotional response that will prime students for a challenge.

My first recommendation is that we implement a choice to students in tutorials so that they can meet their needs at the time. I have successfully piloted this approach for three years in one module and I recommend that

it is used across the cohort.

My second recommendation is that we develop technological solutions to providing rich, timely, personalised feedback on homework to help students stay up-to-date. Students express a desperate lack of feedback in their studies. Automated feedback helps resolve micro-confusions during study to ensure students can complete homework assignments. It also means they can come to tutorials with more conceptual questions that may lead to higher quality discussions.

Automated feedback can also provide motivation in the style of a computer game (Willis, 2010). Although such a suggestion may lead the reader to think of 'serious gaming' (see Qian and Clark, 2016), there are very simple and effective techniques. For example implementing a 'mark as done' feature on online homework, where students can mark for themselves a task as done, has been very popular.

By using an online system, we can use data analytics to monitor student 'up-to-dateness' and target interventions to offer the right type of support at the right time. The role of software is not to replace the teacher, but to do what the tutor cannot do, and enhance the value of the tutor in the classroom — to move from answering questions to asking questions. The rule in the room for tutors should be 'ask don't tell'; not because answers are secret, but because answers can be automated but modelling reflection-in-action is a job that only people can do.

The foregoing recommendations are useful by being concrete, but they do not address the fundamental cultural issue. We need to reflect on the diagnosis that I have made here. Our model of curriculum, as interpreted by students, is causing a toxic environment where students are 'behind' and closed to the benefits of incongruity and confusion, and as a result have a fixed mindset. This is a symptom of our 'curriculum' and we need to explore how to create a culture more around exploration and less around knowledge. Some basic changes will help, such as an emphasis on the 'why'; rewording learning outcomes; changing exams. But it is a cultural challenge and the main contribution of this dissertation is to help frame the problem, rather than to solve it.

5.6 Applicability and limitations of the study

The preliminary research revealed a clear preference for in-person tutorials. The sample size was large (more than half the population in the case of my department), and consistent with changes in attendance. The results were also invariant to department based on the six (out of a possible 10) that participated. Other large scale studies have also replicated the result. These are robust conclusions that have good generality. However, these conclusions are limited in their depth — they do not explain the findings.

Survey data is also limited to a snapshot in time. My original large scale survey (n=1610) was in summer 2021 before students had a full 'in-person' option, so we would need to repeat the survey, for example in summer 2022, to see if these preferences persist.

Surveys only answer the questions that are asked. The subsequent focus groups showed that there is complexity to preferences and that a

'preference' is on the balance of pros and cons, rather than being a binary issue.

The focus groups are limited by the size of the sample and yield qualitative results. As stated in the methodology, the art is open to interpretation. The findings are not unique, especially the emphasis that I make when interpreting the art. The results are therefore, in the form presented here, not generalisable. The use of the results presented here are limited to the following cases:

1. To help the reader make an emotional connection to the student experience and inspire them to consider student emotions in teaching and learning activities.

2. To indicate the types of emotion that might be considered in any further studies on student experience and learning.

Additionally, I have made a case for more feedback to students, and for a cultural change to consider 'thinking' as well as 'knowledge' as the aim of education. These ideas come from my experience in Mechanical Engineering, but specifically with second year students. Mapping to other years of study will require nuance, for example the importance of transition in the first year; career perspectives in the last year. Although I restricted my attention to Mechanical Engineering, the principles apply across other engineering disciplines too. They may resonate with teachers in other subject areas too but that is not something I can currently judge. The case I have made for more reflection-in-action is my opinion. It is based on my interpretation of the students that I know, including those who I have discussed here. It is not a conclusive point and is open to debate.

CHAPTER 6

Conclusion

6.1 Summary

This dissertation was motivated by the unique post-lockdown opportunity to compare online and in-person tutorials. Preliminary research, from a large scale survey and small focus groups, showed a strong preference for in-person tutorials. The reasons for the preference were too complex to be explained by the survey. Preliminary focus groups yielded some insight, for example the 'transactional' vs. 'pastoral' paradigms of online or in-person respectively. However, a problematic aspect of the preliminary focus groups was the student sense that 'something else' — something tacit — was happening in-person, but they found it difficult to articulate. The research question was therefore

> What is the student experience of in-person vs online tutorials, and what is the role of tacit knowledge in this process?

In reviewing literature I made a case that engineering knowledge has a strong tacit component. In fact, it is closer to a way of thinking and being than it is to a set of formalised principles or methods. This conception of knowledge as personal, and its acquisition through indwelling, is compatible with the emerging neuroscience that shows learning to be an emotional process. Emotions of particular interest are *achievement emotions* and *epistemic emotions*. Of the latter, confusion in particular is recognised as playing a key role in learning by stimulating incongruities, which in turn ideally lead to exploration, but alternatively disengagement, depending on the context or environment.

To explore the emotional experience of our own students in tutorials, and acknowledging that direct questioning would not be likely yield insight, I used an arts-based method. Students produced a work of art to express themselves. This approach led to poignant expressions that readers can relate to on an emotional level.

I curated stories of the individuals, based on their art and on audio and transcripts of the focus groups, to build a picture of their personal experience. The results, including graphic art, photos of sculptures are presented in Chapter 4 with selected quotes; a more detailed story for each student is curated in Appendix B. A reflexive thematic analysis led to five themes that I discussed in Chapter 5 and will summarise here.

Emotions behind the preferences In the arts-based focus groups the same overall preference for in-person tutorials was validated but the preferences were shown to be less clear-cut, with pros and cons to both in-person and online tutorials. Student preferences derive from the weight that they personally apply to each benefit and drawback in each mode.

Table 5.1 summarises the key pros and cons and the emotions behind the experience. In-person is popular because of the social support, but distraction by peers is a drawback for many students. Online tutorials allow flexibility but can be isolating and lead to disengagement.

Diversity and inclusion The profound uniqueness of each of the eight students involved, communicated through their art and the experience that it conveys, reminds us that a statistical approach can overlook the experience of the individual.

Perceptions of knowledge I looked for evidence that students perceive some of the knowledge they learn as tacit and personal; however the only evidence I could find was that students perceive knowledge as formalised and objective. This leads to a 'deficit' mentality with students almost always feeling 'behind'.

The role of confusion Confusion is usually considered negative because it inhibits knowledge accrual. Some students are open to confusion as a positive part of learning but only if they do not feel 'behind'.

Reflection-in-action The Socratic method, where the teacher asks the student questions and induces confusion to stimulate, is rare in our tutorial system. This contributes to a culture that values knowledge over criticality and 'reflection-in-action'.

Any change in culture, to emphasise 'thinking' over knowledge, will first require improved feedback and appropriate tutorial experiences that provide a positive emotional experience for all students.

A brief summary of this dissertation is sketched in Fig. 6.1. The conclusions I reached in this dissertation were based on research with Mechanical Engineering students at Imperial College London. Application to other engineering disciplines and institutions will likely be fruitful but cannot be assumed without further evidence.

The quantitative conclusions on preferences are broadly applicable but limited in depth. The qualitative conclusions on student experience themselves highlight how individual the experience is, so these conclusions serve to highlight key themes rather than to reach a concrete or positivist conclusion. The next step to make any of these findings generalisable would be to construct a quantitative study based on the ideas I have used here including the emotions experienced in tutorials, attitudes to knowledge, and the effect of feedback on confidence and openness to incongruity.

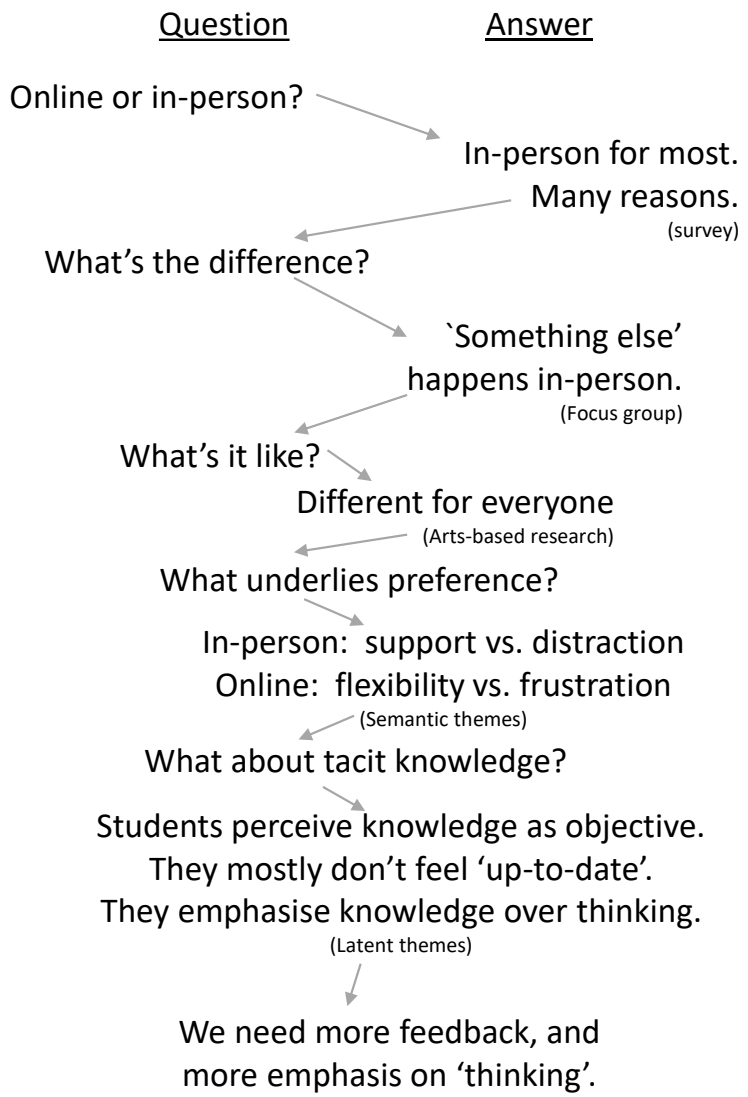


Figure 6.1: A summary of this dissertation

6.2 Recommendations

The following recommendations were made in the Discussion Chapter:

1. Pekrun's 18 achievement emotions, augmented by additional affective states that I detected (distraction, liminal zone, flow, motivation, focus, confusion) are a good basis on which to conduct further surveys of the student experience in our tutorials and related classes. I recommend compiling this survey and using it as an annual gauge of student culture. See Section 5.1 for details.

2. We need to offer choice to students wherever possible, because preferences vary depending on personality. I recommend offering a choice of unstructured or structured tutorials to all second year students. This argument begins in Section 5.2 on diversity, and continues in Section 5.5

on reflection-in-action.

3. Disengagement is a symptom of a lack of feedback. We need to dramatically increase feedback to, and monitoring of, students throughout the year. I recommend developing a basic system of automated feedback to keep students engaged (timely resolution of confusion), enhance the quality of engagement in tutorials, and help us monitor student engagement. This recommendation is articulated in Section 5.5.

4. We need a cultural change to value tacit aspects of the engineering mindset encapsulated in the concept of 'reflection-in-action'. This will be manifested as a willingness to be questioned, and embracing and enjoying confusion as a way to grow. Recommendation 3 is a prerequisuite to this recommendation. Table 5.2 compares knowledge- and thinking-orientated aspects of student culture. The current dominance of the knowledge-orientation (left-hand-side of the Table) needs to be re-balanced. This is a large and nebulous recommendation but in the first instance we could start by encouraging all academics simply to emphasise more of the 'why' behind what they teach, and the context in which it is used (problem framing, and reflection-in-action).

6.3 Personal reflections

This dissertation is the culmination of me taking some academic risks, as indeed I am imploring our teachers and students to do more often. Tackling emotion in the student experience was an intimidating task for me as I didn't have the vocabulary or experience to investigate emotion. Now, on the other side of the process, I find Pekrun's table to be a very useful lens through which to observe and reflect on learning and teaching.

The arts-based focus groups also felt risky because of the uncertainty over what I would find. My heartfelt thanks to those who participated and shared their experience so readily. The students are inspirational and it was a privilege to share the experience with them. It was deeply challenging, but rewarding, for me to try to make sense of what I found.

My own awareness of tacit knowledge has improved as a result of this project. My expressions, in Section 5.5, about curriculum and pedagogy were genuine revelations that I experienced as I reflected on my reading and the data I had obtained.

It is interesting to look back at my essays in the PGCert and PGDip and see threads of the ideas that I have expressed in this dissertation. This project has helped me develop and formalise those ideas.

When reflecting on the arts-based focus groups soon after they finished, I felt compelled to produce my own art. I arrived home one day after giving a lecture and drew the sketch in Fig. 6.2. The students, with varying levels of engagement, are distant. I'm pouring my heart out. A turbulent wind[1] from the clock on the wall blows me away — the clock hand has passed ten-to the hour and time is up.

[1] We teach turbulence!

In this dissertation I was empathising with students who find it hard to connect; in my sketch it's me struggling to connect. I think that undertaking this research has improved my connection to the students.

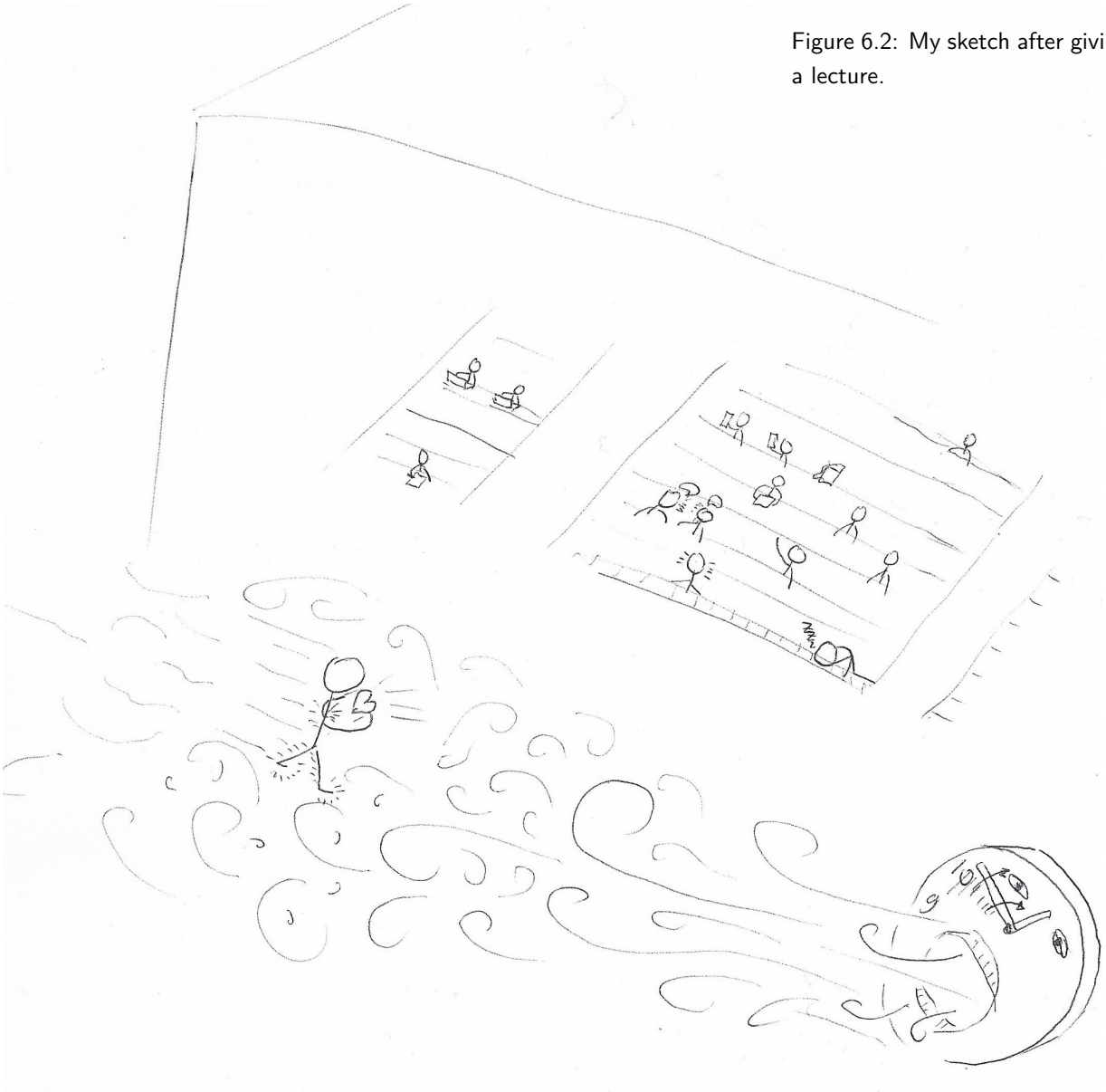


Figure 6.2: My sketch after giving a lecture.

APPENDIX A

Preliminary research

A.1 Survey overview

I coordinated the survey in collaboration with an academic from each of departments involved. Each academic reviewed the survey questions that I drafted, and the same academic in administered promoting the survey in their own department (within the constraints of the ethics approval).

Students were contacted by email after their exams were complete and asked to follow a link to the survey. Vouchers were randomly allocated to participants who clicked a link at the end of the survey to sign up for the voucher lottery.

Response numbers are given in Table 2. Response rates depended on the timing, departmental context (e.g. Timing of other surveys, timing of end of term, general culture), and number of emails sent. Departments also have different size student populations so total response numbers are different from response rates. I do not currently know student population sizes in other departments but in Mechanical Engineering it is in the vicinity of 700 so the response rate is over 50%.

Department	Responses
Mechanical engineering	481
Chemical Engineering	140
Bioengineering	214
Aeronautics	123
Materials	161
Computing	344
Other	32
Total	1610

Table A.1: response numbers from the survey. In Mechanical Engineering in particular, of the 481 responses, about 432 followed through with answers to initial questions. There were 25 questions and the response rate dropped steadily through the questions, ending at around 380 responses in the final questions, which is over 50% of the students in the department. I do not have the total population size for the other departments.

Students were represented proportionately in the following senses:

- Year of study (1,2,3,4, MSc)
- Location (outside UK, in UK far from campus; in UK near campus)
- Origin (UK, EU, international non-EU)
- Gender

Student characteristics were probed in the following categories:

- Introvert (36%), mixture (49%), extrovert (15%) according to MBTI tests completed as part of the programme (Mechanical engineering only)
- Conscientiousness (focussed, self-disciplined, well organised), which students have discussed in the degree programme. Agreement with the statement was self declared as strong (25%), somewhat (45%), neutral (14%), somewhat disagree (11%), strongly disagree (5%).
- Resilient to stress and difficult circumstances: Strongly agree 27%, 42%, 16%, 12%, strongly disagree 3%

All of the above information was associated with the same anonymous student, so we have the option to look for correlations within the data. That analysis has, mostly, not been done (yet).

A.2 Survey questions

Which department are you in?

Your year group

Which of the following best describes your location for most of the 2020/21 academic year? (In UK near campus, in UK not accessing campus, outside UK).

What was your timezone, relative to the UK?

My status as a student is (UK / EU / International non-EU)

How would you describe your gender?

How do you identify in terms of introvert/extrovert? (Remember MBTI) (Extravert, mixture, intravert)

I am conscientious (focussed, self-disciplined, well organised) (Likert)

I am resilient to stress and difficult cirumstances (Likert)

During the 2020/21 academic year, my conditions for working in my residence were excellent and just as good as studying on campus: (Likert)

Overall, compared to pre-March 2020, during the pandemic my wellbeing has been: (Likert better/worse)

Overall, compared to pre-March 2020, during the pandemic my academic learning and development has been: (Likert better/worse))

How important are the following aspects of learning for you personally? (3 point likert for each one) Social learning - learning with peers; Structured lessons (e.g. lecture or structured tutorial); Unstructured lessons (e.g. a tutorial with a tutor/lecturer, for Q&A and informal discussion); Learning materials (lecture notes, slides, etc.); A structure to my learning (timetabled sessions, deadlines); Assessment / feedback (quizzes, progress tests, coursework).

How much would you benefit from some guidance / coaching / mentoring on how to study effectively? (Drag the slider)

How important are the following learning materials to your academic learning in a typical module? Printed Lecture Notes/slides; PDF Lecture

Notes/slides; Tutorial sheet questions; Tutorial sheet answers; Tutorial sheet worked solutions; my classmates' notes; Mech Net[1]; Printed textbooks; Online textbooks (e.g. via library); Online/other resources not from Imperial; Videos of lectures that were in a lecture theatre; Videos of lectures that were online; Pre-recorded videos of lecture content.

[1] An informal network with shared documents

How often (days per week) do you want to attend campus in person?

What percentage of the various types of class session do you attend / use? Live lecture in the classroom; Recording of a lecture that was in a classroom; Live lecture online; Recording of a lecture that was live online; Pre-recorded video lecture - available in advance; Tutorial in the classroom; Online tutorial.

What factors affect your preferences for the format, and your attendance, of lectures and tutorials? It depends on the subject; It depends on the teacher; It depends on how busy I am; It depends on my motivation; It depends if I'm up to date; What my friends/preferred study partners do; It depends on when it is in my timetable relative to other sessions; It depends on the commute/weather/time of day.

What value do you get from in-person classes (lectures and tutorials) if you attend them? It gives structure to my day; It gets me out the house; Discuss academic work with friends/classmates; Socialise with friends/classmates; A reason to visit campus; Helps me focus on the subject matter; I understand the content better; In-person lectures inspire / motivate me; Live (physical) demonstrations are effective; Being in the lecture theatre gives me something tangible (sound, smell, ambience, etc.) to associate my learning to; Seeing the teacher in-person helps me relate to them and to the ideas they are sharing; The random interactions before and after being in the lecture theatre

Even when in-person is an option, the following sessions would be better online: Lectures; Academic tutorials; Design tutorials; Computer-based tutorials; Personal tutorials; Laboratory sessions; Workshop training; Supervisor meetings; Information sessions; Department-organised social events; Informal study with other students; Clubs, societies, sports, hobbies; Sports / exercise / down-time / relaxing.

If we can't offer all options in-person due to restrictions outside the department's control, which of the following do you prefer? (lectures / tutorials)

How long do you think you can concentrate for (in minutes) in a typical (In-person lecture/tutorial); (Online lecture/tutorial)

If you use recorded lectures, what speed do you use?

If you use recorded lectures, how do you watch? (Selected Choice)

If lectures are delivered in pre-recorded videos, what is the best use of the scheduled class time that would have been for the lecture? Extra tutorials: unstructured (traditional); Extra tutorials: structured, familiar problem; Extra tutorials: structured, unseen problem; Extra lab time; Extra demonstrations; Extra lectures; Don't replace the time, we need it for home work; Other

This is the end of the survey. Is there anything else you'd like to share to help us understand how this year has been and/or your preferences for next year?

A.3 Focus groups

Here is an example, told by a student, of a tutor helping in the classroom:

> "It's not necessarily a question that I had, but he just pointed me in the right direction and then moved on to the next person. But you don't have that that privilege when you're online because you have to bring the question. Yeah, there's no particular question that I had, it's just that I'm stuck on this. I don't really know what to do, he can just guide me and then move on."

Another aspect is the proximity of the tutor:

> "For me it does [make a difference], if there's someone close to me, it's more easy for me to say 'hey I need help', to raise my hand... Online I don't really feel comfortable doing that. It's not as easy online"

The contrast is also made clear by this comment:

> "in person... tutorials happen like every week every two weeks like so I kind of built like a relationship with the GTA or the tutor themselves so they get to know me. I get to know them and over time when I become more comfortable with them... But online the thing is, it's just more awkward doing that because there's twenty other people right on the same call."

The time taken to build a relationship was longer in the online context. One student was reflective on the way relationships build and how it is not purely a question of time. It is, rather, a question of 'quality time' which is possible when a small group has a semi-private conversation that helps build rapport

> "we are just doing it together always in like small group that still helped build a rapport with the tutor who's doing it ... that was the biggest difference this year."

It was important to have regular contact with the same tutor in order to build a rapport. Examples, including online in breakout rooms, where the tutor was different each time, did not permit this relationship building. Relationship building was perceived as much easier in-person:

> "It would be easier in-person. The results might be the same in terms of like work output, but you would definitely feel, at least on the personal side, like the relationship building side of things, that it was more fruitful if it was in-person than if it was online, because — I don't know — there's this something in meeting people in-person and building that relationship in person to online. It's just easier to ask certain questions to, to be curious about certain things that you wouldn't see online."

A.4 Validation

In Section 3.2 I claimed that a second round of focus groups validated my earlier findings. This section provides more detail.

As an example, referring to online tutorials a student said

> "Thing is, when you're in a teams call and everybody has their camera shut off and it's like 10 people in a room and it's just like all black, you're more hesitant to ask the question than being actually in a room and just calling the tutor so he's the only person you're actually talking to."

Another student was more positive about online; they were less hesitant to ask questions and valued the 'accessibility': "I showed up for a lot more online tutorials". This second student had what they called a 50/50 preference for online vs in-person tutorials, speaking favourably about explanations in the classroom — "it would be easier in person" — and "It's a lot easier to like collaborate".

These example results from ice-breaking discussions represent a trend where I was repeatedly able to identify the same expressions in students as I had found in my preliminary research.

APPENDIX B

Student stories

The primary purpose of this Appendix Chapter is to allow the reader to get to know the students better. It is a curated piece of work designed to tell their story. It is in the Appendix because it is too verbose to include in the Results Chapter, which is essentially an abbreviated version of this Chapter. Some content here is duplicated in the Results Chapter.

This Appendix Chapter is not the raw text transcripts, which, from 3 hours of sessions, amounted to 255 pages and 39,126 words. The text here is primarily to tell the story of the students but also serves the purpose of being an evidence base on which I make claims in the Results and Discussion. Claims in the Results are based on using a 'TA codebook'. I have highlighted each achievement emotion that I identified. The coding is based on Pekrun's table, which is reproduced in Table B.1 for convenience.

Note that the stories here are structured by sections for each student, but it is a loose structure and the priority is that the narrative flows and compels the reader. There are conversations that involve multiple students and emotions are identified in those conversations. So, for example, some of Amy's emotions are identified in the Section titled 'David' and so on.

In David's case he was central to a group conversation that highlighted most of the emotions in the table. I have attributed them to David even though he may be describing other people's experience to some extent. This is a limitation of the table orientated around the individual, but including evidence from conversations that strayed into the general — in particular with David.

B.1 Maria

Maria produced two pencil drawings, starting with the online experience and then the classroom. Her drawing of the online experience is on p. 36, and an annotated version is in Fig. 4.1. The drawing shows Maria in the third person, from behind, sitting at her desk. The laptop screen shows other students online, with their cameras off and microphones muted. This lack of interaction is a stark reminder of the isolation we all experienced in lockdown. The 'content' of the conversations is represented by a speech bubble, with symbolic notation from across the curriculum. The time period of the drawing is therefore ambiguous because on the one hand it is a snapshot in time, while on the other hand it represents all tutorials.

	Appraisals				
Object focus	Value	Control	Emotion	Tutorial context	Code
Outcome/ prospective	Positive (success)	High	Anticipatory joy	'I'm looking forward to learning'	P+1
		Medium	Hope	'I hope I will be able to learn'	P+2
		Low	Hopelessness	'I can't influence how much I will learn'	P+3
	Negative (failure)	High	Anticipatory relief	'I will solve my problems'	P–1
		Medium	Anxiety	'I worry if I'll have problems'	P–2
		Low	Hopelessness	'I won't solve my problems'	P–3
Outcome/ retrospective	Positive (success)	Irrelevant	Joy	'It went well'	R+1
		Self	Pride	'I did well'	R+2
		Other	Gratitude	'I appreciate their help'	R+3
	Negative (failure)	Irrelevant	Sadness	'It went badly'	R–1
		Self	Shame	'I couldn't focus'	R–2
		Other	Anger	'They distracted me'	R–3
Activity	Positive	High	Enjoyment	'It was fun'	A+
	Negative	High	Anger	'It was a pain'	A–
	P've/N've	Low	Frustration	'I did/didn't understand'	AX
	None	High/Low	Boredom	'It was boring/a waste of time'	A0

Table B.1: Achievement emotions, adapted from Pekrun (2006, p.320) by adding two columns. Firstly to put that work in context for this research, secondly to add a code for ease of reference later. For the code the first character P/R/A is for propective/retrospective/activity; followed by +,–,X,0 for positive, negative, both, neither respectively; and numbers are 3 categories.

This theme recurs later with other students — distinguishing time was hard when online. In Maria's case it is also an artistic expression that her experience was indifferent to the particular subjects.

There is a clear contrast in Maria's drawing between what she says in the speech bubble ('Yee, got it thanks!!!') and what is in her thought bubble ('Might as well dropout'). While drawing these parts Maria explained more in conversation with me

> Maria: "Everything is going on, it's like ..."
> Me: "So we've got some equations"
> Maria: "Everything it's Materials, Heat Transfer, Maths, ... "
> [different modules within the programme]
> Me: "OK"
> Maria: "I can't really figure it out ... they're just talking ... I'm like 'Yeh I got it thanks'"

I sense some despair in Maria's voice. The drawing continues in silence for over a minute.

> Me: "What are you finding difficult? Remembering, or putting it into words?"
> Maria: "Putting it into, yeh, words"
> Me: "So you remember it clearly do you?"
> Maria: "I remember the feeling, I'm just thinking how could I ...?"
> [express/articulate it]
> [pause for a few seconds]
> Me: "I guess it's probably lots of things"
> Maria: "Yeah. Like. It's confusion. It's getting angry at yourself for not understanding. Frustration. 'What am I doing here?'"

Maria's expression is poignant. It's hard not to feel empathy for her, and this is amplified by looking at her illustration (p. 36 and Fig. 4.1)

which helps connect to her on an emotional level. The perspective she has drawn, with no facial expression visible, creates a sense of loneliness.

Maria has identified negative achievement emotions anger (a retrospective outcome achievement emotion, out of her control, R–3; and an activity achievement emotion, within control i.e. aversive activity, A–) and frustration (activity achievement emotion, out of one's control, AX). The existential expressions are of hopelessness (negative prospective outcome emotion with low control, P–3). Epistemic emotions of confusion have arisen, but they are negative and do not lead to exploratory behaviour, but rather to reduced motivation.

Maria's first drawing has not identified an emotional or empathic connection between student and peers or tutor. Indwelling is absent and it's quite clear why — the online mode does not facilitate it for her; the faceless, muted peers, the disingenuous expression to the tutor hiding her true experience, and the feeling that she is not understood.

To appraise the research method after one work of art, Maria's first drawing has been successful in identifying frustration, anger, confusion, hopelessness, and loneliness; and, indirectly, a lack of indwelling or tacit knowledge sharing. Unsurprisingly, Maria was very negative overall about online tutorials. The drawing and discussion give us qualitative insight into why Maria feels this way.

Maria's second drawing, of the in-person experiences, is on p. 37 and an annotated version is in Fig. 4.2. The second drawing was quicker, although — in hindsight — probably only because she was keen to move on and go to a personal tutorial that clashed with our focus group. Maria reflected while drawing her in-person experience:

> Maria: "in the room [...] that's supposed to be a tutorial and there's a tutor inside and everybody has their laptop out working. That sort of motivates more being like that. I get distracted at home. "
> [Later]
> Maria: "I work better when I talk to someone. It doesn't disrupt me."

There is a sharp contrast with Maria's experience in-person. It is a harmonious experience, described warmly and passionately. Her drawing is composed differently by showing herself with a visible facial expression, and an invisible laptop screen. The focus seems to be on a conversation with the tutor, and again the content is being discussed. This time, rather than the frustration, there is an arrow showing

> Maria: [the content] "just goes into my head"
> [Pause]
> Maria: "it's just going in my brain"

The arrow, drawn in pencil, represents this notion of curriculum content going into Maria's head. It reminds me of illustrations of the much-maligned 'knowledge transmission' model — a fictional, never specifically identified, 'bad model' with which we can compare favoured educational models (see e.g. Laurillard, 2002). Clearly, Maria believes that this model works — but only in-person.

Maria was clearly in favour of in-person tutorials and spoke passionately and empathically about the connection she felt in the room. It was

quintessential indwelling, picking up something from the company of others. She has drawn the knowledge flowing from the tutor to here, but I don't think this should be interpreted as a 'transmission' model, it is simply a symbol for the effective conversations and relations that occur in the room and facilitate her learning.

Maria has expressed joy and enjoyment (P+1, R+1, A+); and a motivation to work. She has clearly identified — though mostly through her body language and tone of voice in conversation — indwelling, without naming it as such. [Check for expressions of confusion/surprise/curiosity?]

Maria came chronologically first in my focus groups and was the prototypical student I was expecting to find. She had a clear objection to online tutorials and a strong desire for in-person tutorials. In-person she thrives on the social and emotional connections she makes. These connections motivate her to work; catalyse her focus; and most dramatically, connect her to the curriculum.

None of the other students, whose art will now follow, provided such a prototypical case study. In fact, they were all different from Maria and from each other. A second student, James, began with Maria and drew at the same time and they both drew with pencils. James' first work follows on p. 45, after which I will discuss it.

B.2 James

James drew at the same time as Maria, but had a distinctly different point of view. His first sheet, reproduced on p. 45, is a pair of drawings of himself attending an online tutorial (top) and an in-person tutorial (bottom). These drawings are of concrete, material events, with some expressions added on top to capture the personal experience.

James is dispassionate in describing his experience, and reluctant to show his emotion. On his experience at home he says

> James: "It's just a dude alone in a room"

He seems unperturbed by being alone and says he is "more efficient working alone". He describes his situation as studying in bed,

> James: "kind of paying attention, kind of sleeping."

James is between places, and this is expressed in his drawing by the simultaneous 'uh huh...' reflecting participation, and 'zzzz...' representing his state of sleep.

Separating his portrait-orientated paper into two halves vertically, the lower half shows the classroom. Again he has written 'uh huh...',

> James: "'uh huh' in both cases means I'm getting the same content; in the bed I'm just asleep."

James explicitly makes no distinction about the 'content', suggesting either that the knowledge is purely explicit; or that its tacit transmission or acquisition is uninhibited by the online context. There is no sense of emotion.

James' comparison between the two contexts, unlike Maria's, is quite blasé. He does not strongly distinguish his learning experience between the

two modes. He reflects on some practical differences though, describing the in-person experience:

> James: "The in-person aspect is just for general wellbeing"
> [pause]
> James: "We just start talking and not working. [...] I like seeing people, but that doesn't help me with work."

James positively denies a social aspect of learning, and treats the benefits of social contact as independent of learning the curriculum. He describes talking as antagonistic to 'working', i.e. learning. James has illustrated the behaviour of his colleagues (Fig. **??**) and explains,

> James: "These people here aren't really actually paying attention."
> Me: "OK. There's a device in one of their hands is there?"
> James: "It's a phone. They're not entirely paying attention."

I ask what the actual experience is like,

> James: "Me trying to work me getting distracted by talking to somebody else. Maybe I shouldn't have come to the tutorial? Because I don't actually have any questions prepared with me."
> Me: "Is that regret?"
> James: "Sometimes I am actually thinking if this was online it would be a lot easier to do, and I wouldn't have to wake up so early. [...] I know I'm not being as efficient as I could be. It's hard to put it into a drawing,"
> [Brief discussion] James: "It's hard to convey the emotion"

In discussing the in-person experience, James refers to his emotion but that it is hard to convey. He says he is distracted; and voices frustration at not being prepared. This is a negative activity emotion with low control (AX). I suggested a different approach.

> Me: "You can be more abstract, like just shapes."
> James: "I've never had to draw anything that wasn't like a thing before. [...] Yeah, I'm good at drawing things that I can see in my head and things that are in front of me. But no, it's not, a feeling".

There was some tension but I continued to encourage him. I made conversation around what kind of shape might convey his emotion; or what kind of beach would represent each learning mode. As the conversation moved elsewhere with other students, James produced a second piece of work which is reproduced on p. 46.

James' second sketch is completely abstract. Again he has used a portrait orientation and divided it vertically into the online and in-person experience. It is not clear on first impression what this drawing represents. There is however an obvious difference between the two expressions for online and in-person.

The online expression (top) has clearer definition, with distinct shapes delineated by sharp, straight lines; the interiors of the shapes are shaded in grey; the shapes are set on a background of faint, regular lines that are mostly diagonal. It gives a feeling of order, structure and clarity.

The in-person expression (bottom) looks disordered. Shapes are evident but without clear boundaries; the wiggling lines overlaid over the shape boundaries suggest unclear boundaries or even conflict. The interiors of the shapes are not shaded. Rather than sit on a distinct background, the shapes intermingle with a mesh of lines that both cover the

background and pass through the shapes almost impertinently; these lines follow curved paths but in an irregular manner.

After spending time immersing oneself in the drawings, the viewer eventually draws a connection between the two expressions. They both have the same number of shapes (six). Maybe the shapes represent the content of the curriculum, which itself is ostensibly invariant but is experienced differently depending on the context.

James was initially happy to describe his drawing, for example "There aren't lines going through the shapes in the top one, [but] there are lines going through the shapes in the bottom one". However, as I enquired more, he seemed uncertain over what he had expressed.

James: "The shading of the shapes may indicate something. Not entirely sure what, but it is something yeah."
Me: "Which of these do you want to do now? It's 2:20pm on Friday. You've got a choice."
James: "I would appreciate no lines going through my shapes, so maybe the top."
Me: "OK, so that's like, interruptions"
[James is not direct in his answer]
Me: [on the contrast] "Is this anything to do with the academic content, or is it entirely unrelated?"
James: "The academic content is the same. I guess that would be why the general shapes are kind of similar".
Me: "There's six in both cases. That could represent academic content."
James: "I guess so. I don't know what I drew."

Invariance of the curriculum.

James reiterates his view that the content is invariant. He is elusive about his abstract drawing. It took over half an hour to produce this drawing, so my feeling is that it was not as blasé as James may protest. To some viewers there may appear to be a mystery about James' drawing, though personally I feel quite content about it. I feel connected to his expression, and it provides a data point for me. James finds online tutorials to be 'efficient'; he enjoys the social aspect of in-person tutorials but, in his view, at the expense of efficiency. He has an ambiguous view towards the two modes. The contrast with Maria is profound. The individuality of this particular drawing is strong.

B.3 Helen

Helen used colour acrylic paints and her first painting is on p. 48. Helen has painted herself at a table in a classroom room with a laptop. Beside her are other students working on a different table. The form of people is simplified. Limbs are formed fairly accurately but digits are not distinguished on the hands and faces have no expression. Helen has her elbows on the table and her forehead in her hands as she looks at the screen. Her body language suggests focus and intensity, but some difficulty of thought.

The use of colour has a strong impact, immediately distinguishing the painting from the previous pencil drawings. Helen is surrounded by a red aura that indicates intensity and heat. The black and grey colours of her person, however, suggest that this is a cognitive heat, rather than an

emotional one. She seems challenged.

The students beside her are working. The closer one has a pen in hand. This graphic expression is remarkably skilful, capturing the generic 'student at work' body language that I see day-to-day in the classroom. The other students, also grey and black, are surrounded by a blue aura that suggests general activity. The blue and red seem to clash. The other students seem to be creating a disturbance.

> Helen: "The red is, that's my working. And then the blue is, so I find it really annoying in tutorials when people are talking about [inaudible] and I'm just trying to get on with my work and I just want to be on my own somewhere."

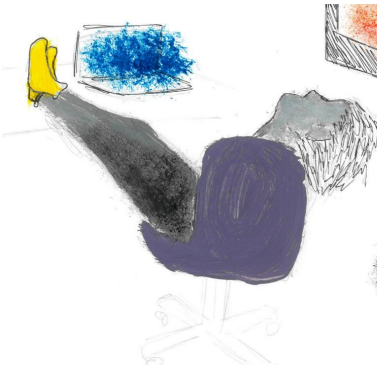
Reflecting on the individuality of the experience

Helen echo's James' sense of disturbance in the room (AX), but she seems more negative about it. She wants to be on her own. So far I have only presented three students' expressions of in-person experiences, yet it is already becoming apparent that the statistical approach that I presented in my preliminary research, from survey data, completely overlooks the individuality of the experience.

Helen's second painting is about the online experience and is reproduced on p. 49. She is in her room. A laptop on the desk emanates blue; across the room the window hosts an orange glow. The bed and chair have a matching mauve hue. Sat on her chair, Helen's feet are up on the desk, legs outstretched and crossed at the ankles. Her head is hanging back over the chair and her hair hangs down. Her arms and body are not visible, presumably hidden by the chair.

> Helen: "So at home, in contrast I have all this space that's my own, but it's harder to concentrate [...]."
> Me: "[And] what's the red outside?"
> Helen: "So, like often when I spend a day at home, I look up at 5 o'clock and the sun's already set and I've already missed the whole day, you know, and I may have been working, but I don't feel like I've done anything that day."

(a) James



(b) Helen

Figure B.1: The liminal zone.

It is a dramatic pose. The sense of lack of achievement is a retrospective outcome emotion, negative and irrelevant of control; this is identified by Pekrun as *sadness* (R–1) and shame (R–2). It is one of a number of student expressions that I can identify as a symptom of insufficient feedback.

Helen goes on to describe the roughest days, with long lectures late in the evening.

> Helen: "Oh my God. It was dark and I've done nothing but sit in a chair. That was the day I really slept through a lot of lectures. I'd put them on and fall asleep *like that* [points to painting]."
> Me: "So are you sleeping there?"
> Helen: "It's ambiguous."

Helen is in a liminal zone, not studying, not sleeping; or both. It echoes James' description (p. 44, 'kind of sleeping, kind of listening'). I have brought these expressions together in Fig. B.1

> Helen: "Yeah, I've been, I've been trying to work all day, but I've just not got anything done. I feel like that at uni as well."

Helen and James have both expressed *boredom* (A0). In neither case does the lesson mode seem to be the cause. In James' case the boredom at home is relieved by the social interaction in the room which brings a sense of enjoyment (A+) but also frustration (AX); in Helen's case the same frustration is present but she doesn't see a positive side. Helen doesn't enjoy in-person *or* online tutorials (P–2), and she chooses to study with peers in a different place. But she can't find satisfaction.

> Helen: "I just don't like studying anymore."
> Me: "Did you used to like it?"
> Helen: "I don't know, I used to like it. Yeah. Recently I've been feeling quite, I'm just [not] interested in my degree."

Helen is demotivated. It is close to hopelessness (P–3); the thrill has gone. This happens to many students in their second year. Again, I think it is a symptom of a lack of good quality feedback. Helen has fallen out of love with studying (R–1).

B.4 Amy

Amy and Helen sat together and both painted with acrylic colours. Amy's first expression is reproduced on p. 42 and it's her bedroom. The painting is bright, colourful, and relatively busy. A small, unenticing laptop is on the table.

> Amy: "When at home, there's so many distractions that it doesn't feel like I should be like in a tutorial, it feels like, oh, it's kind of optional. I could do something else."

Amy describes her painting as she composes it, firstly sketching with a pencil and then adding the colour.

> Amy: "It's kind of to represent that I have so many distractions. I'm gonna do kind of like a scenery outside the window. Then the closet and like a yoga mat. *That's* my bed [points at bed]."

Here Amy highlights distractions in her bedroom. This has echoes of the frustration expressed by other students when they are distracted, but Amy does not see the distractions in a negative light — they are beautiful things. But they distract. Amy is expressing positive frustration (AX positive), leading to boredom (A0).

All the students seems particularly concerned with their ability to work. This is action-control, as opposed to outcome-control (Pekrun, 2006); the distinction is clearly important but would not be possible with the general interpretation of the term 'self-efficacy', hence I do not use it here. The students are so concerned with their action-control, that they rarely delve into reflection on the knowledge and learning itself; they are focussed on their success in applying themselves to study.

Amy has a sunny disposition but is nevertheless negative about working at home. Her second painting — reproduced on p. 43 — represents the tutorial room and she expresses a positive experience of the classroom.

> Amy: "I think this has a lot more structure. So like I walk in there. And I see OK I need to do this. Well, *there* [points at the online painting — p. 42] I'm like looking around."

Through discussion, Amy reflects,

> Amy: "I want more structure, but at the same time I don't want more structure because it's stressful."

Amy looks forward to studying in-person (P+2) and enjoys it (R+1) but is anxious about too much structure (P-2) which can be stressful (close to AX negative). I sense a tension between wanting autonomy but wanting help. That's a natural tension at a time in their academic lives when students are in the process becoming independent but still need support in most cases.

What's clear is that Amy's expression of the tutorial room is a calm and positive expression of structure, in contrast to the distraction and lack of structure at home. She prefers in-person to online. Recalling James' expression of distraction in the room compared to focus at home, we see polar opposites and with a clear explanation in both cases. In that sense, James and Amy are a perfect example of how the personal experience can be directly opposite depending on the individual.

Polar opposites.

Amy is discerning about how preferences depends on the student, and it depends on the module — or in fact the structure of the session. She prefers unstructured sessions.

> Amy: "I like clinics a lot where I can just go ask my question."

Amy thrives on the positive working atmosphere that the classroom creates with its visual simplicity. She is not keen on too much structure, and prefers unstructured sessions where she can ask her questions.

B.5 David

At this point, the harmonious group is disturbed, for better or worse, by David, who enters and fills the room with a loud and confident energy and disturbs the harmony that existed before. I feel like I lose connection with the other students as I try to balance the different needs.

I take the chance to raise an issue with the group now that the discussion has opened up. I point out that student expressions imply that asking questions is one of the primary roles of a tutorial. This is what I would call the 'transactional' paradigm.

> David: "Maybe it's not maybe it's not the primary role of a tutorial, but like it's the only place where that function can exist."
> Me: "There isn't much sense of your tutor asking *you* questions. [though ...] Like 'what if we didn't make that assumption in this particular problem or question? What would happen then?'"
> David: "Sometimes the prompting to think could make it less engaging. [...] I've got no clue whats happening. I'm just tuning out"
> Helen: "That's because the answer isn't part of the course. I don't care, right?"

Probing epistemic emotions

In the above discussion I am trying to probe epistemic emotions. When tutors ask questions it can stimulate incongruity, which Vogl et al. (2020) say can lead to surprise, curiosity, or confusion; and which Schön (1983) says can lead to reflection. David's response about not having a clue indicates confusion, and he tunes out. This is consistent with the finding

of Vogl et al. (2020) that confusion doesn't always lead to exploratory behaviour.

Helen expresses an even more basic barrier to responding to a tutor's question, as she perceives the 'course' to exclude any such activity, so she is not even receptive to a question.

Again it's Amy who is discerning,

> Me: "So that's not part of what you envisage as the learning process?"
> Amy: "I guess it's very personal because I think I'm someone who works well are under pressure. [...] So if I know I'm going to a tutorial tomorrow where they might ask me a question, it's going to motivate me to work.

Amy expresses a positive effect (on motivation) of knowing that questions will arise in a lesson, but the emotion itself is not necessarily positive; it is 'pressure' that motivates, and we could identify this with a prospective negative emotion of anxiety (P–2) or anticipatory relief (P–1), the latter more likely if the student perceives more control over the chance of success.

David challenges the relevance of questions that he receives in tutorials. Amy sees the risk involved in tutors asking questions,

> Amy: "It's also hard to balance, I guess like it could also drive you to just not want to go at all because you know you're going to get asked questions when you don't feel like asking."

Helen, David, and Amy have all expressed scepticism about the tutors. This is associated with negative outcome emotions (P–1,2,3; R–3; A–, AX).

I enquire about the importance of the *relationship* with the tutor, as opposed to just the quality of the tutor. Some tutors care, and students say that that is well received. But in this discussion I see limited reflection from them on the relationship. Throughout the focus groups I found it difficult to obtain evidence of tacit knowledge transfer through the relationship with the tutor (except for Maria).

Learning from peers

In my questioning about the role of the tutor I found little evidence of a relationship, but rather a transactional role of answering questions. In this conversation David, whose art I will present next, is the dominant voice. I enquire further with a provocative question,

> Me: "If the tutor wasn't there, would you notice?".
> David: "Obviously you'd notice but ... I'd still like go there and do some work, and hang out with people."
> Me: "So it's really about your peers?"
> David: "It is for me yeh. Obviously it's not gonna be the same for everyone."
> Me: "How much do you learn with your peers or how much do you just kind of relate to them 'cause it's in a social way and that's nice to do while you're learning on your own?"
> David: "It has been shown [...] it's like a lot better of a way to like work because you know you can bounce ideas off each other. You can help each other with things."

David then explains a practical view on how knowledge is only partial in each student but that between them they have more, hence they can help each other.

Micro-confusions

I enquire about the parts of knowledge that a student lacks. Where do the questions about this come from? I ask if there is confusion involved. David confirms, yes, there is confusion — but in a positive way; he says "confusion is part of learning". I would refer to these as 'micro-confusions' rather than 'threshold concepts'. This is what peers help with but,

> Me: "What happens at home when you get confused?"
> David: "Well, you do what you can. You try and message other people. You try and Google it. YouTube it. But sometimes you just can't work it out and that's how it is."
> Me: "How do you feel about that when that happens at home?"

David goes through options like leave it, go to a tutorial; but often with tutorials far away and being far behind on other tutorial sheets, you just have to leave it and move on.

> Me: "So is that frustration?"
> David: "A little bit. Yeah yeah, yeah. Especially when you want to work but you can't. Because like you feel like you're being held back by other things"
> Me: "So having your peers around basically helps you get through micro confusions, does it?
> David: "Yeah. It can just be like, oh wait, what's going on here they go, oh, you're an idiot, you brought the wrong number."

The attribution of 'other things' is important, hence it leads to frustration (AX). I have established that confusion, an epistemic emotion, is ever present when students study. They continually relieve the confusion through exploratory behaviour. When information sources are exhausted (or potentially before they are exhausted), students ask their peers. Peers answer questions, hence the joy (R+1) and gratitude (R+3) of social learning. Peers do not just answer questions in an explicit way; they provide a lot of implicit messaging. 'You're an idiot' sounds negative but it can be received in a positive way; it means it was a simple mistake and they need to take care; the confusion is resolved; everything is OK.

The receiving peer support relieves confusion and so, over repeated experience, contributes to developing a positive prospective emotion, anticipatory relief, P–1); the activity itself is successful so can be enjoyable (A+), and the outcome, when successful, potentially brings any of joy (R+1), pride (R+2), or gratitude (R+3). These are my inferences; I was not able to obtain strong evidence for these emotions, but David's story provides an initial anecdote.

A few of the students in the room point out that the viability of this social support depends on the social dynamics in the group. When the group isn't social or doesn't bond, the support network doesn't materialise. This leads to lack of attendance, implying frustration (AX), sadness (R–1), or hopelessness (P–3).

Role of the tutor

It seems that despite my earlier hypothetical question about the absent tutor — which yielded useful insight — the tutor does still play a positive role, as evident by the absence of students if a tutor doesn't attend

> "Sometimes on Friday there's like no tutors, and then everyone just left like when they came in."

I point out the contradiction compared to the earlier statement about what if the tutor wasn't there. The students say that they would like to ask the tutor questions (i.e. the 'peer of last resort'); and that the tutor takes attendance. So there is a mixture of reasons. David points out, and others agree, that the tutor can be good for more than that.

> David: "What I have found being good, sometimes in terms of like the tutor going through questions, is when everyone is stuck on the same question. Yeah, and then they're like OK, do you guys want me to go through this? Yeah, and then it was like yes.
> [Others voice agreement]

The tutor arrives like a knight in shining armour. This is a rare but almost magical event, where the tutor identifies a common need in the group, and leads them out of the desert. It is a dangerous game though, lest the tutor misjudge the students' needs

> David: "But then when [...] they start the tutorial by saying 'OK, today we're going to be covering this', right? That's when you know it's not going to be, it's not engaging."

This sentiment will come up again later. So the students do not necessarily see a role explicitly of a relationship with the tutor; yet what they value is a tutor who understands their needs and can resolve their confusion or other incongruities that arise in their studies. Resolution involves actively walking the students through the problem.

Is this event a performance where the students can dwell in the tutor's tacit knowledge? It's hard to say because some modules provide written solutions to problems, and questions still arise — in which case, yes, there is probably tacit knowledge transfer through empathy with the tutor. However, some teachers delay publishing written solutions so it may just be a case of wanting to transfer explicit, but secret, knowledge.

I have doubts about the latter case, perhaps biased by my experience as I am a teacher who provides explicit worked solutions to all homework. But I also know that students from year to year share their written solutions with each other. This is a very popular unofficial channel to receive information; it is not totally reliable, as the working can be poor quality and/or contain mistakes; but my understanding of what this group of students is saying is that there's 'something more' to gain from the tutor.

What's clear, however, is that these students are very sensitive to *when* they want this type of experience. They only want it when they feel the majority of the class has an outstanding and very specific issue. Otherwise they are resistant to such structure.

How can a tutor *know* what student needs are? There are different tutors; one is the module leader, but others are PhD students. If a tutor has an ongoing relationship with the students then they can know the student needs. This does not seem to be happening at the moment though. Students do not express a role for themselves in that relationship building process. They only express frustration (AX) or joy/gratitude (R+1,3) when the tutor incorrectly or correctly, respectively, anticipates their needs.

David is outspoken and has made lots of contributions to the discus- David's sculpture

sion — perhaps at the cost of hearing others — but has been reluctant to express himself through art despite some significant encouragement from me. After I finish the session and stop the recording, he presents a Plasticine sculpture that I didn't notice him making. Two stick figures are present — himself, and the lecturer. A Gaudi-inspired wall blocks the view; "this is my brain" says David. Small holes let some knowledge through, but it is mostly blocked. "Online, it would just be a solid wall". A photo of his sculpture is on p. 41.

David's sculpture is arresting. It betrays a personal struggle that he was not willing to express in words. As a lecturer, I feel like I have witnessed such a wall many times; and I have experienced it as a student too. David's sculpture contributes to a growing collection of student expressions of lack of action-control (unable to focus/study) which is an achievement emotion associated with activities (AX) and prior or subsequently as a prospective/retrospective outcome emotion (P–3/R–1,2) respectively.

The only epistemic emotion I have detected so far is confusion (unable to understand). Confusion is complex; David's sculpture, and his earlier conversation, show that confusion can generated by the learning material, or the situation (e.g. being asked a question), or by one's own internal experience. David is the first student to express this internal battle in such a clear way and this vindicates the use of art in my methodology. It is also the first sculpture I have exhibited and it shows the power of sculpture.

David's sculpture illustrates the challenge that teachers face. With such a barrier between the student and teacher, how can the teacher relate to the student; how can a student connect and 'indwell'? What can a teacher do about this barrier?

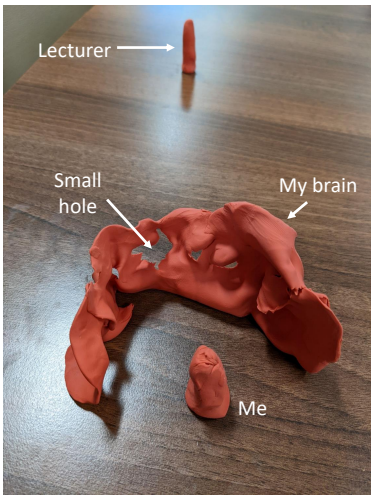


Figure B.2: David's sculpture

B.6 Simon

Simon and Jay are part of the same tutorial group — they are in the same tutorials for all subjects. They came to a focus group with me on a different day to the students I have discussed so far, and they shared the focus group with George.

Simon and Jay acted like a pair throughout our hour-long session; feeding off each other and enjoying each other's company. They decided to work together on their art and shared a single piece of A3 paper on which they produced one piece of graphic art using acrylic paints. The art is reproduced on p. 39.

Simon and Jay sat at 90 degrees to each other at the table so their pictures are orientated differently. Although Simon and Jay ostensibly collaborated, they actually produced independent paintings on two different areas of the page. Simon is on the left, Jay is on the right. They both initially illustrated the online experience, and then augmented it with a comparison to in-person.

Simon uses a very simple painting style, essentially line art with different colour lines. The lines have uniform thickness and are one of a simple range of colours: yellow, blue, red, or black. He paints a yellow outline of himself from behind, sitting at a laptop (red), with cogs on the screen (pencil).

Simon: "I'm about to draw a phone in my hand"

Simon draws a red rectangle, at the end of his yellow arm. Then he draws a blue thought bubble from his head with 'girls, cars, gym, alcohol'.

Simon's painting

Simon: "Those are all my thoughts during first year."
Me: "Not much vector calculus then?"
[The sarcasm is mutually understood.]
Simon: "No there was no vector calculus!"
Me: "And it says ADHD on your back"
Simon: "Yeh. Get distracted easily"
Me: "And how does that change in the room?"

Simon explains that he was diagnosed with ADHD in school and has the option in exams to have his own room and to have breaks, but he always chooses not to take that option.

Simon: "In the main hall, because being around people that are working, it makes me kind of feel like I should be working. I don't know, it kind of gives me a kick in the back of the head, kind of thing. Being like you need to actually do work, otherwise you're screwed."

Simon clearly has a negative experience of working online. He describes himself as an extrovert and he almost always wants company. Being in other people's company helps him work. He refers in particular to large rooms — lecture theatres and exam halls.

When he finished painting his online experience he augmented his painting with the in-person experience (see p. 39). Many lines of nondescript students are in the room, and his label 'me' on one of them shows that he is indistinct — just another student. He has written "Notice Anything? I'm working like everyone else".

The closest emotion in Pekrun's system (Table 2.1, p. 23) to what Simon expresses when working online is boredom which is an activity emotion (A0); distractions are too strong relative to the valence of the tutorial and they win his attention. It's not clear what retrospective outcome emotions Simon has about this experience. Clearly overall it wasn't a good thing, but he does not reflect more on that during the focus group. The lack of engagement in the online context forbids us from discussing epistemic emotions or connections with peers or the tutor when online.

In-person Simon clearly enjoys in-person classes, and it seems to scale with the number of people. He socialises in tutorials but in Lectures it really motivates him to work (P+1, R+1, A+). Simon has strong, positive action-control, i.e. ability to work, when in the classroom.

B.7 Jay

Jay is also keen on in-person tutorials. He found communication online difficult:

Jay: "It's hard to get your point across."
[Explains some of the mechanics]
Jay: "I feel like it's easy to explain when you're next to the person as well"

Jay's attendance was low pre-lockdown, and even lower in lockdown due to these barriers. This is a sense of hopelessness at the value of tutorials (P–3). We see with Jay how impressions are set early in the year:

> Jay: [About online] "I tried it first time, but then it wasn't really useful, so I just said to myself" [he is interrupted, but clearly negative]

Here an activity emotion of frustration (AX) becomes, through repeated exposure, a retrospective outcome emotion of sadness (R–1) or anger (R–3), and subsequently, about future tutorials, hopelessness (P–3).

Jay focussed his painting on the online experience. He painted himself on the bed with a sad face. His laptop is on his desk with 'Bb' on the screen[1]. Jay explains

> Jay: "I might just draw or paint me in bed with the laptop"
> [The others snigger and laugh, interrupting Jay]

This is a sad expression of loneliness and disengagement. Jay clearly has a sad face in his painting — it's a harrowing image (Fig. B.3).

> Me: "So what's drawn you to the to the online scenario?"
> Jay: "Because [it brings back] the most powerful emotions, I think."

The others laugh unsympathetically. It's an immature response because Jay is showing emotion and the other two in this all male group may not feel comfortable about it. But Jay is happy to continue

> Me: "And what does it look like?"
> Jay: "Anger, frustration. Impatience.

Jay is able to express himself directly here. Negative activity emotions of anger (A–) and frustration (AX) are clear. Jay's expression of impatience suggests some retrospective attribution to himself (R–2), which is the first time I have detected this in my focus groups.

> Jay: "I just remember having so many conversations [about] last year this year [...] about how online lectures are for people. And everyone we spoke to seemed to find it in a similar way, yeah."
> George: "I just didn't care to be honest. It made me just feel like I didn't care."
> Jay: "Yeah exactly, I got really demotivated"

Jay and George express hopelessness (P–3). Jay, like Maria, questions what he is doing,

> Jay: "A lot of the times like I'd be sitting there like what am I doing?"

Jay expands later, talking about his painting:

> I've just been inside and when watching online lectures not really getting much from [...] not feel like I was doing a proper degree kind of thing. I didn't feel like I was actually learning. Even if I did try."

Jay expresses the now common sensation of hopelessness (R–3) and sadness (R–1) with no ability to influence it.

Given how many students are expressing action-control issues, I raise this as a question with the group.

[1] Bb is Blackboard, the virtual learning environment

Figure B.3: Anger, frustration. Impatience. What am I doing?

> Me: "a lot of what I'm hearing from you and others is about whether you can concentrate, whether you're distracted, whether you're up to date, whether you're motivated."
> George: "I think part of the reason for that is because it's the thing that we feel like is in our control"

The implication of George's comment is a rational approach to the situation — focus on what you can control. This is why students are alert to their action-control issues. This may explain why it's hard to gear discussions towards, say, tacit knowledge and indwelling. But it doesn't explain the lack of reports of reflection. Reflection is a process under one's control, but I am not detecting much reflective learning. There is reflection in general, but not reflection on the knowledge itself such as might be prompted by highlighting an incongruity.

It may be that my methods are inadequate to capture reflection-in-action. However I have spent hundreds of hours with these students in tutorials over the past four years and I very rarely see reflection-in-action.

On being up to date

One conversation with Jay provides some insight. When I organise tutorials I label the rooms with different activities and students choose where to go. I enquire about this.

> Me: "Which ones do you go to?
> Jay: "I'm like I've gone to the structured tutorial a few times, but I've also gone to the non-structured tutorials, depending on how up-to-date I was. So if like I feel alright with this topic by I want to learn a bit more about it [...] I just go straight to the structured tutorial. OK, but if I'm a bit behind I'd rather focus on finishing everything before make sure I know that some of the ..."
> Simon: [interrupts] "I prefer doing one by one [tutorial sheets in order] and not kind of jumping around."
> Jay: "yeah exactly."

Probably the number one issue affecting students on the whole during their second year is being 'up to date'. This is emphasised by Jay's comment during a discussion about how many sheets behind they all are: "I'm not gonna count for my mental health". The workload is extremely heavy, and most of them claim that it is essentially impossible to be up to date. Being up to date means that if a tutorial sheet was issued last week, and another one this week, then you complete the one from last week before this week's sheet is issued. With 9 subjects occupying their time, each with weekly lectures, homework tasks; and coursework from the other modules; it only takes one or two unproductive days to get behind and then it's almost impossible to catch up.

What Jay has articulated clearly here is something that many other students have alluded to in my preliminary research, the present focus groups, and general conversations that I have. The desire to be stimulated only happens when there is not outstanding work to do; outstanding incongruities to resolve. In other words, while there are issues to resolve, new issues are not welcome. When Jay is not up to date, he attends a transactional-style tutorial to meet his needs. This is the familiar 'deficit' model, getting help to catch up.

When Jay is up to date, he is open to stimulation. He wants novelty and challenge. He welcomes an incongruity. He wants surprise; he is

curious. These positive epistemic emotions are only going to arise if the student is in the right frame of mind. Not being up to date is what is precluding such a positive experience.

Vogl et al. (2020) established causal links between incongruities and exploratory behaviour. Exploration followed surprise and curiosity. It is important to emphasise that all the results of Vogl et al. (2020) are for *high-confidence errors*. Confirming correct knowledge, or identifying inaccuracies in low-confidence knowledge, does not lead to epistemic emotions. When a student is not up to date they are not confident and we cannot stimulate surprise or curiosity.

Vogl et al. (2020) established a weak link between confusion and exploration. The reason for the weakness is due to a variation in responses by students, potentially due to varying action-control and outcome-control achievement emotions among participants. Only those who believe that they can resolve their confusion are likely to pursue a resolution. Belief in the chance of resolving one's confusion is likely to drop when students are not up to date because they cannot handle further confusion.

Essentially, some combination of us overworking our students, or our students not working enough at the right time of the year, is causing a lack of reflection-in-action; and lack of desire for incongruity and challenge; a lack of curiosity and exploration; a lack of openness to challenging questions from tutors.

B.8 George

George is working on a sculpture. In our conversation he has expressed the opposite experience to Simon. Referring to Simon's expressed inability to work online and strong preference for in-person tutorials, I invite George to contrast his point of view

> Me: "It's almost the polar opposite with you two, isn't it?"
> George: "Yeah, so I have ADHD as well, but it manifests in a different way to me where everything is just like an insane level of distraction and I can't work to other people's methods at all if that makes any sense. So just 'cause somebody is working, it doesn't mean that I feel like I need to be working."

George expresses frustration at being distracted (AX). Remarkably Simon and George both have ADHD diagnoses but express clear opposite preferences in terms of being in the room. Earlier George, who has retaken a year so spent his first year in-person explained

> George: "The problem I had with in-person tutorials [... was] I didn't get on with my personal Tutor group particularly well at all, and so it kind of forced me into an environment where I had to be with them trying to work while also trying to in some ways avoid them while being in one room with them."

George's objections to the in-person experience are clear and Jay, the discerning one in the group, acknowledges — despite his own positive experience — that "it does greatly depend on your tutorial group".

George is not anti-social though; in fact he speaks very positively about a recent experience working in a group for a whole week.[2]

[2] An activity called 'design week' where students stop normal study for a week and spend the week working on a design together in a group of four.

> George: "I managed to get into a hyperfocused state for almost the entirety of design week. [...] I had an amazing design week that I think that was possibly the best work I've ever done. Because I was in a reasonably good group."

George is describing a state of *flow* (Csikszentmihalyi, 1990) which is a positive activity emotion (A+), and he attributes it to his group, showing gratitude (R+3). George agrees that the room is not the problem, but rather the quality of the experience in the room, which can be variable; often very negative, but sometimes very positive.

During the conversation, to which George made many contributions, he builds a sculpture out of Lego: "this is an attempt at a brain". Later he adds Plasticine to the bricks. George talks in quite extreme terms about his negative experience in-person, which has led him to need to retake a year. He attended lectures to tick a box, but

> George: "I was going to lectures thinking I should know this, but actually I couldn't pay attention in the lectures. I wasn't taking anything in and it was basically destroying my brain for the next couple of hours while I tried to recover."
> Me: "The hidden cost."
> George: "And yeah, exactly."

> Me: "So tell us about the brain. You've got this structure of Lego"
> George: "Yeah, so it's a brain and the brain is on fire basically, which is pretty much how I feel in any kind of tutorial."
> Me: "OK."
> George: "Or to be honest, most lectures as well whether it's in person or online. [...] the contrast between being online and being in person would be where in person I feel trapped, whereas online I feel like I can separate myself or uhm, even leave much more easily." Me: "Yes, it's the autonomy."
> George: "So I mean, I guess I guess the visual representation of that would be either the brain just being on fire and then online I can sort of leave and stick my head in a, you know, in a swimming pool or whatever to cool it off. But then in person it's it's not only on fire, but it's also like trapped in a box so all the heat is just staying in and and getting worse."

George says he is frustrated in tutorials. He talks at length about how uncomfortable it is, both physically (e.g. the chairs); but also "I feel locked in". He is frustrated at other people's questions; he feels like he's wasting his time. So now he just doesn't attend.

George experiences strong frustration (AX), anger (R–3), and hopelessness (P–3). This is not a uniform experience for him though. George distinguishes two welcome forms of tutorial structure; the Q&A model for question transactions, and a special type of structured tutorial.

> George: "the tutor goes through questions almost like examples and tries to get. People from people from the group to effectively work through bits and then if somebody gets stuck swap out the person and sort of more like guided examples sort of thing, which is how I felt your fluids tutorials went first year, which was one of the only tutorials I actually found benefit to be honest.

George has said the same thing as other students: the tutor should guide us and get us to interact, push us to our limits and then move on to

another student; all in a group together. *But* — and it's a big *but* — George's burning brain is a warning of the effect that tutors can have if they misjudge the situation.

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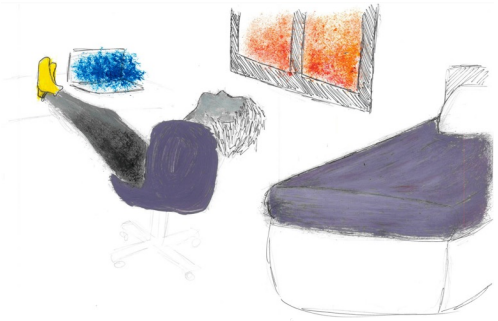

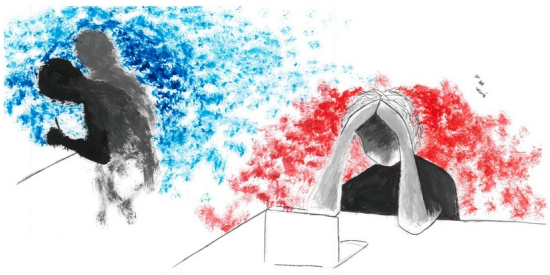


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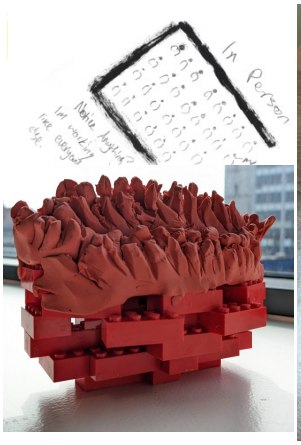
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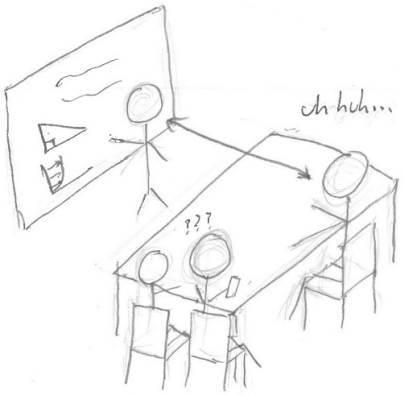
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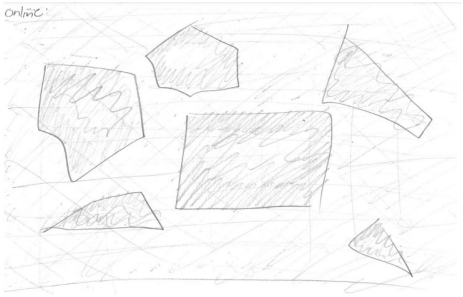
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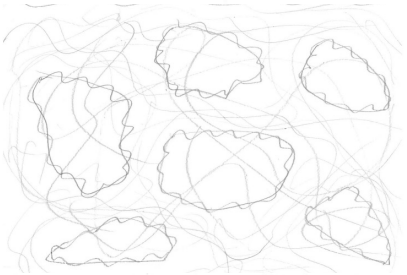


Might as well dropout