Supervisor perspectives in STEM PhD supervision: a social realist analysis of current trends

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ABSTRACT

The traditional academic pipeline has branched out significantly in recent years. The motivation of students pursuing higher degrees has also changed dramatically in response to wider socio-economic needs. Supervisors of PhD students are consequently faced with the need to adapt supervision practices to equip graduates with a broader suite of workplace competencies. However, PhD supervision is a practice located in the broader setting of a higher education system, conditioned by factors that change over time. In this paper we share the perspectives of a range of STEM supervisors from varying backgrounds on their conceptions of the purpose and goals of the PhD. Archer’s Social Realist theoretical framework was used in a comparative analysis between groups and across themes. It also enabled a novel visualisation in the form of a heat map, illustrating the mechanisms shaping supervision practices, highlighting the strong interplay between student agency and the development of particular dispositions.

Introduction

The higher education landscape has shifted dramatically in the past 20 years. Worldwide, staff and student demographics have changed and the very purpose of higher education is being challenged. The Covid-19 pandemic and rapidly evolving technological landscapes have also accelerated the shift towards an era of supercomplexity (Barnett, 2000), with new skills and competency requirements emerging constantly. There is thus increasing pressure for lecturers to shift postgraduate supervision practices to adequately prepare graduates for the current and future needs of society (Ashwin & Case, 2018). This is particularly true at the doctoral level, where doctoral research and the doctoral qualification is seen as an important means of generating solutions to society’s complex problems (CHE – Council on Higher Education Transformation, 2014). Academic posts are also increasingly challenging to secure (Roach & Sauermann, 2017), and many graduates are forced to look outside academia for employment (Walters, Zarifa and Etmanski, 2020).
The branching out of the academic pipeline, with graduates of higher degrees entering workplaces that are vastly different from the academic and research environments for which they have been prepared (Acker & Haque, 2017), indicates the need for doctoral graduates to develop in depth, highly sophisticated understandings of the knowledge of their disciplines and the ability to apply this knowledge to a broad range of contexts and fields of practice. Increasingly, there is also greater emphasis on the ‘skills push’, where the focus of the PhD is the development of high level skills and competencies (Mowbray & Halse, 2010) as well as critical thinking dispositions (Ennis, 1996; Siegel, 1999) valued by potential employers. At the same time, employment goals may also have implications for the type of identity graduate students develop, based on their intrinsic motivations and their intended career paths. Consequently, doctoral education has needed to adapt in response to the shifting societal pressures and requirements to enable the development of PhD graduates with flexible dispositions and a new type of disciplinary ‘gaze’ (Bourdieu & Wacquant, 1992) that would allow doctoral graduates to more easily integrate into new contexts and apply their knowledge seamlessly in fields of practice beyond the academe. This shift may, however, present challenges for the development and training of postgraduates especially in Science, Technology, Engineering and Mathematics (STEM) disciplines, particularly for PhD supervisors.

In this paper, we demonstrate how the preparation of PhD graduates, and doctoral supervision practices in particular, has transformed (and may still need to change further) whilst still ensuring that the pursuit of deep disciplinary understanding and knowledge creation that are the hallmarks of the doctoral qualification, is not compromised. Our aim is to share the perspectives gleaned from a range of STEM supervisors from varying backgrounds, ages and experience levels on the changing nature of the PhD and impact of the changes (if any) on their conceptions of the purpose and goals of the PhD and how this might have changed over time. We reveal the factors and mechanisms that influence conceptions of supervision as a professional practice, critically examining the interplay between these factors, highlighting areas of concern and challenges faced by supervisors in their quest to support PhD students in appropriate and responsive ways. The unique contribution of this study is the sharing of insights from supervisors on the current and future objectives of doctoral programs and the use of a heat map to illustrate the mechanisms shaping supervision practices and interaction. The heat map is used to make the salient aspects of the data more accessible, specifically with respect to the resulting intersections of the social realism categories and the interview themes. Understanding the mechanisms shaping supervision practices and interaction, and the interplay between them, could lead to the conceptualization of more effective PhD supervision models, and potentially higher completion rates in the long term.

**Motivation for this study**

The authors of this paper are all located within STEM fields and are all involved in the supervision of postgraduate students, including PhD students. Although we are in different institutions, it became apparent to us that our experiences of the factors influencing our supervision roles are very similar as a result of being actors within the South African higher education sector. We are all strongly encouraged to take on an ever increasing number of doctoral students, where this comes from government funding
models and the stated strategic objectives of related government ministries to increase the number of PhD graduates in the country, the latter being a strategic priority for South Africa (Herman & Schoole, 2017). We note, however, that while these issues are made overt in the South African higher education sector, these are not unique to our country. Our findings may, therefore, contribute to the broader global higher education community at what appears to be a crucial moment in higher education.

With the above aim in mind, what follows is a brief account of the reported purposes of the PhD, the role of PhD supervisors and currently dominant approaches to postgraduate supervision. An overview of Critical Realism as the overarching theoretical framework, and Social Realism as the analytical framework for this study is then provided, after which we present our approach to the research, our findings and a discussion of the implications thereof for supervision practices and PhD outcomes.

The purpose of PhD studies, PhD supervision roles and models

The PhD, being located at the apex of the higher education qualifications suite, has traditionally been associated with the development and acquisition of particular skills, attributes, competencies and dispositions, drawn largely from the Aristotelian notion of intellectual virtues, including impartiality, courage, open-mindedness, attention, care, honesty, humility, autonomy, perseverance, patience, and industriousness (Mowbray & Halse, 2010). Mowbray and Halse further explain that alongside these intellectual virtues focused on in the PhD is the development of other critical competencies, including the development of in-depth disciplinary knowledge, research skills, critical thinking skills, project management and communication. It is the combination of these intellectual virtues, skills and competencies that makes a PhD candidate attractive for employment in a variety of workplaces.

The role of the PhD supervisor is to attend to the development of disciplinary competence and critical thinking dispositions, acknowledging the many and varied stages of liminality or ‘stuckness’ that PhD students will experience as they struggle with threshold concepts and troublesome knowledge (Meyer & Land, 2003) that they will encounter in the journey to becoming a PhD graduate (Keefer, 2015; Thomassen, 2009). PhD supervisors are thus also expected to provide an enabling and supportive environment and opportunities to transition students through those spaces of liminality as students develop their disciplinary identities. Linked to this is another fundamental role of the PhD supervisor, viz. enculturation, described by Hockey (1994) as the process of developing disciplinary dispositions and cultural capital (Bourdieu, 1986), and the induction of students into disciplinary communities. This role may be linked to the ‘qualities’ model of supervision (Wisker, Robinson, Trafford, Lilly, & Warnes, 2003), where the emotional intelligence and flexibility of the supervisor plays a big part in working with students through to a successful completion.

Other styles are that of a mentoring process, described by Pearson and Kayrooz (2004) as a facilitative process requiring support and challenges, with the role of the supervisor as mentor seen as a non-judgmental adviser. Here mentoring builds upon the belief that self-experience and self-discovery are important facets of learning (Morton-Cooper & Palmer, 2000) that lead to emancipatory outcomes (Lee, 2008). Hockey (1994) also describes the functional or project management role played by the supervisor, in
agreement with the functional model of supervision which Wisker et al. (2003) define as the supervisor’s task as being one of directing and project management. The PhD supervision role thus spans a number of different dimensions (Hockey, 1994), although it can be argued that the traditional supervision roles have been to support the development of intellectual expertise, and enculturation into academic communities.

Although participation in disciplinary-based communities of practice are essential, the PhD journey is, however, largely centered on the interactions and relationship between supervisor and students, underpinned by the individualized traditional apprenticeship approach to supervision inherited from the Oxbridge tradition. As stated by Manathunga (2005), supervision is often seen as a ‘private pedagogic space’, while Mackinnon (2004) calls it a paternalistic style of supervision which is counterproductive, as it prolongs the dependence of the student on the supervisor. Nevertheless, this approach is still the most favored mode for supervision in South Africa (De Beer & Mason, 2009), where many propose that the untrained supervisor will emulate (or consciously avoid emulating) the qualities that their supervisor demonstrated, as a first instance when supervising.

Whilst supervision is criticized for being seen as an individual space based on individual styles and attitudes without accountability, which may cause problems within the context of increasing numbers, distance and diversity (Wisker, Robinson, & Shacham, 2007), this apprenticeship model is clung to due to the familiarity with most supervisors’ experience with this approach, and possibly a lack of knowledge and exposure to other approaches. The isolation characteristic of the apprentice approach (Samara, 2006; Wisker et al., 2007) may, however, be circumvented by using group supervision (Wisker et al., 2007), an approach rapidly gaining traction as the realities of massification emerge in the postgraduate domain.

Group supervision can vary from clustering students of similar levels to those of varying stages, where Wisker et al. (2007) suggest that work-in-progress seminars involving peers encourage weaning of students from supervisors towards creating independence. These group approaches would seem to be translatable to hierarchical knowledge fields such as science and engineering as they enhance the enculturation process. However, this may come at the expense of disciplinary knowledge, as highlighted by Malfroy (2005), where an inexperienced group could be a way of pooling ignorance. Furthermore, Dysthe, Samara, and Westheim (2006) note that supervision groups in their study operated alongside an individual supervisor process, taking the onus off the individual meeting by saving individual supervision time.

The supervision relationship is thus exceedingly complex and multi-faceted and usually requires inclusion of elements from each model. This is especially true for PhD supervision, where there must be a growth in the relationship from hierarchical to that of equals. Such a shift in relationship is, however, even more complex, influenced partly by the motivations of the students themselves, including the students’ end goals which, as already mentioned, are not necessarily to follow in the footsteps of the supervisor and pursue a career as an academic. The process is also influenced by the institutional and national policies as well as a multitude of other factors that intertwine in their influence on supervision practices and student–supervisor relations. The research conducted in this study aimed to unravel these complexities and reveal the dominant factors influencing supervision practices at the present time.
Social realism as a theoretical framework

In light of our focus on supervision practices within the context of the South African and global higher education systems more broadly, we have chosen to underpin this study in the philosophical tradition of Bhaskar’s Critical Realism (Archer, Bhaskar, Collier, Lawson, & Norrie, 2013) and to conduct our analyses using the related framework of Social Realism (Archer, 1982, 2007; Archer & Archer, 1995; Porpora, 2013).

The critical realist strata of the ‘real’, ‘actual’ and the ‘empirical’ have proved useful in attempts by social scientists (and higher education researchers in particular), to unravel and explain changes (or lack thereof) in social systems, including the higher education system. This is because it provides a mechanism through which events and practices may be understood, how it came to be so, and subsequently, how it may be changed. As such, Critical Realism and the related meta-theory of Social Realism by Archer (2013; Porpora, 2013), provide useful philosophical and analytical frameworks in this study, for examining supervision interactions and revealing the conditions and factors holding dominant paradigms in place, as well as elements that could be leveraged for change.

Archer (2013) suggests that any change in society or any social grouping (e.g. higher education) may be due to a variety of factors arising in the realm of the ‘real’ that result in the emergence of new phenomena and events in the realms of the ‘actual’ and the ‘empirical’. In attempting to understand the nature of postgraduate supervision and possibilities for change, researchers may make assumptions about the structure of the higher education system within which supervision occurs and how these condition supervision practices. Practices are however also influenced by individual perceptions and beliefs. Explanations of change based on consideration of structures alone may, therefore, not be a true reflection (or possibly an underestimation or overestimation) of the ‘real’ causes or conditions. Social Realism addresses the potential challenge of under- or over-estimation (termed ‘epistemic fallacies’ (Archer, 2000)) by providing a framework that allows the higher education researcher to analyze how complex effects or social events arise within the higher education system, by independently examining the existence and interplay between people (agents) and the ‘parts’ (structure and cultural) in any social system/society (Archer, 2013). Archer posits that to understand each component in-depth and to sequentially analyze their influences on each other and on the system as a whole, structure and culture must be separated from agency. This separation for the sake of analysis is referred to as ‘analytical dualism’ (Archer, 2013; Porpora, 2013).

Applying social realism to the practice of postgraduate supervision, the structures influencing supervision may include institutions such as universities and government, as well as national and institutional policies, as indicated in a recent publication by Motshoane and McKenna (2021). Social structures may also include position and status or social class (of supervisors and students), gender and race, as well as material resources such as funding. Culture, on the other hand, refers to the ideas, beliefs, values and ideologies held by individuals that have been learned (through social interactions or through reading and contextualizing information), and which may be shared with others (Archer, 2013; Case, 2013). It may also include the sets of ideas on what constitutes legitimate knowledge in a given context (a PhD in Digital Arts in the Humanities, for example, would be underpinned by very different knowledge typologies compared with
a PhD in Theoretical Physics within the Sciences (Archer, 2013; Case, 2013). Human agency, in comparison, refers to the personal and psychological makeup of individuals, their social roles and their capacity to act in different ways to defend their interests and realize their goals, driven by personal motivations and values (i.e. culture) (Case, 2013; Porpora, 2013). PhD students and their approaches to the qualification may thus be conditioned not only by disciplinary knowledge, norms and practices, but also by students’ own intrinsic motivations; while the approaches and actions of PhD supervisors too, will also be governed by their own intrinsic values and beliefs about the purpose and nature of the PhD.

Given the complexities of PhD supervision, Social Realism, thus, proved to be an ideal analytical framework for examining, identifying and categorizing the factors and mechanisms influencing supervision practices amongst participants, and the resultant effects on the student–supervisor relationship and outcomes of the PhD.

**Methodology**

The study followed a qualitative research approach, beginning with a narrative inquiry on supervisory experiences and practices between the three authors of the paper. This initial enquiry led to the identification of the overarching research question and thematic focus areas for more in-depth enquiry and analysis. We then obtained ethics clearance to invite participants from STEM disciplines in two different institutions (2020–09-04/Cornell), thus creating a broad pool of supervisors to interview. Ethical consent for the study was granted by the institutional ethics committees of both institutions. Based on the responses to the invitation to participate, three separate semi-structured group interviews were conducted online with consenting participants from both universities. All participating supervisors provided informed consent.

Each interview group consisted of 4 participants with different levels of experience and from different disciplinary backgrounds. For example, group one included a participant from biology, a participant from mathematics, and 2 participants from engineering. In total, there was representation from physics, mathematics, engineering, biology, and computer science fields, allowing for further refinement of the STEM field’s perspectives on supervisory practices (specifically from the supervisor’s perspective). The group interviews were facilitated by the third author who has experience in group interview facilitation, guided by the themed questions contained in the interview schedule approved by the ethics committee, with co-facilitation from the other two authors.

During the group interviews, participants were asked about their experiences and perspectives with respect to the four thematic focus areas. These focus areas included their motivations for pursuing a PhD compared with their perceptions of current students’ motivations; perceived constraints; time to completion, and their view on liminality and the development of PhD dispositions. The questions and discussions were thus intended to not only get the participants’ perspectives as supervisors, but also their experiences – with respect to the focus areas – as PhD students themselves. In this way, we aimed to elicit responses whereby participants would compare and contrast their own PhD experiences with their perspectives on their students’ PhD experiences.

The interviews were recorded with permission from all participants, and all participants were anonymised by replacing their names with pseudonyms – e.g. Supervisor 1.
These were then transcribed and systematically coded relative to the four focus areas underpinning the study, viz., Motivations for pursuing the PhD, Time to Completion, Liminality and Dispositions and Constraints. The responses in these themes were then further analyzed and coded against the social realist categories of Structure, Culture and Agency. The coding allows for collation and analysis of the supervisors’ experiences with respect to the intersections of study themes and categories, and protects the anonymity of the individual supervisors. The study also presents specific responses from participants to further explain or exemplify significant patterns found in intersecting themes and categories. This approach not only enabled a route for conducting a comparative analysis between groups, across themes and categories, but also allowed for a visual representation in the form of a heat map (shown in Figure 1), thus making the salient aspects of the data more accessible.

Figure 1, presented in the Findings and Discussion section, is a heat map that gives a visual representation of the frequencies with which responses from interviewed supervisors appeared within the intersections of categories and themes, as further discussed in the next section. To obtain this visualization of interplay between the categories and themes, individual responses of participants from the interviews were firstly coded. The responses to questions under each theme (on the vertical axis of the heat map) were recorded, analyzed and categorized in terms of their relevance to one or more of the social realist categories (on the horizontal axis of the heat map). For example, if a participant responded to a question of reasons for pursuing a PhD (under the motivations theme) as being related to cultural motivations, then this was counted as an intersection between the motivation theme and culture category. The total number of responses within each of these intersections were then recorded and normalized against the number of questions in each theme (as the total number of questions under each theme varied) to obtain the overall frequency with which each of the social realist categories intersected each of the study themes. These frequencies are visually represented as a color gradient on the heat map, illustrating the spectrum of different frequencies of participants’ responses that amounted to an interplay between themes.
and categories. A darker shaded block represents more responses in the specific socialist realism category within a particular study theme, whereas a lighter shaded block represents relatively lower frequencies of intersecting themes and categories. It should be noted that the substance of individual responses falling outside the specified themes and categories used in the process of generating the heat map were not disregarded in the study because of lower frequencies. Such points were still deemed important and were considered in the more general findings and interpretations. We also highlight that the decision to use the heat map was based on it serving as a mechanism to prioritize the factors influencing conceptions of PhD supervision as a professional practice, and the interplay between these.

**Findings and discussion**

The analytical approach adopted in this study enabled the collation of responses and a nuanced categorization of these into each theme of questions, relative to the categories of structure, culture and agency. This categorization revealed the highest number of responses to be those within the intersection of the theme of Liminality and Dispositions and the social realist category of Agency (Figure 1). In this respect, liminality was highlighted by participants’ accounts of moments of cognitive disruption and dissonance experienced by doctoral students as they engaged with threshold concepts, dispositions being those critical thinking skills and attributes that students develop in this cognitively challenging process, and agency signified by statements related to students’ personal goals, motivations and values for the PhD qualification.

Figure 1 also highlights the intersection of the category of structure and the theme of constraints as the second highest area of significance for supervisors, and the areas of intersection between structure and time to completion, as well as agency and motivation as two other note-worthy areas for supervisors. These intersections are discussed next, where we examine factors and mechanisms operating at these intersections that influence supervision practices, as extracted from responses from the group interviews.

**Motivation and agency**

During the group interviews, the discussions were initiated with questions directed towards an exploration of the supervisor’s own motivations for pursuing a PhD, followed by their views on their students’ motivations for registering for a PhD and a reflection on how these motivations might (or might not) be different from their own. The responses from supervisors suggest a shift over time in terms of what factors motivate pursuing a PhD. Most supervisors, particularly more experienced supervisors, expressed their motivations as being intellectual curiosity and/or personal background, i.e. coming from a scholarly family, primarily suggesting factors in the agency and cultural categories as main motivators. These motivating factors contrasted sharply with the majority of the supervisors’ experiences of what motivated their students to pursue a PhD. Responses to the latter suggested that obtaining transferable skills, career advancement, competitive edge in industry settings, through the qualification, were some of the key motivations for students pursuing a PhD. This links directly with our aim of how motivations have changed over time, highlighting the greater frequency of responses in Figure 1.
Supervisor 10, for example, expressed their own experience, highlighting a key motivation for their students pursuing a PhD:

‘They want the end result, they don’t necessarily want to be scientists. They want the qualification that will give them a good job.’

This sentiment was shared by Supervisor 3, commenting that,

‘They want to be competitive when they go to industry’, when referring to their students’ motivations for registering for a PhD.

The strong link between motivation and individual agency was not unexpected. Higher degrees are seen as leverage for better employment options and higher levels of remuneration. However, it was not the sole reason cited for students registering for PhDs. Four of the interviewed supervisors expressed that there are some students, albeit fewer than in the past, who shared their own motivations for pursuing a PhD (such as interest and curiosity), as seen in the quote below from Supervisor 7:

‘In my opinion, it’s a mix of those with genuine curiosity and those that want to achieve a higher qualification.’

This quote demonstrates the value placed on intellectual curiosity and thinking dispositions described by Mowbray and Halse (2010) that PhD graduates are believed to possess, and which relate closely with the theme of liminality and dispositions.

**Agency in relation to Liminality and dispositions**

This theme was explored during interviews to ascertain supervisors’ perspectives on the conceptual and cognitive ‘boundaries’ that PhD students usually transition across during their candidature, which are, in turn, linked to the sought-after graduate attributes and dispositions valued by employers. As mentioned, the overwhelming majority of interviewees pointed out factors in the agency category. Figure 1 illustrates this point, showing the relatively high frequency with which participants’ responses eluded to agency within the liminality and dispositions theme. All supervisors notably referenced elements of students’ attitudes as being the main factor influencing their ability to transcend moments of conceptual struggle and liminality (Keefe, 2015), citing independence, initiative, commitment and resilience as key elements required in this process. Interestingly, independence was also regarded as an important disposition and outcome of the PhD process, with most participants recognizing independent thought and action as a clear indication of PhD graduateness. This consensus amongst interviewed supervisors around independence as being an important disposition is typified by the following statement from Supervisor 4:

‘... when we look for the key dispositions, I would say its independence, ... and this is when I have the “aha moment” that the student is now thinking like a PhD’.

The intersection between liminality and the development of dispositions such as independence and industriousness was, however, not surprising, given that these attributes are part of the suite of intellectual virtues associated with the PhD (Mowbray & Halse, 2010). It would seem, therefore, that the transition to being a graduate-worthy candidate is largely dependent on student agency, with the role of the supervisor being to support and challenge the student in the process. We note however that some participants, particularly the more experienced supervisors, agreed that there has been a notable change in supervision practice as a result of shifts in student expectations of supervision
over time, and that students seem to require more supervisory input now than in the past. The findings also link to our stated aim of analyzing the changing nature of the PhD as it revealed that although student agency tended to be the most prominent underlying factor for motivation and successful completion of a PhD, there was also a broader influence of other social realist categories viz., structure and culture, that influenced PhD outcomes and supervision practices, as discussed next.

**Structure and time-to-completion**

When participants were asked about their perspectives and experiences with regard to constraints, the most commonly reported issues related to time-to-completion. Figure 1 illustrates the relatively high frequency with which participants’ responses eluded to structural factors within the time-to-completion theme. Participants reported significant and increasing pressures on supervisors to minimize the time to completion. These were reported to be institutional pressure which, in turn, was directly related to funding and government subsidies.

An example of institutional pressure highlighted by interviewed supervisors, the inclusion of PhD supervision as a key performance indicator in the evaluation of the academic, whereby time-to-completion was noted to have become a salient factor in managing performance. Supervisor 1 expressed this as a mechanism that ‘changes the behavior and practices of supervisors’;

‘... this changes the student-supervisor relationship. It means I have to measure beforehand if a student is likely to complete on time...’

Supervisor 4 expressed that the importance of time-to-completion depends on whom you ask, but shared the overall sentiment across the groups with respect to institutional pressures:

‘... certainly our administration is on our case to reduce the time-to-completion...’

The emergence of time to completion as a significant challenge is supported by the findings of Carter, Kensington-Miller, and Courtney (2017), in their study of the problems of doctoral supervision practices. Those authors reported on the impact of time constraints imposed by regulatory bodies on the level of engagement, the quality of the research and the overall enjoyment of the doctoral process. Similarly, Bastalich (2017, p. 1145) highlighted a ‘core premise within much policy and management discourse around doctoral education in the non-US context is that supervision is the key to both quality and efficiency in higher degree research’. With the massification of higher degrees, this premise has manifested in intense scrutiny of doctoral supervision within cost efficiency drives in which supervisors are often blamed for unsatisfactory completion times and high withdrawal rates. Participants in the present study also highlighted that the pressure to get students to complete in minimal time strongly constrains their supervision practices. This pressure has been increasing over time, impacting the type of projects that can be pursued and therefore the in-depth disciplinary nature of the PhD going forward. Interestingly, a supervisor in the present study also referred to the knock-on effect of the emphasis on reduced time to completion on supervisor reputation, stating that the negative perceptions associated with having graduates with longer times to completion tended to be viewed as poor supervision ability. The impact of steadily
decreasing time to completion imposed by higher education regulators thus presents a significant challenge for both students and staff.

Another critical issue that emerged as a result of pressure to ensure that students complete in minimal time (which has been significantly reduced over time) is a concerning element of gatekeeping at the point of accepting the student into the qualification. Some participants pointed out that supervisors increasingly have to base the decisions of whether to accept a PhD applicant on a tacit evaluation of whether the applicant has the dispositions described earlier – dispositions that could (and should), with sufficient time and appropriate supervision, develop during the PhD. Participants in the focus group in which this point emerged strongly acknowledged this evaluation of potential students as problematic, with possible unintended negative consequences for access and broader transformation goals, particularly in contexts such as South Africa, with legacies of educational inequality.

**Structural factors and supervision constraints**

Supervisors were asked to describe some of the foremost constraints they experienced as PhD supervisors. Supervisors’ responses under this theme were most frequently related to factors in the structural and cultural categories. This is illustrated in Figure 1, where the darker shading of the intersecting block demonstrates the relatively high frequency with which participants’ responses eluded to structural factors within the constraints theme. In addition to pressure related to time-to-completion, another prominent structural factor expressed as a constraint by supervisors was the lack of funding. This finding is again in line with Carter et al. (2017), who also reported the negative effects of financial constraints. In the present study, supervisors who were interviewed lamented the fact that finances often present serious challenges both to students as well as their own capacity in terms of providing research capabilities, i.e. research laboratories and spaces, and equipment. In the current economic climate, national and private funding mechanisms for research are extremely limited and likely to dwindle even further in the wake of the Covid 19 pandemic, with serious consequences for PhD student and project support.

Another significant structural challenge was the issue of massification and the pressure to grow postgraduate numbers. Supervisor 1 analogized this to a ‘sausage factory approach’, a view that was shared by most participants interviewed. This suggests a perception of increasing constraints on research creativity, a notion also highlighted by Hockey (1994). The drive to supervise more students coupled with dwindling resources and the push for students to complete in minimal time has reportedly placed serious constraints on the ability of supervisors to engage with PhD students in the ways that they would prefer, and may impact negatively on the supervision relationship, with participants reporting that they are increasingly unable to give students the attention they need. There also seems to be a shift in supervision models as a result, with less time for direct supervisor–student interaction characteristic of the apprenticeship and mentorship models that have traditionally dominated STEM fields (De Beer & Mason, 2009), towards greater use of group and team supervision. As pointed out by Malfroy (2005), this shift to group and team supervision may potentially result in loss of quality of outcomes if supervisors, as the disciplinary experts, are significantly less involved.
The structural influences on PhD supervision have also impacted institutional culture, with greater competitiveness and increasing lack of collegiality negatively emerging as a consequence in some instances. Seen through the lens of social realism, we argue that this observation may be seen as evidence of structural mechanisms leading to structural elaboration in the first instance, and a second phase of cultural conditioning and cultural elaboration. This is akin to Rönnerman and Kemmis (2016) demonstration of institutional practice architecture shaping, limiting and holding supervision practices. The present study provides further evidence of the impact of these institutional structural and cultural mechanisms on supervisors and doctoral students who find their agency constrained as a result.

**Conclusion**

Our study allowed us to demonstrate the dominant factors currently shaping postgraduate supervision, which has already undergone significant shifts in the last 20 to 30 years, alongside the emergence of the neoliberal university. As we had stated earlier, our aim was to share perspectives gleaned from a range of STEM supervisors from varying backgrounds on the changing nature of the PhD, and the potential impacts of these changes on practice. Our results show a distinct shift in the degree of self motivation that supervisors perceived of themselves, compared with their current students, and a related perception of current PhD students expecting more supervisory input. However, while supervisors acknowledge the need for more support and different types of supervisory input, structural constraints such time limitations and ever increasing student numbers may severely constrain the amount of additional input that can be provided. In addition, institutional culture and increasing competition may further constrain supervision practices. We thus demonstrate from this exercise that we appear to have reached a tipping point where the existing constraints are beginning to impact quality in a potentially very negative way, curbing agency, particularly of the supervisors, to adapt practices and better prepare graduates. Our findings, although limited in scale, are in line with the broader body of literature on supervision, which is increasingly critical of the ways in which the personal agency of supervisors and students is increasingly being constrained by bureaucracy. What we have to determine next, is the potential pivot points that can be leveraged for positive change, while being fully cognizant of existing constraints and the potential consequences of changing the status quo.

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