Supporting project-based education through a community of practice: a case of postgraduate renewable energy students

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ABSTRACT: Research in rapidly evolving fields of engineering, such as renewable energy (RE), is becoming increasingly complex and multidisciplinary in nature. This ultimately affects the aims of higher education, which include student personal growth and exposure to the research field, the consolidation and generation of new knowledge, and the building of human capacity to support future industry and academic activity (in essence knowledge, skills and citizenship). In this article, the authors suggest that project-based learning is enhanced through a community of practice approach in which the cognitive, affective and systemic (CAS) educational support dimensions are relationally considered. In order to investigate this hypothesis, this case-study-based research uses these support dimensions to analyse the efficacy of a postgraduate community of practice (CoP) within the RE engineering space through engagement with CoP survey responses. The article contributes to an improved understanding of the relationship between responsive CoP systems, holistic student pastoral care and new knowledge generation in project-based learning environments.

INTRODUCTION

Higher education (HE) in an era of *supercomplexity* [1] is tasked with multiple, conflicting roles, with the overarching intention of educating graduates with the requisite knowledge, skills and citizenship values [2] to be able to contribute to socio-economic development and progress. The general expectation, from both HE and industry, is graduates with advanced personal and technical abilities [3]. Project-based learning (PBL) has often been proposed to equip science, technology, engineering and mathematics (STEM) students with real-world competencies for 21st Century problems [4][5]. Project-based learning is a *student-centred* pedagogy that is *context-specific* and *inquiry-based* learning within the context of *real-world practices* [4] and involves *knowledge acquisition, teamwork, critical thinking and decision-making* [6].

These higher order intentions are not dissimilar to the objectives of STEM postgraduate education: *the acquisition of disciplinary knowledge* and *the ability to apply knowledge and skills beyond the domain of academic science* [7]. There is the expectation of HE students to be *adequately* prepared for *diverse* and demanding future careers in the *knowledge economy* [7].

Hancock and Walsh deem *professional identity* (of the post-graduate (PG) student) a crucial consideration in preparing students for real-life problems [7]. The professional identity of the student becomes increasingly important as *transferable skills* [7] are increasingly required in the rapidly changing era of supercomplexity. This professional identity dictates the expected attributes (often soft skills) of a well-equipped graduate [7], which includes perspective on social, economic and environmental issues [3].

Although the objectives - and challenges involved in completion - of PG education are of personal and technical orientation, recommendations to improve the PG experience often appear mostly systemic in nature [8], in support of what Sampson and Comer verbalise as a shift to an *economic and productive position* in the *knowledge economy* [9]. These pressures seem to overpower the focus on student development, their agency and ability to contribute to new knowledge creation - crucial elements of effective PG and project-based education. So, the impetus for this research study was how to more effectively support a large cohort of PG students engaged in PBL?

In this article, the authors use the cognitive, affective and systemic (CAS) support dimensions [10] to analyse the impact of a community of practice (CoP) approach in project-based education through a case study on postgraduate education in a renewable energy (RE) research centre at a South African university. Drawing on an initial qualitative supervisor and PG student survey, the research team adopted a design-based research (DBR) approach in engaging with CoP members in subsequent, iterative, semi-structured discussions. These sessions were designed to better understand, as well as improve the functioning of the CoP within its context, as part of a faculty-wide project impact evaluation initiative.

METHODOLOGY

Conceptualising the Study

The concept of a community of practice (CoP) emerged from anthropological accounts of the social nature of learning, entailing participatory, dynamic and identity characteristics [11]. Unsurprisingly, the concept of a CoP is thus found in both project-based education and postgraduate literature; collaboration is a key learning goal in project-based learning, often through a type of community [5], while the *professional identity* of the PG student is founded in experience and knowledge associated with a specific CoP [7]. The purpose of a CoP is then collective endeavour of practice itself, drawing on *meaning-making person[s]* who are *not just cognitive entities* [7]. An effective CoP *provides the space for collaborative interrogation of practices* [12], which can contribute to challenging and transforming the *status quo*. CoPs have evolved across sectors and are utilised increasingly for peer-to-peer learning, professional development and learning partnerships beyond singular professions. CoPs are necessarily multifaceted and diverse, depending on their contexts. So, what does CoP PBL look like in a STEM PG context?

Barnett's model of a curriculum for supercomplexity is a useful starting point for differentiating between graduate competency dimensions according to epistemological (knowledge), ontological (being) and praxis (doing) imperatives [1]. In other words, a holistic curriculum needs to entail all three dimensions. Gilmore et al [13] develop this model of curriculum through the addition of an educational support layer [10] entailing cognitive, affective and systemic (CAS) dimensions, as shown in Figure 1. For each of the curricular dimensions, there is a requisite education support dimension. Together, the dimensions represent a framework for the development of knowledge, identity and practice.

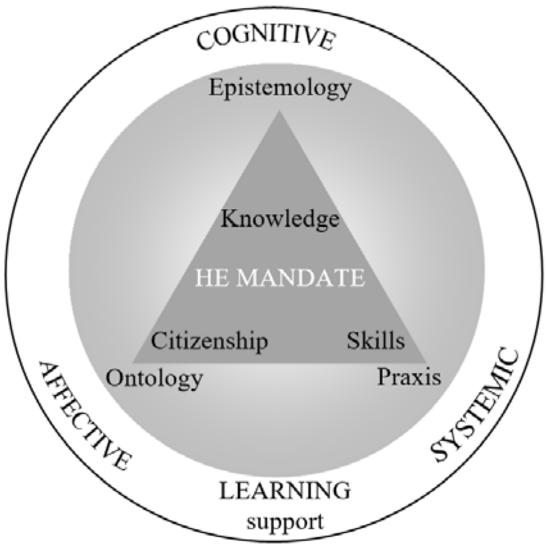

Figure 1: The cognitive, affective and systemic (CAS) imperatives for effective project-based education support, adapted from Gilmore et al [13].

The primary learning support dimensions as proposed by Tait are: 1) cognitive - *supporting and developing learning through the mediation of the standard and uniform elements of course materials and learning resources for individual students*; 2) affective - *providing an environment which supports students, creates commitment, and enhances self-esteem;* and 3) systemic - *establishing administrative processes and information management systems which are effective, transparent and overall student-friendly* [10].

This article foregrounds the purpose of project-based education, in a PG context, as one of knowledge generation capacity development, which is best facilitated through supported access to the *epistemic values of a community of inquiry* [14]. If the goal of education is to enable *learners to develop the sense of values that guide the practices of inquiry*, which are necessarily socially mediated [14], then educators, supervisors or the knowledgeable other, are tasked with the responsibility of mediating this process. If the HE mandate is one of *mediating access* to particular forms of inquiry by providing a cognitive, affective and systemic support structure, then this article examines what such social or shared mediation looks like, and how it enables what kind of access.

Contextualising the Study

This study is located at a leading, internationally recognised research-intensive South African tertiary institution. South Africa has experienced a significant uptake of renewable energy (RE) sources in the form of onshore wind, solar photovoltaic and concentrated solar power for electricity production. An industry-academia collaboration platform was established to increase research and human capacity-building to support expanded industry activity in the growing field of RE, and address South Africa's national electricity utility's technical challenges.

The RE specialisation was established within the engineering faculty of the institution (the research site) and is at the time of writing, funding and coordinating the study of more than 60 postgraduate students. Through engagement with these students, a potential challenge has been identified: the postgraduate student's journey to graduation risks being insular and lonely. This challenge is especially prevalent in emerging multifaceted and multidisciplinary research field, such as the integration of RE into the electrical power system, where the likelihood is low of existing peer support networks. To address these challenges, a group of RE academic supervisors came together to form a research group with the aim of creating a peer and resource network to stimulate cross-pollination and collaboration.

Practically, weekly research seminars have been held since the end of January 2020 (migrating on-line during the Covid-19 pandemic), where students present their work to peers, academics and members of industry. Other forms of support include collaborative research writing sessions, a mentoring system, as well as the launch of a Web site for presentation of the group's focus areas and publications.

In order to reflectively evaluate the benefits, challenges and efficacy of the research group, a core team of researchers undertook a qualitative impact evaluation study situated within a faculty-wide research project designed to improve engineering education practices.

The Analytical Instrument and Process

A key imperative in this qualitative case study is the adoption of a practicable, theoretically informed and evidence-based set of research instruments with which to interpret, describe, analyse and respond to participant data. The survey responses were analysed using an *external language of description* [15], in combination with Gilmore et al's CAS dimensions [13].

This qualitative case study draws on a number of methodological frameworks. First and foremost is the iterative, improvement-orientated design-based research (DBR) approach common to engineering education initiatives seeking to evaluate the *connections between designed learning environments and desired outcomes* [16]. The iteration involves additions and amendments elicited through processes of *reflection*. In this context, *reflection* was initiated through an on-line, voluntary survey of 34 regular participants in the research group in question. Participants, both PG students and supervisors, could remain anonymous and were required to complete ten questions designed to enable categorisation of responses according to the CAS dimensions. The questions covered the usefulness of resources and opportunities, as well as their experience of the research group.

This deductive approach became an inductive one when the research team determined that initial responses were predominantly related to the systems and resources in place for the group - they were systemic. Engagement with the survey responses stimulated a discussion among the research team around the question of collaborative reflection.

Survey and subsequent participant discussion data were recorded, transcribed and iteratively coded in a shared database. All responses were considered and coded, with participants numbered according to contributions via the survey (S). Further data were drawn from a review of the recorded weekly participant research presentation and discussion sessions, as well as weekly research team discussion and observation notes. In other words, iterative engagement with the data has provided a nuanced and enriched space from which to understand the synergies, the constraints and affordances of a CoP project-based education model.

FINDINGS AND DISCUSSION

A purposive selection of participant feedback is supplied in Table 1 to: 1) illustrate orientations; and 2) interrogate the relationship between and beyond the sorting categories. Although the CAS dimensions are relationally structured, it is useful to distinguish between them. Literature on the problem being investigated, i.e. effective STEM PG support, predominantly offers either systemic solutions or focuses on affective elements. Given the importance of PG contribution to new knowledge, one of the aims in the analysis is to illuminate the cognitive orientations that emerge through the coding categories.

A coding of the survey (S) responses in Table 1 reveals statements supporting the explicit intention of the CoP: establishing a system through scheduled opportunities that enable pastoral care in support of the knowledge creation process.

The word access seems to arise quite often in the context of the cognitive dimensions, such as access to the *…broader idea…* (S1) and *…to a much broader source of knowledge [having all the academic research in one group]* (S22). While Porter and Roessner note that innovation emerges from *direct access to research knowledge* [17], Sampson and Comer talk of *bridging ties* and how opportunities, such as conferences allow for the *access* to *different sets of intellectual experiences and resources* [9], in other words, access to what Bernstein terms the collective *reservoir* [15]. The cognitive access referred to in both the participant responses and literature points to a more comprehensive concept of access, which includes *codified knowledge* [18] known by others within the CoP, often by the *knowers* [19] who possess *intellectual experiences* [9].

Table 1: CoP survey coding examples.

Coding category	Example
Cognitive	
Access	*…access to knowledge. Rather than reading article upon article to get a broader idea of the field, I can attend the seminars to gain this knowledge* (S1).
Interest	*I am very interested in this field and I thoroughly enjoy listening in on research done by others to ultimately improve my knowledge* (S11).
Relevance	*Developing my understanding of other research areas related to my research focus* (S27).
Affective	
Community	*...the belonging to a community value of the group is even more important than before lockdown, as students do not have regular interaction with their peers outside of these seminars* (S2).
Engagement	*Because the presentations are interesting, it is nice to learn through engagement and it keeps one connected as well* (S7).
Systemic	
Space	*A better than expected structure to a research masters at* [the university] (S28).
Time	*…decoupling my direct time investment versus research outcomes. I.e. the total is more than the sum of the parts* (S2).

The participant responses also indicate that although they are not yet *knowers* in the specific field or topic, it is of interest - a core feature of an established CoP [20] - since they perceive or recognise the CoP scheduled opportunities as knowledge building processes:

> *I find them very interesting. I* [am] *currently doing a mechanical masters,…so all these talks are of interest to me* (S18).

Relevance is closely related to interest and CoP interaction:

> *I attend the seminar that are closely related to my area of research* (S24).

With a CoP of this size, it is expected that some members are less interested in some of the opportunities hosted by the CoP as a result of the perceived relevance to their own work. From an unequivocal affective perspective, the combination of interest and relevance would result in the type and frequency of engagement by the members of the CoP.

The participant who noted that the *presentation is interesting* (S7) seemingly also implies that because it is interesting, they and others *learn through engagement* (S7) within the CoP. An important activity expected in project-based [5] and PG learning [21] is feedback, which is gained through engagement:

> *The* [research group] *also has a* peer reviewing *function allowing students to get constructive feedback on their work* (S27).

Sampson and Comer note that students perceive the peer review (feedback, i.e. engagement) from other students as a process in which their work becomes more accessible, while implying that this engagement forms a critical part of knowledge building [9]. *Meaningful engagement with individuals…* is a critical opportunity to also attain the affective imperative in the learning process [10]. Smit in fact, characterises CoPs as the *mutual engagement* of members with a common goal [22], while Motshoane and McKenna refer to the necessity of engagement to realise the *…culture and structure of a discipline…* in PG learning [23].

This engagement, which results in a community culture, is therefore determined by what each individual contributes to the CoP and what participants perceive as the contribution by others to the community:

> *Gain knowledge and in-depth insights on specific topics… that would otherwise not have been easily available. Build a network of individuals in the same research field* (S28).

The CoP was established as a system to provide a community, and engagement to support the cognitive imperatives in PG learning. One participant points out that the CoP enables learning of more affective skills:

> *Student training in aspects other than the technical work they are busy with* (S31).

The establishment of a CoP is inherently supplying the space and time for meaningful engagement and both physical and cognitive access:

> [A] *convenient place for new students developing any of our research tracks to access past research…* (S27).

From the supervisor's perspective, the CoP is an important time management tool, *decoupling my direct time investment versus research outcomes* (S2), to that of the students':

> *I would consider a two-weekly schedule - this would give students more time to prepare and also would allow me to engage more often* (S14).
>
> *…it is the perfect break from my own research* (S18).

The same student reflects that *To be painfully truthful,* [the CoP] *is a wonderful break from my family for an hour each weak* (S18), during the Covid-19 lockdown. However, to another CoP participant the lockdown resulted in time-constraints:

> *I had more meetings* [at the same time as scheduled CoP seminars] *during lockdown, and projects that are running behind (due to lockdown) which I usually have to attend to in the mornings* (S23).

The systemic dimension is elementary, but fundamental to the CoP in providing opportunities for both cognitive and affective development. In changing the system, however, seemingly unpredictable affective and cognitive consequences emerge. However, considering the previous examples on time it becomes apparent that the consequences and resulting orientations are in fact contextual. Although the system change (lockdown) does not necessarily result in positive consequences for the participant (S23), this participant's systemic context affectively and cognitively benefits the CoP as a whole:

> *I think coming from a public services industry I can sometimes provide a different perspective to full-time researchers* (S23).

This initial coding, which largely demonstrated anticipated responses based on the literature, suggests the necessity for further research to illuminate the nuances, which have emerged with respect to the synergy between systemic and affective elements, and tacit cognitive implications. These include the concepts of identity *…I do not feel alone and my research feels relevant* (S26), and reflection *…it made me reflect upon my progress…* (S7). Professional (scientific) identity is an important objective of PG education, while reflection even beyond technical work is an important process within the development of a professional identity [7]. Project-based learning is student-centred learning that requires soft skills [5] which rarely develop adequately without a sense of identity. If active reflection is a primary focus in project-based learning [4] and real-world competencies are an objective [3], then the development of identity cannot be ignored.

CONCLUSIONS

It is indisputable that the postgraduate STEM student is burdened with often divergent expectations, including pressures of timely completion, meaningful knowledge creation and professional scientific identity development. Recommendations on the management of these burdens, in the case of both the student and supervisor, are often systemic in nature. However, this study has provided a framework through which to demonstrate the relationship between the cognitive, affective and systemic learning support dimensions. In order to effectively support a large cohort of PG students engaged in PBL, designed to facilitate knowledge creation, an effective CoP is one in which all three dimensions are relationally considered.

Although only a first coding of student and supervisor survey responses were considered, tacit implications emerged that are the cornerstones of both postgraduate and project-based education. Identity and reflection are two important affective attributes that are crucial to the development of adequately prepared graduates for 21st Century problem-solving and meaningful knowledge creation. Hancock and Walsh argue for reform in doctoral PG education, which include *interdisciplinary discussion spaces*, *promoting reflection*, and *experience of sites of scientific knowledge production or application outside the university* [7]. If these are the type of reform actions required to support PG student development, then this study showed through the analysis of the CAS synergy that the required actions are well suited to the collective purpose of an effective CoP.

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