Advances in Transdisciplinary Engineering series

Volume 60

Engineering For Social Change

Proceedings of the 31st ISTE International Conference on Transdisciplinary Engineering, London, United Kingdom, 9-11 July 2024

EDITED BY
Adam Cooper
Federico Trigos
Josip Stjepandić
Richard Curran
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ENGINEERING FOR SOCIAL CHANGE

Advances in Transdisciplinary Engineering

Transdisciplinary engineering is the exchange of knowledge about product, process, organization, or social environment in the context of innovation. The ATDE book series aims to explore the evolution of engineering, and promote transdisciplinary practices, in which the exchange of different types of knowledge from a diverse range of disciplines is fundamental. The series focuses on international collaboration and providing high-level contributions to the internationally available literature on the theme of the conference.

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Preface

We are delighted to disseminate in this book of proceedings a collection of peer-reviewed papers presented at the 31st ISTE International Conference on Transdisciplinary Engineering (TE2024), held during July 9–11, 2024, at UCL's East Campus, United Kingdom. The conference was organized by UCL's Department of Science, Technology, Engineering and Public Policy (STEaPP), with support from the UCL Centre for Engineering Education (CEE), United Kingdom, and in collaboration with the International Society of Transdisciplinary Engineering (ISTE).

TE2024 brought together more than 100 participants from reputed educational institutes and well-known global corporates located in 21 countries across five continents to set an international forum for academics and industry professionals to exchange their knowledge and ideas connected to the conference theme ***"Engineering For Social Change"***.

You may well ask, what do you mean by 'social change'?

We wanted to explore how engineering design and manufacturing processes – whether they are digital twins or systems models, new innovations or the use of machine learning – can be turned towards a wider good? How can product design be better, not just for the business wanting to make a new, better version, but also for wider society and for the environment more generally? How can systems approaches address these challenges and what are the ethical, philosophical and justice considerations hidden in them? What is the role of the engineer in this? How do we train or educate engineers to see the opportunities for inclusive design, sustainable construction or ethical manufacturing? What skills, analytic approaches, design or collaboration practices are effective? What challenges are encountered in working across boundaries – between academia and industry, interdisciplinary practice experiences and insights, especially with the social sciences.

And how then does this relate to 'transdisciplinary engineering'?

Transdisciplinary Engineering is an emerging approach that extends and evolves the initial basic concepts and practice known as Concurrent Engineering (CE). CE has matured and has become the foundations of many new ideas, methodologies, initiatives, approaches and tools. Generally, CE concentrates on enterprise collaboration and its many different elements; from integrating people and processes to very specific complete multi/inter/trans-disciplinary solutions, taking the user into account. Current research in this area has evolved to be driven by many factors like increased customer demands, globalization, (international) collaboration and environmental strategies. The successful application of such research in the past has opened the perspective for future applications like overcoming natural catastrophes, sustainable mobility concepts with electrical vehicles, and intensive, integrated, data processing, with an increasing importance of Transdisciplinarity. Here, 'transdisciplinarity' can be formally described as:

“Transdisciplinarity and its application through Transdisciplinary Engineering methods involves the integration of two of more disciplines in an application through both the sharing of both common drivers and goals, into a higher-level transdisciplinary process that combines these and other drivers with the aim of achieving a common goal and output characterized by formalizing and structuring the explicit and tacit, scientific and contemporary, management of knowledge for a holistic goal that is characterised and defined at the highest system level and from all perspectives”[1].

And equally, how do we approach ‘engineering for social change’?

Well, engineering plays a direct and indirect role in shaping the lives of everyone in all societies. The kinds of objects and processes that engineers design or maintain or dispose of reflect the kind of society we have. This includes the way in which design and management of engineering allows or prevents different types of people from benefiting from them or bearing the risks generated by them. For TE2024, we took inspiration from UCL STEaPP and UCL CEGE's new undergraduate degree programme - BSc Science and Engineering for Social Change - to provide a focus for the conference theme. So, if your work normally involved testing or designing a new object or process, such as ways of making an industrial process more efficient, or creating a new product design that makes it simple to manufacture, we asked people to submit a paper that did any of the following:

- reflect on **who benefits** (or who bears what burden) from this analysis or innovation? Is it just the product or process owner? Who else could benefit if the design or approach were different? What challenges does that present for your analysis?
- are there opportunities for the design to be **more sustainable** by using less energy, cleaner inputs or outputs, less waste?
- are there opportunities to make the product or process **more accessible** to different groups of users or even new product designers? Who is in control of the product or process?

How democratic is that, and should - or could - it be?

And that is exactly what 126 authors did and the 103 participants gathered at UCL East for TE2024 to explore our theme of ‘engineering for social change’. We saw an incredible array of papers addressing this topic and the broader field of transdisciplinary engineering in the context of enormous sustainability challenges, and the role of autonomous vehicles, renewable energy and machine learning to support energy planning. We saw a strong focus on the role of digital technologies in industry and the challenges of integrating new systems into old processes, taking account of both worker needs and looking to use technology to maintain and improve wellbeing. This year also saw the first time the TE community gathered with the related community on Transition Engineering – which sees transdisciplinary engineering as a mechanism by which better

[1] Curran, R., Foundations of Transdisciplinary Engineering Theory: Sustainable Airport Application. In: Proceedings of the 31st ISTE International Conference on Transdisciplinary Engineering, London, UK, July 9–11, 2024, Advances in Transdisciplinary Engineering.

– more sustainable, fairer and more inclusive – engineering can be achieved. And that is the kind of social change all engineers should have an interest in.

Adam Cooper
Irina Lazar
Richard Curran
Federico Trigos
Josip Stjepandić

About the Conference

Peer review statement

Number of submitted papers: 144
Number of accepted papers: 102
Acceptance rate: 71%

Committees, Organizers and Sponsors

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Organizer

University College London, United Kingdom

Past Transdisciplinary Engineering/ Concurrent Engineering Conferences

2023: Hua Hin Cha Am, Thailand
2022: Cambridge, USA
2021: Bath, UK
2020: Warsaw, Poland
2019: Tokyo, Japan
2018: Modena, Italy
2017: Singapore, Singapore
2016: Curitiba, Brazil
2015: Delft, The Netherlands
2014: Beijing, China
2013: Melbourne, Australia
2012: Trier, Germany
2011: Boston, USA
2010: Cracow, Poland
2009: Taipei, Taiwan
2008: Belfast, UK
2007: Sao Jose dos Campos, Brazil
2006: Antibes-Juan les Pins, France
2005: Dallas, USA
2004: Beijing, China
2003: Madeira, Portugal
2002: Cranfield, UK
2001: Anaheim, USA
2000: Lyon, France
1999: Bath, UK
1998: Tokyo, Japan
1997: Rochester, USA
1996: Toronto, Canada
1995: McLean, USA
1994: Pittsburgh, USA

Sponsors

UCL Department of Science, Technology, Engineering and Public Policy (STEaPP) mobilises science, technology, engineering and policy expertise to help change the world for the better.

UCL Centre for Engineering Education (CEE) brings together UCL's Engineering and Education Faculties, in figuring out how to get more engineers into the UK economy.

International Society of Transdisciplinary Engineering (ISTE)

Conference Topics

The invite to participate at TE2024 went out to engineering researchers, educators and industry practitioners, and researchers of engineers and engineering, to submit abstracts addressing questions, challenges and solutions, and/or related issues in transdisciplinary engineering.

Topics historically of interest to the TE community are always welcome, and those highlighted for TE2024 included:

- Research & systems analysis
- Product & process design
- Decision support tools
- Education, lifelong learning and skills
- Risk and knowledge management
- Collaboration, management & teamworking
- Smart systems, IoT and Industry 4.0/5.0
- Megatrends and new methods

However, we also invited new collaborators from industry & non-engineering academia to explore areas such as:

- Engineering practice in industry & policy
- Design research & interdisciplinarity
- Engineering ethics & philosophy
- Business practice with engineering
- Engineering activism & justice
- Engineering consultancy
- Engineers in non-engineering organisations
- Development engineering

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Transdisciplinary Engineering Education: The Student Perspective

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Abstract. Engineering problems are becoming increasingly complex, ill-defined, and socially relevant, and thus require us to combine insights and methods from different disciplinary fields, and to seek input from non-engineers, including communities and public organisations. If graduates are to be successful in working towards such problems, they need to develop meta-disciplinary skills, attitudes and understanding, and learn how to talk critically across disciplinary perspectives. Teaching the required competencies explicitly is essential because students are unlikely to have learnt them previously, primarily because of the focus on disciplinary teaching within most education systems. Supporting the evolution of engineering practice and emergence of transdisciplinary engineering therefore necessitates a change in teaching and learning methods. One approach to this has been the emergence of interdisciplinary and transdisciplinary programmes primarily at postgraduate, but increasingly at an undergraduate level. Such degree schemes are relatively understudied due to their recent emergence. This paper reports the findings from the first part of a longitudinal study into the lived experiences of students studying on a transdisciplinary undergraduate programme and focuses on expectations and motivations of incoming students. Data was obtained from semi-structured interviews with first year students. A summary of the perceived benefits of studying such courses, as well as the associated challenges, is provided. The paper ends with recommendations in terms of fostering transdisciplinary approaches to engineering education.

Keywords. Education and training, transdisciplinary, engineering education, transdisciplinary skills and competencies, student perception

Introduction

It is now widely accepted that the complex socio-technical challenges faced by society necessities a departure from traditional programmes available within higher education institutions (HEI), which primarily focus on domain-specific knowledge and development of transferable skills. Although the specialist disciplinary expertise currently supported by university cultures and structures remains critical, there is increasing emphasis on preparing students to work across disciplinary boundaries [1] [2].

There has thus been a growing focus on interdisciplinary understanding or what Mansilla and Duraising describe as [3] "the capacity to integrate knowledge and modes of thinking in two or more disciplines or established areas of expertise to produce a cognitive advancement – such as explaining a phenomenon, solving a problem, or creating a product – in ways that would have been impossible or unlikely through single disciplinary means" (pp. 219), and transdisciplinary approaches, which are typically considered to be more pragmatic in nature, and move beyond academic disciplines, involving a wider range of (non-academic) stakeholders.

1. Approaches to inter and transdisciplinary education

Various approaches to the incorporation of interdisciplinary and transdisciplinary learning experiences exist within HEIs. For example, in some locations (primarily USA) students study a broad variety of topics before specialising, whereas in the UK students typically choose one (or two in the case of joint honours) main subject(s) of study. Conversely, some degree programmes, such as geography, are already considered interdisciplinary in nature. One approach to interdisciplinary education is to provide students with additional specialist knowledge and perspectives to supplement their existing disciplinary knowledge, for example through optional modules in external departments. Such approaches have been considered as lacking integration and being more reflective of multidisciplinary education. In comparison, interdisciplinary and transdisciplinary educational offerings may come in the form of individual modules or, increasingly, fully integrated programmes. Whilst such approaches are more common at postgraduate level, an increasing number of initiatives can be identified at an undergraduate education. In such instances, there is a need for educators to focus on understanding the extent to which students should be equipped with different disciplinary knowledge in addition to the didactic approaches that enable integration [4].

The disciplinary approaches which dominate much of the education system result in a need to ensure the explicit teaching of the skills and attitudes required to engage in such work. For example, students will have to understand, take account for, and be critical of, different perspectives and must develop the ability to synthesise information across domains. Such abilities require a level of knowledge as to the problems certain disciplines address, and the methods, epistemologies and ways of thinking involved.

There are varying options regarding the extent to which disciplinary depth constitutes a prerequisite to interdisciplinarity work. For example, Golding argues that disciplinary expertise is not necessary, and that efforts should focus on fostering an ability to identify when disciplinary expertise is needed and to access and use it [5]. In comparison, interdisciplinary founded on disciplinary depth requires students to draw upon their own disciplinary expertise, as well as interdisciplinary skills.

To better understand the benefits and challenges associated with these emerging educational offerings, it is important to explore the views of stakeholders involved, including students. To date, work which focuses on the experiences of those enrolled on inter and transdisciplinary programmes tends to consider postgraduate education. For example, Abbonizio and Ho explored the effect of students' incoming disciplinary background on their experience studying an interdisciplinary taught postgraduate programme [6]. Students considered benefits as associated with career relevance and expanded knowledge and perspectives of issues, whereas challenges were linked to jargon, knowledge barriers and clashes in perspective, including norms associated with teaching and assessment in different subject areas. The participants of a different study [7] believed that learning from each other, particularly in terms of disciplinary language, allowed them to reach objectives associated with a given problem. The authors [7] call for the "interdisciplinary nature" of programmes to "be visible in the curriculum and in the teaching", with a focus on "explaining interdisciplinary terminology, visualizing the interdisciplinary context, describing differences between disciplinary and interdisciplinary work, and proposing a methodology for students to use when working in an interdisciplinary mode" (pp. 9).

In comparison, undergraduate degree schemes are relatively understudied due to their recent emergence. Students enrolled on such programmes are less likely to be encultured in disciplinary fields or have preconceptions about other fields, and it is therefore probable that they experience different benefits and challenges to interdisciplinary learning than those at postgraduate level. This work therefore aims to answer the following research questions (RQs):

RQ1: Why do students choose to study transdisciplinary undergraduate degree programmes and what informs their decision making?

RQ2: What are the expectations students hold of both transdisciplinary education and subsequent opportunities and challenges which arise?

2. Method

2.1. The research and the researchers

This study constitutes the first part of a longitudinal project focused on the experience of students throughout their study on a new transdisciplinary undergraduate degree programme at a UK based Russell Group university which has been described previously elsewhere [8]. In brief, the programme uses project and problem-based approaches which allow students to apply technical and social science skills to contextualise learning.

The study adopts an interpretivist constructionist approach [9], [10] to understand the meaning participants draw from experiences over a variety of contexts. In-depth interviews were used for data collection to provide an opportunity to explore subjective meanings, experiences, and specific details of participants [10]. A semi-structured interview protocol was developed to ensure coverage of key research questions and dimensions of interdisciplinary education identified in the literature, but also allowed the opportunity for the interviewer to guide the discussion in directions not previously considered or that were interpreted as meaningful for the interviewee. Questions focused on participants' prior educational experience, their reasons for enrolling on the course, and their understanding of interdisciplinary and expectations of the course.

In keeping with calls to ensure qualitative research is communicated in such a way that allows readers to understand how researchers arrive at their conclusions, the authors outline aspects of their positionality in relation to the six fundamental aspects of research which positionality impacts, as outlined by Secules et al. [11]: research topic, epistemology, ontology, methodology, relation to participants, and communication.

Natalie Wint (She/Her): I am currently an engineering lecturer whose research focuses on engineering education. I was trained and socialised within a positivistic paradigm, having previously conducted research in the field of materials engineering. When teaching engineering students, I tend to lean on ideas from other disciplines, for example policy, sociology, psychology, as well as economics and business management. I also consider ethical and sustainable practice and pose questions about who, and what, engineering is for. In part, the interest in this research is born out of the frustrations experienced when faced with a perceived choice between studying 'STEM' based disciplines, and those associated with arts and humanities and the social sciences, as well as conflict between personal and professional identity.

Irina Lazar (She/Her): I am an Associate Professor in engineering and public policy, with a background in civil and mechanical engineering, and professional education in public policy at a later career stage. For me, interdisciplinarity came into play organically, as a consequence of working at the interface between multiple engineering disciplines. My transdisciplinary work started as I shifted from engineering to public policy in an engineering context. I largely identify as an engineer, and my path is fundamentally different to that proposed in the degree programme this paper focuses on. This research stemmed from a desire to understand how professional identities develop within transdisciplinary context at undergraduate level, rather than by integrating and layering multiple disciplines. This is meant to help the programme team better articulate the programme to prospective students, as well as support them once enrolled.

Having worked at the interface of social science and engineering, the authors wanted to bring together the experiences of others in a similar position. During the writing and review process, they were reminded of the continuous nature of such work. In outlining their positionality, the authors acknowledge the limitations associated with their own academic background within STEM disciplines and the need for collaboration across disciplines. They also recognise the challenges associated with multi/inter/transdisciplinary research, for example, those associated with 1.) questions pertaining to the point at which one becomes a 'legitimate' researcher within a new field, and 2.) differences in disciplinary 'norms' and expectations associated with peer review which, at times, necessitates a 'brokering' process [12].

2.2. Procedure

All 15 students enrolled on the programme were emailed an invitation to take part in the study within the first five weeks of the programme. Five individuals provided informed consent to participate (in line with ethics approval granted). 4 identified as female, and 1 as male. All were international. Further details regarding participant demographics are not given here due to the small population and sample size.

Interviews took place online or in person, according to the preference of the participant and each lasted approximately 30 minutes. After completing interviews, the audio recordings were transcribed verbatim and read by the first author. The first author made regular journal entries throughout both data collection and transcription allowing them to consider their role in the research process. Whilst re-reading each transcript, notes were made (as comments within the Microsoft Word document) about ways in which they were interpreting and making sense of the data.

Interview transcripts were analyzed using reflexive thematic analysis (RTA). RTA is generally considered a useful method during the study of under-researched areas and is viewed as reasonably accessible. This is believed to be important when considering 1.) the varied audience of research of this type; and 2) a relative lack of any consensus as to acceptable theoretical frameworks or research methodologies for use within the space. The authors followed the six-stage analytical process proposed by Braun and Clarke [13]. An abductive approach to data analysis was adopted and thus coding was both driven by data (inductive) and by theory (deductive). Code generation initially followed an inductive approach (whilst recognising that pure induction is impossible). Later, the first author began to notice connections with the literature and started coding around theoretical ideas and concepts. All codes were noted, and in some cases, combined, ensuring that the nuanced differences were not lost. A list of final codes and the data items associated with each was then compiled. Initial themes were generated, and a thematic map was produced to allow for visualisation of the relationships between codes and themes. Data extracts which represented the themes were then selected.

3. Findings

Three overarching themes were generated 1) dualisms and hierarchies 2) self-assured but outwardly uncertain and 3) breadth vs depth. Excepts featured within the findings have been labelled (1)-(5) to allow readers to identify quotes from the same participant.

3.1. Theme 1: Dualisms and hierarchies

This theme focuses on the perceived existence of disciplinary hierarchies and a dualism which was believed to exist between STEM (science, technology, engineering, and mathematics) and AHSS (arts, humanities, and social sciences).

Students tended to place more emphasis on STEM subjects, attributing this to how much they enjoyed the subjects and the positivism with which they are associated, one student saying "like, moments where all these theories make sense. And you know, calculations make sense…those kinds of moments really were enjoyable for me" (2). This enjoyment seemed to be reinforced by the fact that STEM subjects, in general, were considered to improve career prospects, with one student saying, "science or engineering seemed to be like, broad enough for me to be going into basically anything I want afterwards" (4). A different participant highlighted the role of culture saying that engineering degrees were "especially" (2) valued within their home country as graduates were highly likely to get a job.

Despite students choosing to study a transdisciplinary course, in general, there appeared to be a belief that you could not study both STEM and AHSS subjects. For example, one participant stated that the GCSE subjects they had chosen to study (aged 14-16) meant they were "more of like a science person. I never really thought about social sciences" (1), later adding "sociology was the different one for me" (1) when describing their A-Levels. They described this choice as "very difficult, because it's not the mix anybody ever expects" (1), saying their father had questioned "why am I deviating" (1).

For some participants, subjects that fell within AHSS were considered as interests or hobbies as opposed to legitimate fields of study. For example, one student said that there was "kind of a click where I realized that. Maybe like. yeah, like, art, literature, Econ(omics), all of that didn't have to be just like hobbies. I could also like, integrate them into my studies" (4) later saying that their subject choices were driven by "the money factor" and "that if money wasn't a factor, I would have said something completely different" (4), with respect to the reasons they chose STEM subjects. Another participant explained how their interest had been instigated by comparing the political systems in countries in which they had lived, saying it was "very interesting" (3).

These beliefs appeared to be associated with societal perception and views of others. The same student that mentioned art as a hobby also said that "sciences in general, are always like very respected, like people are always a bit impressed when you tell them that…. But yeah, like art, for example, is not always well looked at, because it's a really uncertain area" (4). Another participant claimed that "society does have a very positive perception on math and further math. And I also think that's the same, like similar for politics, but I would say math is like a higher level" (3). They went on to highlight the importance of the programme being "a science bachelor" (3).

One participant explained that the way in which disciplines are defined across contexts may mean that there is a lack of clarity around what is involved in transdisciplinary courses. They described how they "also had that kind of set mind that science meant natural sciences... so, I kind of went in with that mindset and came to that to realize that there's a heavy focus on social sciences. So that's kind of a concern in my family" (2). The same participant stated that they were "conflicted whether to choose chemistry to go for completely scientific pathway or kind of, you know, broaden my options" (2). The existence of such dualisms may explain why "some people want more maths and physics" (1) in the course, with one student saying that "lack of natural science and engineering is a big concern" (2). The degree to which this student was influenced by this hierarchy was also demonstrated later by their belief that the inclusion of STEM would mean they felt less "concern for my future career" (2).

In most cases, the reasons to 'broaden' subjects of study were associated with working on "actual world" (2) problems, with one participant claiming to have a "more problem-solving mindset" (5). The societal nature of problems also seemed to be important, with one student saying, "I do like anything related to society" (1) and another that "humans, you know, make your world function" (2) and that they wanted to "pursue my interests other than engineering and looking at the actual world…actually coming up with ideas that can, you know, potentially change the world" (2). For one student the motivation came as a result of "being very interested in inequality" (3)

3.2. Self-assured but outwardly uncertain

This theme focuses on the way in which participants tended to describe their own confidence in their decision-making, whilst, at the same time, reflecting on their confusion and uncertainty. It is split into two sub themes.

The first subtheme focuses on the uncertainty associated with initially deciding to enroll on the course. Much of the language used appeared to be associated with having faith and trust. For example, one student described an "affinity" towards a course which was "made for them" (1). They later said, "I believe I'm feeling the right thing for me at this time" (1). Although they mentioned people who questioned their decision making, they explained that being "grounded" and "dedicated" (1) allowed this to have limited impact. One student was just willing to "have a try on this course" (5), having already completed the first year of a different degree and later saying "I'm still young, and I have a lot of time to try different things" (5).

It is worth noting that, for some, the decision to study the course was more associated with the location and university. This presented in three different ways: 1.) students were studying this course because they had not been accepted for their first choice at the same university, 2.) students would not have been interested in studying similar programmes elsewhere and 3.) had they not been accepted on this programme, they would have chosen to study a more 'traditional' degree programme, but at the same university.

Although parents were generally not seen as having a major influence, "let(ting) me do what I wanted" (2) and were described as "very supportive" (1), some spoke of a need to be "convincing" (1) and that they "sold the idea" (1) and had to "pitch" the course. One student said that their parents were their biggest influence and had they not agreed with the course choice they would "probably have to rethink a bit, or maybe like present the course to them in more detail" (3). For some participants, the confidence in their own decisions appeared to be associated with being a new generation who were ahead of the curve. For example, one participant claimed that they had had to tell their dad, an engineer, that “your time has kind of passed. And now we kind of find a way of bringing new things in” (1). A different participant believed “interdisciplinary should have always been bigger thing from the start. We are kind of starting to realise the urgent need of interdisciplinary work” (2). A different participant believed this would change saying “it is still something that's very new…so, I think that in like 5 years, maybe, like, it will become something like more normal, and it will eventually become an advantage because of right now I'm not completely sure because it's so like unusual” (4).

The perceptions of friends were often associated with the complex and long course name and the fact that most people are only aware of traditional courses, or that transdisciplinary courses tended to be available only at postgraduate level. The disciplinary nature of traditional undergraduate programmes was also considered to cause pragmatic issues with the application process UCAS (which operates the application process for British universities), whereby one personal statement should be submitted for all programmes for which students apply, and in this case, meaning that they could not be easily personalised for transdisciplinary course.

Despite this apparent confidence and self-assurance, it was still important for participants to feel reassured, with one participant saying they felt “a bit better about my choice” (1) after talking to a close family member who was also an engineer.

The second subtheme focuses on uncertainty whilst on the course. Such feelings were typically associated with either career opportunities or experiences of learning, teaching, and assessment. Participants described being “confused” (1) about job roles available and that they were “not quite sure what other path there is that this course has to offer?” (3), or “not completely sure of what new opportunities this course gives me, like what areas I could go into” (4). Another said they would need to go about “convincing employers you are unique in a good way” (2). It is important to note that although this uncertainty existed, a benefit of the course was perceived as its flexibility, and it was considered “broad enough for me to be going into basically anything I want afterwards” (4). As with the decision to study the course, participants appeared to have faith in the process, for example saying that “it always works out, doesn't it?” (4).

One participant explained that the “transition (to university) is difficult as well as learning. It’s a few different things at the same time and can make somebody feel overwhelmed” (1). The challenges associated with interdisciplinary learning is perhaps best articulated in the following excerpt:

“What are we meant to learn from this? And how can we apply this in other areas and in terms of interdisciplinary I think, it is confusing. Especially when you go from one class to the other, and there's like one thing from somewhere, the other thing from another place like, how does this all come in? It's so confusing, like, everybody is like, where is this getting us like, okay, we've learned this. So, I think that's where the confusion comes in, and it's like, what exactly am I doing? Did I join the right course? And then you start having these deep thoughts…” (1).

As was true of the process associated with selecting the course, participants tended to make use of their own self-assurance, for example saying “I do feel like I'm trusting in the process. And I feel like they have, or the course has more to offer us” (1).

3.3. Breadth vs depth

This theme focuses on the perceived advantages and disadvantages of studying a transdisciplinary course.

For most participants the benefits of transdisciplinary programmes were related to the complexity of problems which needed "simplifying" (2), and for which there was often "more to it" (1), and it was believed that "if you don't really think of things in different perspectives or different areas, you would not be able to solve a problem the way you would want to" (1). Wicked problems, sustainability, and climate change were also mentioned. In terms of policy, transdisciplinary was associated with the ability to "come up with very well-rounded policies" (3).

Being "scared about the employment benefits" (1) appeared to be counteracted by "benefits…in terms of skills having an open mind, not necessarily tunnel vision…communicating your ideas to people" (1). For most, this approach involved teamwork, whereby "you're kind of trying to overlook through the whole process and being able to understand most of the things that are happening. It is a really good thing with the kind of general knowledge of like diverse topics" (2) with one participant saying that "a lot of traditional courses don't really have that. They're like more technical. And they need to know the numbers on this and that, or they forget that they're working with people, and they do these things for people" (1). The breadth in knowledge was thus seen as a source of differentiation which means they "could just bring something new" (1). Another benefit of the breadth involved in transdisciplinary courses was the aspect of choice it allowed. For example, one participant compared the degree to their previous education saying there was "a fixed like syllabus of what I need to do. But then, in my course right now…I can kind of choose myself what I'm interested in this problem, what I want to find out" (3), with another saying, "you get the best of both worlds" (4).

For most, the flexibility in career options was desirable. For example, one participant said that "the whole reason for interdisciplinary was for me to not narrow my options to just engineering, or social sciences …the reason was to have a broader range of options" and another claimed that it "opens you to more opportunities" (4) but went on to say "it's broad. But right now, I feel like… too broad, because I'm not sure. Where does that put me, you know" (4). A different student said that they may want to go into engineering but were worried as they didn't believe that they would "have much engineering skill like how to use the software" (5), but later that they "would more prefer flexibility, because I can work in different industry, different sector" (5).

For some, the language associated with being interdisciplinary could be problematic, for example one stating "I'm not sure if the term generalist is a good word" (2). Furthermore, the lack of depth of knowledge involved was seen as limiting options for postgraduate study, with one participant saying, "I think it would kind of be a disadvantage because I wouldn't have the skills that a traditional course would" and that courses "might not accept" (2) them.

4. Discussion

The findings highlight key areas in which to focus future efforts. Consistent with the work of Abbonizio and Ho [6], participants seemed motivated to study transdisciplinary degree programmes in order that they may contribute toward complex global and societal problems which were seen as requiring input from multiple disciplines.

Although students had chosen to study a transdisciplinary programme, they appeared to emphasise STEM subjects, and in all cases more mathematical content had been expected. Such findings are similar to those discussed in previous work which explains that students' expectations about teaching and learning will be based on their disciplinary leanings [5]. The work [5] references that of C.P. Snow [14] who describes two cultures, Science and Arts. The authors thus claim that, "students will be disheartened if an interdisciplinary subject is too 'sciency' or too 'artsy', and they will resist (or be phobic about) working with numbers if they see themselves as Arts students, or writing essays if they see themselves as Science students" (pp.10) , something which McCalman et al. [15] calls "resistance to learning outside their comfort zones" (pp. 17). This, alongside the confusion and uncertainty that appeared to be associated with learning, as well as the concerns regarding depth of knowledge, necessitates an approach which allows students to understand, and step beyond disciplinary thinking, and make connections and identify differences between them. This is particularly important in the case of undergraduate courses, for which students would not have advanced training in individual disciplines and the associated theories, methods, and limitations. Such meta-coordination is deemed as important to prevent students from feeling overwhelmed [16]. Such approaches allow students to switch between disciplinary perspectives and achieve both depth and breadth depending upon the context [16]. This, of course, has implications for the teaching team, who must ensure that they facilitate this process and integration of disciplines within a supportive environment [16].

It is interesting to note that although students wanted the flexibility that they considered transdisciplinary courses to bring in terms of career options, they were also worried by too much choice. This, alongside the fact that some would feel more comfortable with increased STEM based content, suggests that students would like the benefits of transdisciplinary education, alongside those seemingly associated with having studied STEM subjects in terms of societal perceptions and job prospects. Another consequence of undergraduate transdisciplinary programmes is that the lack of depth may be considered to limit postgraduate opportunities.

5. Conclusion

This work focused on understanding why five UK based students chose to study one transdisciplinary undergraduate degree programme and the factors which informed their decision making, as well as the expectations they held of both transdisciplinary education and subsequent opportunities and challenges which may arise.

Students were motivated by the opportunity to address complex societal problems. Although STEM subjects were not required to be accepted on the programme, all participants had studied mathematical sciences post aged 16 and stressed the degree to which they enjoyed these subjects, which were also considered as highly valued by society. Although they seemed self-assured regarding the need for such courses, some uncertainties, primarily around career options, did exist. They recognized the need to develop communication and teamwork skills, as well as the ability to deal with complexity, but acknowledged confusion associated with learning across disciplines.

Based on these findings, further work in both teaching practice and research should focus on ensuring that students are able to see the value and need for inclusion of all disciplines, as well as having the opportunity to compare disciplinary approaches in ways which allows them to incorporate both depth and breadth. There is also a need for the provision of adequate careers guidance and student support and guidance.

For some students, attending the specific university offering the course was more important than the course. This raises questions regarding the risk associated with studying courses at universities which are viewed as less prestigious, or in cases where students don't have support of their family or financially, or who are more risk averse.

The work describes the initial part of a longitudinal study and future work will focus on the experiences of students throughout their degree scheme. A limitation of the sampling method is that participants were self-selected. The findings reflect the perspectives of students on one course in one UK based university and transferability is thus limited. In future it would be desirable to conduct the study with a wider range of participants studying transdisciplinary courses in different universities. It is also of interest to compare the views of participants (who were all international) to those of home students and to further understand the role of socio-economic background and university reputation on perceptions of transdisciplinary programmes.

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