Beyond the STEM Comfort Zone: Activating Disciplinary Literacy to Enable Student Success Through Diversity

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Abstract: How are student expectations aligned with the reality of higher education? As the students attending university continue to diversify, academics struggle to create meaningful learning experiences. This article summons authenticity as a trope and tool to activate disciplinary literacy for the diversity of students that now populate the laboratories, fieldwork and classrooms of higher education. In moving beyond homology and experience, university academics can step beyond their comfort zone and create meaningful learning for the massified and marketized higher education sector. The goal of this article is to align disciplinary literacies from science and education, requiring all teachers to move beyond their personal and professional experiences, and towards authentic – and challenging – learning.

Keywords: Disciplinary Literacy, Authentic Learning, STEM Education, Diversity, Student Success

1. Framing Disciplinary Literacy Enabling Student Success Through Diversity

An array of political events – from the election of Donald Trump and Brexit decision, through to the 'Freedom Convoy' and 'Anti-Vaxxer' protests – has demonstrated the tenuous and frequently conflictual relationship between democracy and expertise. Populism voids citizenship of rationality, evidence-based decision making, compassion for diversity, and respect of expertise. What makes this last five year even more extraordinary is that there are more humans in schools and university – more of the world's population in formal education – than at any point in human history. The 'mass education' movements commencing in the nineteenth century developed into the widening participation agenda in the twentieth century. This is a powerful movement, ensuring that democracy is founded on and by informed citizens making rational decisions. And yet. And yet. The politically divisive nature of many systems around the world demonstrates that education is not the answer to social (in)justice. The underfunding of public education, caused through the Global Financial Crisis and the 'bail-out' of the banks and the COVID-19

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pandemic, means that teaching and learning, research and dissemination, appear tangential and unimportant in comparison to rebuilding lives, workplaces and families.

Tom Nichols logged the "death of expertise" (2017), confirming that, "It's not just that people don't know a lot about science or politics or geography; they don't but that's an old problem. The bigger problem is that we're proud of not knowing things. Americans have reached a point where ignorance, especially of anything related to public policy, is an actual virtue" (Nichols, 2017, p. 1). Clearly this is not only an American problem. But if opinion is rendered equivalent to expertise, what happens to formal learning? How can university academics infuse authenticity, knowledge, and the courage beyond the campus?

This article does not offer another polemic about why universities are 'dumbing down.' Although alarmed and angered, the writers of this article are not wringing our hands at the treatment of New York University's Professor of Chemistry, Maitland Jones Jr. He resigned after a distinguished career when confronted by a petition from students describing his organic chemistry course as too difficult. *The Guardian* rendered this narrative tabloidized through a headline: "New York University professor fired after student says his class was too hard" (Marcos, 2022). The *New York Times*, when reviewing this case, asked a more provocative question that propels our work in this article: "Who is responsible if students fail a university course?"(Mcmillan, 2022). The students complained about the grades, teaching quality and support they received. Such events raise powerful questions about the relationship between teaching standards and the standardization of andragogy, and how the historical models of a university are transformed when the students attending the institution are enlarged in number and diversified in background.

Such stories are disrespectful of scholarship and teaching, and the work of – and in – learning and training, which are the keystone of Universities. Yet the key is to remain focused on the role of expertise in higher education, and the relationship between disciplinary expertise and educational literacy. Therefore, we action a positive project. How can student success be enabled in these troubled times? Instead of 'giving up' in response to the 'dumbing down,' are there key strategies to enable diverse students to attain educational success? This article explores overtness in teaching and learning, with attention to disciplinary literacy. The first part explores the gift and challenges of student diversity in higher education.

2. Art (and Science) of the Possible

Among school leavers in Australia, participation rates in higher education have significantly increased in the last twenty years, more than doubling since the uncapping of undergraduate places (Norton et al., 2016). The undergraduate higher education student cohort is more diverse than at any point in Australian history, bringing a variety of experiences and expectations to universities. Noting the complexity of the phrase, 'the student experience' is a metric that is nationally benchmarked, branded and advertised. Yet what does this phrase mean? The student experience has been linked to factors including motivation, level of preparedness, personal resources and social networks (Baik et al., 2019), much of which is formed prior to entering the higher education space. During this time, attempts have been made to understand the needs and experiences of students entering higher education (Brinkworth et al., 2013) and align expectations of students and educators for a more successful outcome. These efforts have seen an increasing focus on transitions between educational, personal and professional environments for students, ensuring a portfolio

of support for commencing students. Many institutions have a 'Transition Officer,' with a team of staff. This has resulted in more positive experiences in first year cohorts as indicated by Baik et al. (2019, p. 531): "Over the past two decades of Australian FYE studies, students' views about the quality of teaching have become significantly more positive, from 66% agreeing in 1994 that the quality of teaching in their courses was generally good, to 78% in 2004 and 89% in 2014. The vast majority of students in the 2014 study also believed that staff were enthusiastic about the subjects they were teaching (80%), good at explaining things (73%), and put great effort into make the subjects interesting (74%)". Again, the variables been assessed and measured are ambiguous: 'quality,' 'enthusiasm' and 'explaining things.' Huffmyer and Lemus (2019) confirm that these variables are highly varied and act at a local level in individual units as students interact with various teaching staff. Additionally Gravett and Kinchin (2020) note that increasing diversity in student cohorts creates a challenging space to measure student experiences and that many learners consider themselves intruders in the institutional space, particularly in performing academic writing. With an increasingly diverse student body, it is difficult to make clear comparisons of such long-term approaches to improving the student experience.

Debates in these areas are slow, dependent on interpreting large data sets, and understanding the influence of many complex changes in the higher education system. It is important that researchers do not render correlations to be causal and inferences with actuality. Efforts from educators to engage with students do not necessarily translate to a student connection with their studies or their discipline, which is typically more pronounced in students from non-traditional backgrounds (Willans & Seary, 2018). This type of responsiveness to the changing student cohort is a strong step to improve student outcomes, however this approach is merely a band-aid solution to a growing problem. Educators must approach the issue of aligning student expectations and experience by addressing the cause rather than the symptoms of this issue. Instead of students simply enjoying their learning experience, they must be truly engaged in it. Immersion in the discipline allows students to gain experiences needed to develop disciplinary literacy that produces engaged graduates. Rather than treating the external symptoms of poor engagement, educators must respond to the trigger of the problem, which is poorly developed disciplinary literacy. 'Student experience' cannot include a right to dictate educational standards or influence marks or grades. Confidence is built through disciplinary literacy development, not the superficial perception that 'this class is easy.'

Students' sense of self and belonging are deeply connected to the discipline of which they are part (Shanahan & Shanahan, 2012), and are closely tied to feelings of empowerment to contribute towards and engage with their discipline (Eccles & Wigfield, 2002). This is vitally important to how students develop confidence in engaging in the learning process and - if well-scaffolded - will address many of the issues that students experience with disconnection. Strong connections are important both within an academic discipline, where the learner sees themselves as capable and valued, as well as within an institution more broadly, having a capacity to contribute. Lizzio (2006, p. 2) noted that,

> students with stronger connections are more likely to be successful learners, effective colleagues and happy people. A student's sense of connectedness depends on the quality of relationships with peers, with staff and their feelings of identification or affiliation with their School or University. Teachers can help develop connectedness by providing

> opportunities for students to form good working relationships with their fellow students and with staff, and encouraging them to get involved with the university.

These measures have impacted on student experiences in higher education, with the majority of students reporting that they are more engaged and satisfied with the quality of teaching they are receiving (Baik et al., 2019). These are strong outcomes, yet there is more research work required to ensure that the diversity of students entering higher education experience the strong connections to the discipline that are needed.

Much of the teaching experienced by learners in higher education follows a traditional didactic model, using lectures and practical sessions designed to impart information from an expert to a novice. This has changed little with the shift towards online content in the wake of COVID-19, with research indicating traditional lectures are commonly replaced by online versions that differ little from their didactic ancestors (Lee et al., 2021; Videla et al., 2022) While these methods may be useful for learners developing basic understanding during the initial stages of learning literacies, they are less effective for developing a strong grasp and comprehension of advanced disciplinary content that empowers them to wield deep expertise with 21st century skills of communication, critical thinking and problem solving. Didactic teaching methods place the focus of the interaction on the teacher, rather than the learner, and can lead to low levels of engagement in learning. Over the last two decades, there has been a shift towards engaging learners with teaching experiences that not only develop their discipline-based, content knowledge but cultivate an understanding of research processes. However, few students understand the complex relationship between research and teaching within higher education institutions. Those that do hold a view consider the relationship a negative one, with research valued more highly than teaching (Kandiko & Mawer, 2013). This issue is further compounded by unequal power relations between academics and students, frequently intensified by credentials, titles and age. While academics position themselves as experts and students as novices unable to understand research or to have sufficient capability to participate in research (Kinchin & Howson, 2019) any potential to reshape and reconfigure learning will be hampered. The shift towards research-led education has been embraced particularly amongst science disciplines (Smyth et al., 2016) and provides an opportunity for students to engage in research in a meaningful way. Through the process of performing and communicating authentic research, students develop skills that are essential for all scientists and include a wider range of skills than could otherwise be taught in a traditional didactic model. Yet in traditional undergraduate curricula, these opportunities are limited and not widely accessible to aid in student engagement.

Student engagement with content – or, indeed knowledge - is vital to learning and occurs in a variety of ways, but writing is perhaps the most difficult to research and crucial to understand. The development of knowledge through writing occurs through the cognitive processes of evaluation and generation of ideas, described via the cognitive process dimensions proposed by Anderson and Bloom (2001) that builds upon Bloom's taxonomy of hierarchical models classifying educational learning objectives. The act of writing involves creative processes where writers generate understanding and synthesise meaning from information. They must evaluate information, rather than simply remember or understand it. When performing writing, learners must use higher order thinking skills to bring together what they already know into a coherent model that can be expressed through written text, using writing to construct knowledge, developing innovative ideas based on prior experiences. Writing provides an opportunity to synthesise

understanding and thought, "because writing, after all, is the material expression of our immaterial thinking" (Hogsette, 2019, p. 1). Through writing, we discover knowledge and incorporate it into our understanding of the world around us.

Writing in the sciences is linked to the development of critical thinking and conceptual understanding (Gunel et al., 2009), enabling learners to make connections between concepts as they clarify meaning with – and through - writing. Students perform this task reasonably well within the framework defined by their audience, usually their assessor. However, writing tasks that are designed to focus on an audience of peers or younger students result in an increased understanding of discipline content more effectively than writing for teachers or an older audience (Hand, 2017). Through the act of distilling concepts and redefining them for younger audiences,' students must actively engage with the material, considering the critical aspects to relay understanding they must first understand the concepts themselves. Previous research has focussed on primary and middle school writing to learn programs where a less experienced audience is naturally younger (Gunel et al., 2009; Hand, 2017; Prain & Hand, 2013). However, it is unlikely that age is the significant factor in this relationship, rather the experience of the intended audience.

Writing tasks that focus on communication with others outside of the discipline are likely to be equally important to learners developing deeper understanding of concepts and context of their discipline. As Gunel confirmed, "Audience awareness is a critical component of all good writing. Effective writers develop an understanding that the language and content they use and create are interactive and that these must be taken into account by analyzing who their audience is" (Gunel et al., 2009, p. 356). Educators guide students and frame the learning experience in writing to communicate with a range of audiences appropriate for the discipline. Educators have a responsibility to introduce their students to audiences outside their discipline and a recognition of the parameters and limitations of a discipline, allow meaningful and authentic dissemination.

3. From Experience to Expertise

Educators in higher education are derived from a wide range of knowledge systems, fields and disciplines, and activate a variety of approaches to teaching and learning. Views on involving learners in the research process are broad and are well described by Kinchin and Howson (2019, p. 289): "The 'knowledge-first' versus the 'knowledge through research' perspective represent a reflection of the academics' conceptions of teaching, with the more positivist colleagues requiring the students to be given the facts in advance and the more constructivist teachers allowing for the understanding to emerge." Whilst academic faculty in higher education institutions are considered experts in their specific fields based on their specialised training and involvement in current research, there is often speculation that in the classroom they simply "teach the way they were taught", without formal training or instruction in educational practice and theoretical understanding (Oleson & Hora, 2014). This argument is supported by Mazur (2009, p. 50) in his commentary regarding his own practices early in his career in Physics education. He stated that,

> The traditional approach to teaching reduces education to a transfer of information. Before the industrial revolution, when books were not yet mass commodities, the lecture method was the only way to transfer information from one generation to the next. However, education is so much more than just information transfer, especially in science. New

> information needs to be connected to pre-existing knowledge in the student's mind. Students need to develop models to see how science works. Instead, my students were relying on rote memorization."

Mazur's experience of teaching is not unusual, however his response to this experience is provocative and fascinating. Instead of persisting with traditional approaches he is seeking to solve the perceived issues using novel and engaging practices (Mazur & Hilborn, 1997).

Such honesty is important, but its generalizability and representativeness must be questioned. Higher education teaching and learning is more than observations and experience in front of a class of students. As Oleson and Hora (2014, p. 30) describe, "it assumes a causal and linear relationship between past experience and behaviour, and it overlooks other sources of professional knowledge and expertise that may influence teaching." Profound examples of excellent teaching practice are abundant in higher education, and in much the same way that disciplinary literacy is deeply embedded in and influenced by one's experience in a disciplinary community (Shanahan & Shanahan, 2012), a teacher's professional identity is also deeply influenced by their discipline, with "knowledge of the subject matter, social and political context, family influences, and especially the knowledge that they develop over time about how to teach particular topics (i.e., pedagogical content knowledge)" (Oleson & Hora, 2014, p. 30) forming the basis of their relationship with teaching and learning. SoTL – the Scholarship of Teaching and Learning – is a powerful field, fuelled by journals, conferences and refereed monographs. This article is part of this suite of (post)expertise theorizing of teaching and learning in higher education.

Given that Piaget's (1973) ground breaking work in learning theory demonstrated that learning occurs in relation to experiences and already existing understanding, and Vygotsky (1980) theory of social constructivism described how relationships with knowledgeable adults and peers contributes towards developing a learner's skills, it is not surprising that many academics will fall back on what they have experienced themselves - an educational comfort zone - where they teach in the way that has been modelled to them, either as a student or by their colleagues. Relying on this homological method of information transfer is no-longer appropriate. Past practices that encouraged educator-focused interactions may have worked for them as students but are not suited to a wider and more varied cohort that now populate higher education.

The challenge lies in how to promote a change in teaching practice when academic staff are under increasing time, task and work pressures from their institutions. Summarised in the following statement from a senior lecturer reported by Cleary (2013, p. 21), "To do research well I think you have got to be incredibly selfish … the motivational drive for any researcher has to be themselves … ultimately it's their own progression up the research hierarchy (that motivates them)…that doesn't necessarily come across in teaching, where the rewards don't come from their progression, but from the progression of others". In a time where teaching is commodified to manage the marketization and massification of higher education, research and teaching are being separated, with devastating results for the quality of learning. With teaching specialists and part-time academic positions being used as cost-cutting exercises (Altbach et al., 2019), the nexus between teaching and research will continue to be difficult to foster in student learning. This challenge is exacerbated by the increasing demand to focus on the preparation of graduates for the workplace – narrowly defined - and devaluing traditional intellectual research. Whilst these past

experiences cannot be changed, they can be reframed within present circumstances. Understanding this volatile context, and researching and writing SoTL, higher education scholars can impact the future of science education by examining teaching practices and ensuring that education praxis encompasses a range of practice-based, practice-led and learner-led approaches. Teaching staff have little time to re-develop curriculum. Therefore, there is a need for an intervention, to recognize the (in)capacity for change to the traditional structures of degree courses, while embedding new platforms and modes of communication. Requiring particular attention is a focus on writing in and to student learning.

The discipline of Science, and more broadly STEM (Science, Technology, Engineering and Mathematics), is an area of intensive research and rapid growth in knowledge. The nexus between science research and science education is complex, with many scientific researchers also involved in science education. Advancements and achievements in science are often used as the basis of content delivery in higher education, ensuring students are kept abreast of the latest developments in technology and scientific discovery. However, this ever-increasing volume of highly complex material presents a challenge to educators. How are they to enable learners to access current and relevant content while developing scientific literacy and critical thinking skills, supposedly required by employers? Some of the answers to these multiple goals and imperatives is found in the trope of authenticity. Authentic science, authentic experiences and authentic examples provide meaningful learning that is relevant and contextually rich and diverse. Authentic experiences combine the variety of forms and literacies necessary to engage multimodality, multiliteracies and context into a single, meaningful learning experience. The next section of this article explores how authenticity can provide opportunities for students to move from novice to expert within a discipline, using carefully scaffolded experiences to support the development of disciplinary literacy.

4. The STEM Lens

Scientists maintain deep connections to their disciplines, (Davis & Wagner, 2019). Research indicates that a strong identity is tied to a sense of belonging, self-efficacy and confidence within the discipline (Robnett et al., 2015). These deep connections to an academic discipline form a disciplinary identity and develop through disciplinary socialisation (Wilson et al., 2012). The student's intrinsic self-confidence must be above a certain threshold before the confidence from disciplinary literacy can be developed. But with increased diversity (of background knowledge and skills), the need for self-confidence development is becoming increasingly important. This lack of student confidence can trigger superficial learning and assessment measures. That is one reason why Professor Maitland Jones was questioned by students at New York University. If a course is labelled ‘too hard,’ then there are many causes for this determination, including student self-confidence. Student self-confidence has not – historically – been a university’s problem. However, unless pre-requisites and considered pathway programme are in place, standards will drop and student dissatisfaction will increase.

As scholars learn how to perform within our discipline, we become enmeshed within it. Immersed in and transformed by our discipline, we can lose sight of the constructs that underpin the way we value and produce knowledge. Constructs such as scientific methods become part of our everyday thinking within a discipline. These unspoken assumptions, enabled through secondary socialization in classrooms, labs and via fieldwork, frequently configure a singular way of viewing, interpreting and understanding the world.

Wolfe (2017, p. 75) suggests that "to begin to address this issue … you have to have a theory of disciplinarity, and in particular of how knowledge production happens in the contemporary university." Yet Science Education requires two large, complex and diverse disciplines to dialogue. To provide one example, the word 'theory' reveals diverse connotations throughout these disciplines.

Stephen Grimm (2016, p. 1) described the innate differences in how we understand humans and the natural world when he stated that, "When it comes to human beings, the thought seems to be, our goal is not simply to explain or predict their behavio[u]r, as we might explain or predict the behavio[u]r of rocks or stars. Rather, our goal is to understand why people act the way they do, and in order to understand their actions we need to adopt a different stance—a different methodology—than we find in the natural sciences." Divisions are currently being revealed between philosophers, with more recent movements towards a naturalistic view "that denies that there is something special about the social world that makes it unamenable to scientific investigation" (Kincaid, 2012, p. 1). While there may be a profound impact of disciplines on human thinking and behaviour, there appears to be consistency in how this develops that transcends disciplines themselves. Therefore, the social world can be explored through scientific methodologies, and enhanced through the development of disciplinary literacy. This metacognition necessitates an evaluation of how and why empirical evidence has been collected, analysed and interpreted.

'Theory' outside of universities reveals problematic understandings. With the phrase 'it's just a theory' or 'I have a theory' commonplace among the broader community, high levels of confusion emerge around scientific meanings, even among science school teachers (Williams, 2013). A theory in the scientific sense explains the world around us by applying a strict set of criteria to measure and evaluate empirical evidence. It is not simply an idea but rather is formed only after many observations and measurements that show a consistent trend. A scientific theory is defined by a vast body of supporting evidence that explains phenomena. Incorporating many hypotheses, scientific theories are based on the careful examination and interpretation of facts. Empirical data or facts are balanced in the context of discovery, via interpretations in relation to the theory. As Swedberg argued, "The core idea behind this distinction is that there comes a moment in your research when you develop your main insight. This insight, however, cannot be presented in the form in which it occurs; it is much too intuitive and underdeveloped for this (i.e. 'context of discovery'). For this insight to become acceptable to the scientific community, it has to be translated into a different language, often in the form of hypotheses that are confronted with data ('context of justification')" (Swedberg, 2016, p. 8).

Kincaid (2012, p. 2) suggests that key tenets of positivist philosophies of science are that "a mature science ideally produces one clearly identifiable theory that explains all the phenomena in its domain. In practice, a science may produce different theories for different subdomains, but the overarching scientific goal is to unify those theories by subsuming them under one encompassing account." In practice, Kincaid confirms that, "scientists certainly can act as philosophers, but the philosophy and the science are different enterprises with different standards. The corollary is that philosophy of science is largely done after the science is finished." However, as Kincaid (2012, p. 3) argues, "often we find no one uniform theory in a research domain, but rather a variety of models that overlap in various ways but that are not fully intertranslatable." Theories may complement or oppose, or simply not fit context. A theory that may

explain phenomena at a molecular level may not hold at the ecological level. Context is sensitive. Positionality, viewpoint and the scholarly lens are crucial. Additionally, science is not fixed. Theories and methods are debated as philosophers of science consider the nature and purpose of scientific investigations, in contrast to the widely-held perceptions that scientific methods are set and theory does not change over time. Kincaid (2012, p. 5) also points out that "philosophy of science is something that scientists themselves do, and in a sense, science is something that philosophers of science do." Whilst scientists are clarifying theoretical concepts, they use empirical methods, verifying how researchers think and practice science. The nature of the questions asked and answered in scientific exploration limits the type of knowledge that can be developed.

A scientific theory is influenced by the lens through which it is viewed. The discipline controls which facts are valued over others and how these should be interpreted. While scientific methods attempt to reduce the influences of the observer, they can never be fully removed. Science has long stood on the building blocks of facts as described by Ivan Pavlov in his final work: "No matter how perfect a bird's wing may be; it could never make the bird airborne without the support of the air. Facts are the air of the scientist. Without them you will never be able to take off. Without them your theories will be barren" (Green, 2016). For scientists, research is viewed as the tool with which to support or refute a theory. The theory itself is independent of influencing the scientist. Within a discipline, the lens is invisible. It is the way of seeing. Facts are facts. There is no alternate view. So deeply is the practice of being a scientist entangled within the person and the practice that it becomes indistinguishable. As Grimm has shown,

> it is not the practice of science itself that understands, but instead the individual practitioners—i.e., scientists .... scientists themselves understand by 'taking up' or cognitively appropriating these relationships in the right way—by being able to apprehend how these relationships work, and by being able to put them to good use, for instance, in making accurate predictions…. Meanings are therefore only properly appreciated from the "inside." The distinctive nature of the object—meanings—therefore gives rise to the distinctive way in which these meanings are taken up or appropriated, namely by participating in certain forms of life. (Grimm, 2016, p. 1).

The notion that there is a single version of a fact, or truth, is the foundation of scientific research and separates scientific and educational theorising such that "scientific knowledge was seen as general and abstract in form: consisting of laws that capture relations operating across all times and places" (Hammersley, 2012, p. 23). Scientific knowledge, when free of bias, is viewed as independent from the subjectivity of the researcher, an objective and singular fact or truth. Yet, this viewpoint is itself an example of a singular version or fact, configuring educational theory as based on something other than developing meaning from observation. Instead, within the social sciences and humanities, theories are an interpretive tool to understanding, explain and extend an idea, phenomena, context or event.

Within educational philosophy, the term theory has a different meaning. Rather than a theory developing from a body of evidence based on empirical data, a theory may not be able to be empirically tested. Educational theories provide multiple lenses through which meaning can be made about phenomena. Educational theorists recognise the existence of these multiple lenses which are often ignored in scientific research. Unlike in the natural sciences where one (or rarely, a few) theory(ies) help to explain a series of

events, in the field of education there are many and varied theoretical ways of understanding teaching and learning.

As educators, theory is a way to create, explain and justify our practices. We are guided by theory in understanding how students learn and use theory to develop a set of principles that can be applied through curriculum design. What is designed and observed, and the evidence collected, is interpreted through the lens of theory. While there are practitioners that view educational theory as simply a way to "explain and justify" educational practices (Carr, 2006, p. 137), this perspective is not common. In tertiary education settings many educators find themselves teaching without formal qualifications. Through their ignorance, they are disconnected from educational theory. We do not know what we do not know. They are experts in the discipline they teach, but ill-equipped to enact educational theory in a classroom. Unless sweeping policy changes emerge that will require tertiary educators to undertake additional training, it is unlikely that practices will change. Therefore, educational research must be made accessible to academics, and greater efforts required to disseminate these refereed publications. The challenge is translation. By building connections between disciplines – with authenticity – university academics can focus on their specialty content, while understanding good practice that is supported by research and theory.

In the late 1990s and through to the early 2000s, there was much debate about the role of theory and methodology within the discipline of education (Berliner, 2002), stemming from the introduction of the No Child Left Behind policy in the United States of America 2001. A focus on evidence-based practices aimed to identify which educational practices work well in classrooms (Biesta, 2007). This imperative emerged to placate policy makers at the time, who were unsatisfied with a perceived lack of evidence in teaching practices. Unlike the natural sciences, education is embedded with the specificities of individual teachers, schools, and societal groupings (such as class, race and family structures) that influence students' achievement far more than educational pedagogy (House et al., 1978). The diversity observed in educational settings is far greater than would be normally considered within scientific contexts.

There is a long-standing controversy that has existed between Education and the Sciences. As Berliner (2002, p. 18) confirmed,

> Educational research is considered too soft, squishy, unreliable, and imprecise to rely on as a basis for practice in the same way that other sciences are involved in the design of bridges and electronic circuits, sending rockets to the moon, or developing new drugs.

Disciplinary bridges are difficult to build and maintain. They require a movement beyond comfort, experience and past practice. Therefore, quantitative results alone will not do justice to science education research. Educational settings summon qualitative information that adds strength and flexibility to our understanding and interpretations. Educational researchers have the added complexity of managing the individual influences of their student cohorts, including those that vigorously reject research findings, and students that do not slot into normative behavioural patterns or learning strategies. Without subtle interdisciplinarity and careful alignments of qualitative and quantitative research, student diversity will be lost. If there is one way of learning, then Indigenous and First Nation students, older students, rainbow students, and students with an impairment or disability – just to name a few learning communities – may be squeezed out of the normative science education model (Brabazon, 2018). The variation in educational

settings is enormous, and if presented in a traditional scientific study would likely render the results non-sensical, unable to be interpreted due to unacceptable levels of 'noise'. Yet learning must take place, and motivations may be irrational, inconsistent, confused and confusing. As Berliner (2002, p. 18) describes,

> we have the hardest-to-do science of them all! We do our science under conditions that physical scientists find intolerable. We face particular problems and must deal with local conditions that limit generalizations and theory building—problems that are different from those faced by the easier-to-do sciences.

This is learning in the contemporary university. It is not comfortable. But it is meaningful.

To understand and activate educational theory, researchers must grasp and apply the concept of interpretivism, which describes how a researcher must draw on their own social experiences. Interpretivism underpins the uptake and embedding of educational theory into educational design because individuals will naturally draw on their social experiences to inform their practice. Hammersley (2012, p. 26) describes this as emerging when

> studying the social world it is essential to draw upon our human capacity to understand fellow human beings 'from the inside' – through empathy, shared experience and culture, etc – rather than solely from the outside in the way that we are forced to try to explain the behaviour of physical objects.

For those outside of the education disciplines, educational methodologies, epistemologies and ontologies may be filled with "unfamiliar paradigms, language, research approaches and methods and perhaps also may challenge … understandings of 'validity'" (Cleaver et al., 2018, p. 5). The configuration of evidence and what can and should be considered appropriate evidence (Kvernbekk, 2016) is a key difference between scientific and educational theories. Understanding and translating between these disciplinary literacies is integral to creating a matrix of agreed terms and definitions to enact research, and change through learning and teaching.

5. Conclusion

This article commenced logging Tom Nichols and his monograph, *The death of expertise*. We also acknowledged the resignation of Professor Maitland Jones and the petition against his teaching in an organic chemistry class. Higher education teaching and learning are so difficult to discuss because they require dualling – and often duelling – literacies. Between disciplinary and educational literacies is a space for conflict and confusion. This space also enables dynamism, energy, excitement and transformation. Expertise is crucial, as confirmed by Nichols. However, to teach well in universities requires at least two disciplinary literacies, and they must be aligned through expertise, rather than experience, and authenticity rather than superficiality.

At its best, the dialogue between disciplinary and educational literacies creates a theoretical space that is dynamic and mobile, able to transfer to a variety of learning environments. Whilst this research is deeply nested within a scientific context, the process of performing this dialogue and creating – and holding – this interdisciplinary space will transform learning and teaching in higher education. Disciplinarity is

crucial for learner development, and formation of learner identity, yet "disciplines are calcifying, rigid and reifying. Post disciplinarity is creating space and opportunities for innovation" (Redhead, 2018, p. 40). To be aware of disciplinary constraints and limitations is freeing and will enable this research to be truly transformative in the post disciplinary space. Through acknowledging the limits of disciplinary literacy, authentic learning can be activated.

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