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Steps towards a philosophy of computer education. [Discussion paper]

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Steps Towards a Philosophy of Computing Education (DISCUSSION PAPER)

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ABSTRACT

Is it meaningful to talk about the philosophy of computing education? What is its subject matter and methods? Is it different from, or a subfield of, the philosophy of science education or the philosophy of technology education or the philosophy of engineering education? And how does the study of the philosophy of computing education help us with the goal of teaching students about computing? In this paper, we attempt to examine these questions. We look at the role of philosophical inquiry in the STEM fields and examine the philosophies of education found in those subjects. We first attempt to identify a framework for characterising questions of a philosophical nature that is appropriate for application to the STEM subjects. We describe the categories such questions fall under and consider methodological questions associated with this kind of inquiry. We also look at issues that arise within the philosophy of education and which are relevant when considering the philosophies of disciplinary education. We investigate some of the similarities and differences that exist between these fields and a philosophy of computing education and provide an initial description of the latter. We briefly consider other "sense-making" vocabulary used in computing education research, such as "theory" and suggest reasons why philosophical inquiry should be an important part of computing education research.

CCS CONCEPTS

• **Social and professional topics** → Professional topics; Computing education; Computing education programs;

KEYWORDS

Philosophy of Computing Education, Philosophy, Philosophy of Engineering Education, Philosophy of Education

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1 INTRODUCTION

If we examine the fields of mathematics, computing, technology, engineering, and the natural sciences, we observe that each of them possesses well-established research communities dedicated to exploring the philosophical problems arising within those domains [1–5]. Additionally, the STEM disciplines themselves have distinct research communities that specifically focus on investigating the philosophical implications of educational processes in their respective subject areas. However, if one searches for "philosophy of computing education" in, say, Google Scholar, there are no papers with this term in the title, and only one that has it as a keyword/phrase. The term "Philosophy of Computing Education" does not appear anywhere in the ACM Computing Classification System. This lack of explicit reference stands in stark contrast to the many hundreds of results yielded by searches for terms such as "philosophy of mathematics education," "philosophy of science education," "philosophy of technology education" or "philosophy of engineering education." While it is worthwhile making the distinction between "philosophy in computing education" and "philosophy of computing education", this is still a somewhat unexpected finding and raises the question of why this is the case, and also, whether this actually matters.

These issues will form the subject of this paper, and we argue that the lack of a clear and explicit subdiscipline of the philosophy of computing education does indeed matter for the academic health of the wider subject. area When done correctly, application of the philosophical method involves the systematic analysis and critical examination of fundamental problems in the subject to which it is applied. It is built on the exercise of established patterns of critical inquiry, logical reasoning, and rational evaluation, to form transparent judgements and conclusions about problems, paying close attention to the supporting assumptions and beliefs that underpin the results. As such, it can help to structure research within the field in a clear and epistemically justifiable way. Furthermore, it allows computing education to be situated within a wider critical discourse afforded by the STEM subjects allowing more coherent comparisons with activity in those disciplines.

The aim of this paper is, therefore, to investigate the role of philosophical inquiry in computing education as we attempt to identify what a philosophy of computing education would look like and what contribution it could make to the educational enterprise of teaching and learning in the computing discipline. We start by examining what general features characterise the philosophical study of some subject area, and make a heuristic distinction between intrinsic categories of philosophical investigation - metaphysics (focussing on ontology), epistemology, and axiology - and extrinsic application domains such as mathematics, natural sciences, engineering, education, etc. We give very brief descriptions of some features of the philosophy of education, both as an autonomous field of study and in its STEM-disciplinary variants, and examine some of the ways in which the process of high-level sense-making, which appears under various terms – philosophy, theory, metatheory... – occurs in those subject areas. In doing so, we consider whether the specific activities in computing education can be used to identify characteristic philosophical problems in the discipline which are distinct from those found in other STEM disciplines. For example, does a reliance on abstract notions of information give rise to distinct philosophical issues in the constructive activities of software development that are different from those found in the engineering disciplines which typically generate physical artefacts? Does a pedagogy based on the concept of computational thinking differ in kind from more established approaches based on abstract mathematical problem-solving or, indeed, critical thinking in general? Does the scientific method provide a good pedagogical underpinning for the development of competencies in computing? And how do issues such as these relate to operational aspects, including university computing curricula, and the national and international curricular documents intended to guide them, e.g., Computing Curricula 2020 [6]?

Many philosophers would argue that the main contribution that philosophical inquiry makes when applied to a subject is actually the methodological approach that it brings. We therefore start with a brief discussion of the notion of philosophical inquiry.

2 CATEGORIES OF PHILOSOPHICAL INQUIRY

While Philosophy is a notoriously difficult subject to define, it is possible to identify characteristic topics that describe the main areas of study, by looking at the content areas which philosophers have traditionally investigated. For example, the subject is generally held to encompass metaphysics, epistemology, methodology, aesthetics, ethics, logic, the philosophy of mind, the philosophy of religion as well as other specialist branches. Presenting a minimal classification of the subject area, we could say very broadly (and with one eye on later application) that it is about the nature of reality (metaphysics), the nature of knowledge (epistemology, but also valid ways of arriving at knowledge, such as methodology and logic) and the nature of value within the subject (axiology, which includes aesthetics and ethics). While this division of the subject may well be criticised, especially by philosophers, for eliding important distinctions in subject matter, we believe that the advantage of parsimony in the classification outweighs the use of a more fine-grained approach and is helpful when describing what constitutes a philosophy of an applied domain.

In order to discuss what constitutes the subject matter and methodology of a "philosophy of computing education", one starting point could be to examine what characterises the subject of philosophy itself. However, identifying the common features in the work of, for example, Thales of Miletus (c 648-548 BC), often described as the first philosopher of the Greek tradition, and, say, that of a 20th century analytic philosopher such Wittgenstein (or even comparing a philosopher of the 20th century Analytic tradition with one of the so-called Continental philosophers of the same period) is a challenging enterprise. Nevertheless, we can still determine some aspects of basic subject matter and methodology that were, and have remained, central to the Western philosophical enterprise over the past twenty-five centuries. One characteristic feature, since at least the time of Socrates, has been a focus on making distinctions, and analysing the differences and similarities between the categories that are so distinguished – an approach that has successfully been applied to the subject matter of philosophy itself. This gives us a set of categories into which philosophical problems fall and which can be seen as branches of the subject, although the details of this have often been controverted by philosophers themselves.

A basic distinction that could be made is between intrinsic categories of philosophical study and those that arise in its areas of application. By intrinsic categories, we mean those areas of study that have characterised the field of philosophy from its inception, and which still provide much of the content of the subject. This distinction will be useful and, for the purpose of this paper, we divide up the subject matter of philosophy (or the focus of philosophical inquiry, which we take to be the same thing) into three broad areas, which we then use as ordering principles for philosophical problems in application domains.

The first category is Metaphysics, and like philosophy itself, the conceptual boundaries of the subject are hard to delineate. Traditionally, it includes the study of essential properties and substances, the theory of universals, the identification and classification of causes, ideas about modality, necessity and contingency, the nature of the mind and its interaction with the body, free will and determinacy, and space and time. As a somewhat simplistic overview, we can say that it is the study of what is, or what exists. For this reason, and with an eye to application areas in the sciences which have typically taken a Kantian view, we will use the term "Ontology", i.e., the study of what objects and relationships can be recognised as fundamental (or at least important) in the area under discussion, and how the non-fundamental or composite objects depend upon them.

The second intrinsic philosophical category is Epistemology, i.e., the study of knowledge, its nature, scope, sources, and limitations. Epistemology examines how we acquire knowledge, what kinds of knowledge are possible, what is the relationship between knowledge and belief, and how we can distinguish between true and false beliefs. Because it seeks to examine the nature of knowledge, it provides a foundation for understanding how we can make reliable claims about the world, and so is a fundamental area of philosophical inquiry that supports the practice of almost all other fields of study. In the context of this paper (and somewhat anachronistically), we use the term to include what methods of knowledge acquisition are accepted as relevant within a particular application domain. This means that we will use it to also include other philosophical subdisciplines that would normally be counted as separate from epistemology, such as methodology, i.e., what approaches to inquiry are counted as legitimate within the application domain, and logic, i.e., the systematic study or reasoning and the methods for evaluating the validity and soundness of arguments. Again, this definition is open to objection but we believe that it suffices for the purposes of the paper.

The third intrinsic category of philosophical study is Axiology, the study of the nature of value, its generation or recognition, and its functional role within an area of discourse. This category investigates what values are discussed and prioritised in application areas, as well as basic questions about the attribution of meaning. This is clearly a fundamental process in any human enterprise, and so it encompasses a number of well-known philosophical subdisciplines. These include ethics and aesthetics, as well as social and political philosophy, cultural criticism, some aspects of the philosophy of religion and the philosophy of law. For the purpose of this paper, we can focus on the first two of these. Ethics is the subcategory of axiology that investigates questions of morality and what actions and behaviours are morally acceptable. It seeks to provide a framework for making moral decisions and evaluating actions and behaviour that occur in the world. Aesthetics, on the other hand, is the subcategory concerned with ideas about beauty, art, elegance, and expertise or virtuosity. It considers how one evaluates these concepts, and how, for example, one can legitimately discriminate between examples of good and bad production or practice. In terms of application, it considers what kinds of things within a subject area are considered stylish or elegant, as well as seeking to analyse the experience of beauty from the perspective of someone engaged in that area. These three categories are similar to those described by Ferré, as cited by Heywood [7] except that we have denoted metaphysics by the term ontology, and have chosen to include methodology as a subcomponent of epistemology. Note that the use of this categorical approach allows us to distinguish "philosophy", as a technical term, from more colloquial uses that denote a general, high-level, often individual, approach to doing something.

Another way of characterising philosophy, rather than looking at a structural categorical approach, is to ask what philosophers do when they "do philosophy". This functional view emphasises the philosophical method that is used. This presupposes that there is indeed a defined philosophical method that characterises philosophical inquiry, in the same way that the scientific method characterises scientific inquiry. However, providing a complete description of that method has, historically, proved challenging, with different philosophical schools appropriating their own specific methodology. For example, analytic philosophy is characterised by reductive analysis, especially of the linguistic elements of problems; phenomenology focuses on the intrinsic or essential structures of phenomena as directly experienced by the subject; the hermeneutic approach seeks to understand how meaning is generated and negotiated in the dynamic interplay between the interpreter and the thing that is interpreted. Nevertheless, central to almost all of these different approaches, is the process of conceptual analysis, which seeks to define and clarify the meanings of particular terms and concepts used in any discussion. This typically involves the use of techniques such as critical reasoning, analysis, and logical argumentation, to examine and evaluate such problems in the light of other philosophical concepts and theories. Conceptual analysis seeks to systematically decompose the concepts being studied into their fundamental constituents, determining conditions for their validity and domains of application. Coombs and Daniels [8] identify three elements in this analytic approach: conceptual interpretation (the attempt to provide an adequate account of a concept in ordinary language), conceptual development (the development or defence of a concept or conceptual structure) and conceptual structure assessment (which determines the adequacy of conceptual structures to frame further inquiry). Other authors have provided alternative description of the forms of inquiry that take place. Short [9], for example, identified a number of different functional perspectives based on the types of question that might prove useful in an educational context. For questions in an applied domain such as computing education, these would provide a variety of different perspectives on the problem. For example, there would be an analytical perspective (what logical forms of argument are being presented?), an ampliative perspective (what assumptions and norms are implicit in the arguments presented and what inferences can be made?), a phenomenological perspective (what is the subject's intentional, first-person experience of the phenomenon under question?), a hermeneutic perspective (what interpretation should be given to the phenomenon?), a normative perspective (what value does the system have or what ought to be the state of affairs with regard to the subject being studied?), a critical perspective (what contradictions or inconsistencies exist between fundamental norms and existing practice?), an evaluative perspective (how do we measure the properties of the system?), a deliberative perspective (what kind of decisions can be made based on reflection, rational analysis, and consideration of evidence when confronted with phenomena), etc. This is not an exhaustive list but it serves to provide an alternative characterisation of philosophical inquiry based on the types of questions that are asked rather than the content area studied. While not independent of each other, both the structural and functional perspectives allow us to recognise philosophical issues when they arise in the practice of a discipline.

It is, perhaps, worth noting at this point how philosophical inquiry relates to scientific inquiry within the STEM-disciplines. This distinction between philosophy and science (or the application of the philosophical method as distinct from the scientific method) has become more problematic in recent times as the methods of empirical investigation have been applied successfully to areas once reserved for philosophical inquiry. For example, consider the impact of cognitive psychology and neuroscience on the philosophy of mind, computational linguistics on the philosophy of language, or social psychology and behavioural economics on ethics or political philosophy. Nevertheless, as impressive as these contributions are, they are grounded in empirical study rather than conceptual analysis, and it would be a mistake to understand science as simply replacing philosophy as a discipline matures. Indeed, the case of computing suggests that the very maturation process of a subject gives rise to autonomous philosophical questions that, while obviously dependent on the specifics of the discipline, are not questions that can be answered solely by empirical study within the subject itself.

In order to discuss this further, we first attempt to give some account of what a philosophy looks like when applied to some domain. Following that, we give a brief overview of some issues in the philosophy of computing before moving on to the look at the philosophy of education.

3 WHAT IS A "PHILOSOPHY OF SOMETHING"?

The structural categories of philosophical inquiry discussed earlier can be used as a means to determine philosophical questions that arise in an application domain. From this viewpoint, what characterises a "philosophy of X" (where X is some subject domain) is that X is analysed under one or more of the categories - ontology, epistemology, or axiology - described earlier. The ontological category frames investigation into the fundamental elements of the subject, their causal processes, the relationships that constituent entities, be they physical or conceptual, have with each other at various levels of analysis, and how these can be represented and modelled within the application domain. The epistemological category encompasses questions of how knowledge is discovered, created, and justified, as well as the legitimate modes of inquiry that are accepted within the subject. The axiological category situates questions about the values, whether ethical or aesthetic, that emerge from the subject and which inform its practice. This structural characterisation is sufficiently broad to accommodate the philosophical questions that arise in the various application areas we wish to discuss, and is orthogonal to the functional approach which focuses on the characteristic questions and methods of inquiry used by philosophers when investigating problems in the application domain. In this approach, we can describe the philosophy of X as the study of X when carried "in a philosophical way", using the methods and questions described above. Thus, for example, in terms of Short's approach, we can try to take an analytic, ampliative or hermeneutic perspective on the subject.

There are two main ways to identify philosophical problems within an application domain. The first is by taking a "top-down" approach in which the subject area is analysed from the perspective of the structural categories of prototypical, philosophical content areas; for example, in mathematics, what is the ontological status of numbers, or in physics, what are the epistemological implications of the uncertainty principle? This process provides a structural view of the philosophical issues that arise and seems to be natural when dealing with abstract or theoretical aspects of a discipline such as the natural sciences or computer science. The second way is to take a "bottom-up" approach in which practical questions, that arise naturally from within the subject domain, can be analysed using the functional philosophical questions described earlier. This may seem a more natural process in, for example, the social or educational sciences where practice is often a key feature of the subject, but is frequently messy and inherently contextual, making a top-down analysis difficult. As an example of the latter approach, we consider how such questions arise in the philosophy of education.

3.1 The Philosophy of Education

Philosophical concepts abound in the educational sphere. For example, ideas about ontology make their presence felt in discussions about curricula, epistemology lies at the heart of any appreciation of pedagogy and the learning process, while in recent years, the axiological notions of value and ethical judgement have seen prominent consideration within the educational community. In this section, we give a brief tour of some of the philosophical issues which occur and which will be of interest when we discuss the philosophy of computing education. We note that some philosophers of education, e.g., Biesta [10], refer to the existence of "two cultures" of educational research. The first is the Anglophone tradition in which the academic study of education within universities established itself in the context of teacher education, and which is characterised by a robust, practice-based approach which makes use of subjects like history, psychology, cognitive theory. In contrast, the European tradition, exemplified by the emergence of the subject in Germany ("Erziehung"), saw its aim, not so much in terms of skill acquisition, but as the development of the virtuous person with rational autonomy. In Europe, "Education" as a discipline established itself as an academic subject in its own right, with its own forms of inquiry that integrated theory and practice, e.g., the discipline of "*Pädagogik*" in German and "*pedagogik*" in Swedish.

Traditionally, the philosophy of education has not usually been approached by the top-down method of explicit reference to the intrinsic philosophical categories of ontology, epistemology, and axiology. The reason for this may be traced to the practical nature of much educational activity: teaching, assessing, certifying competence, etc, are all connected to human interaction at a fundamental and natural level, and the many of the problems that arise require practical and, often, contextual solutions. As such, it is more common to see philosophical problems arise from within this practice. In addition, the irreducibly human element of teaching and learning means that, while epistemological problems are central to the subject area, axiological questions concerned with ethical and aesthetic values in the learning process, are also prominent, as are ontological questions about curricula.

Moore, in his textbook on the philosophy of education [11], writes that the subject deals primarily with problems that arise from the nature of educational practice, with a focus on achieving conceptual clarity to justify that practice in the light of theory. This pursuit of clarity involves philosophical analysis of educational concepts as well as scrutiny of the various theories of education that have been proposed, by educationalists but also by other philosophers. Philosophers of education are therefore concerned with a scrutiny of what is said about education by those who practise it and by those who theorise about it. Education is, of course, a complex and interrelated social phenomenon, which occurs at a range of hierarchical levels. The most basic of these is the set of practical activities such as teaching, instructing, motivating, advising, and correcting students' work. Those engaged in these activities, primarily teachers, use a specific language, employing terms like "teaching," "learning," "knowledge," "skill", and so on, which form the foundation for higher-order activities, such as educational theorising, which is the initial stage of the development of educational theory. The theorising may make general, though empirically testable, claims about education practice, in which case, they can be evaluated by the methods of the social sciences. However, the theorising may also focus on providing normative advice and recommendations for those engaged in teaching. Sometimes these pedagogical theories will be narrowly focussed, especially when concerning specific disciplines (e.g., theories about how to teach programming in computing) but sometimes they will be of such scale as to aim to provide comprehensive prescriptions for the educational process. Such cases may be termed general theories of educational practice and themselves may depend in a fundamental way on other broader philosophical approaches (e.g., pragmatism, constructivism, perennialism, essentialism, ...) and hence constitute one theme in the philosophy of education. An interesting point made by Moore is that these general theories are not theories about education (which would be the remit of the social sciences) but theories of what education ought to be like, or how education should be done. However, a normative theory, i.e., one that expresses how a thing should be, assumes that there is some desirable end, and in the case of education, this almost always relies upon some general assumptions about human nature and society. This normative element also means that one should distinguish between general theories of education that have been put forward by philosophers (e.g., Plato, Rousseau, Dewey, etc) and actual philosophies of education. Such general theories of education tend to suggest that the educated person would be one who had acquired some kind of worthwhile competence or virtuosity. However, the word "worthwhile" here clearly indicates some kind of axiological basis found in society, which then uses the educational process to transmit sociocultural values. The body of knowledge and skills deemed valuable in this tradition then constitutes what we might call a curriculum, which itself can be differentiated into elements such as what is taught, how it is taught, why it is taught, etc. In this approach, the "what" can be thought of as part of the ontological basis of the curriculum, the "how" deals with epistemology (including methodology), and the "why" with axiology.

The varied sociological aspects of education also impinge upon its philosophy. Education is not just an individualistic enterprise but contributes, in part, to the ordering of human society. As Moore states "Education may be seen as one of the devices which society employs to preserve its present integrity and its future survival". This social phenomenon can be investigated in a range of social science disciplines by sociologists, political commentators, as well as historians, which result in social theories about education. However, social theories are often deeply ideological in nature, utilising, for example, notions of equality and democracy, freedom and authority, and so require investigation at the conceptual level.

From this, admittedly brief, discussion, it can be seen that the "bottom-up" approach of identifying aspects of the educational process and identifying specific questions which can be investigated using the philosophical method, is not in opposition to the "top-down" categorical framework, but is another way of framing the issues that can be addressed.

4 THE PHILOSOPHIES OF STEM-SUBJECT EDUCATION

Having discussed some of the basic categories of philosophy, and its application to education, we now briefly examine the idea of philosophy of education found in some of the STEM subjects before we look at the philosophy of computing education. It is useful to make a few preliminary remarks about models of philosophical inquiry in discipline-based education (such as the philosophy of science education or the philosophy of mathematics education). Each of the STEM disciplines, as well as Computing, gives rise to a range of distinct, domain-centred areas of investigation that can be seen as expressions of more general questions about philosophical subject matter, and which can be usefully addressed using the methods of philosophical investigation. Among the things we would like to know is whether there are specific theoretical and practical topics in computing education that give rise to questions that can be usefully addressed using the perspective and methods of philosophy, and whether there is a set of such problems which are sufficiently different from those found in the neighbouring disciplines so as to constitute the basis for a philosophy of computing education which is not simply an aggregate of problems found in other disciplines. These questions are different from whether students should engage with the philosophy of the discipline within an educational programme; that is almost certainly true. There are clearly some domain-specific problems that fall under the philosophical categories, say, questions of professional ethics, that a practitioner would be expected to know about. Assuming that these are considered important enough to be part of the university curriculum, the learning process would almost certainly involve direct engagement with those questions by students as part of their course of study. An examination of the computing curriculum (e.g., as expressed in the CC2020 document) in the light of the philosophical categories of ontology, epistemology, and axiology, reveals numerous examples of this. Philosophical notions of ontology provide the foundation for the kind of knowledge representations that form a framework for identifying necessary and desirable elements of competence within the Computing curriculum, as well as describing the network of relationships between such competences. Questions about problem-solving methodologies, e.g., the application of so-called computational thinking, and the analysis of how this may or may not differ from other types of heuristic, have clear epistemological underpinnings. The ethical considerations that underlie the protection and security of information, as well as the calculation of risk in software engineering, are common topics embedded in most computing courses. The question of the best way to teach these philosophical topics would primarily be a pedagogical one, not a philosophical one (although the question of which way to teach the subject (e.g., whether to take an instrumentalist approach in Physics or a foundationalist approach to the teaching of Mathematics) may well be a philosophical one).

The issue, then, is not simply to enumerate potential philosophical questions in computing education (as important as this may be), but to try to see if there are some characteristic features of computing education which gives its philosophy a focus which is different from, say, the philosophy of engineering education. Mathematics (taken in the broad sense to include applied subdomains such as statistics), the natural sciences, as well as engineering and technology, can all point to similar questions about the fundamental basis of their curricula, their characteristic methodologies, and concerns about ethical problems that flow from the practice of their subject, and students are required to engage with these as developing professionals in that area. The question therefore is what is it about computing, or any other discipline, that gives it a distinctive or a characteristic philosophy of education?

An intuitive way to conceive of philosophies of discipline-centred education is that they are philosophical questions that arise within the general educational process, but which are based on the content area of the discipline. However, if a philosophy of discipline-based education, e.g., computing education, is to be a genuine object of study, at least some of these questions should be distinctive within the discipline, and independent of those found in other disciplines. Some philosophical concerns will, no doubt, overlap with those in the philosophy of education of neighbouring disciplines (in the case of Computing, with Science, Engineering, Mathematics and Technology) but there should be a core of philosophical problems which should emerge from the educational concerns of the discipline itself, and which are not, primarily, philosophical problems of education addressed in neighbouring disciplines. Insistence on this independence criterion ensures that we cannot simply reduce the philosophy of computing education to an aggregation of issues found in the philosophies of education of other STEM disciplines. It would also give us a basic characterisation of the fundamental issues in the subject itself. One way of doing this would be to take a narrow, intersectionalist view that the philosophy of computing education is simply that subset of the philosophy of the education which deals specifically with the issues arising with disciplinary content of computing, rather than another subject (or alternatively, that subset of the philosophy of computing that deals with educational issues – which may, or may not, be the same thing). However, while this reductive approach may be useful as far as identifying some of the subject matter, it will fail to capture any emergent philosophical issues that can arise when viewing the subject of education from a distinctly "computing" perspective.

4.1 The Some Issues from the Philosophy of STEM-subject Education

In his work, Philosophy and Curriculum, [12], the educationalist, Israel Scheffler, described what he called "philosophies-of" and outlined four ways in which their investigation might usefully contribute to the improvement of education. He believed that analysis of such philosophies would offer detailed, analytical descriptions of what he termed "forms of thought", i.e., the characteristic cognitive processes by which experts conceive of issues in a discipline such as science. Among the educational benefits that would emerge from such study would be a systematisation of the content as well as an understanding of the forms of thought accessible to novices. This emphasis on usefulness was raised by Schulz [13, 14] who argued that "any philosophy of science education is first and foremost a philosophy, [his emphasis] and as such, receives its merit from whatever value is assigned to philosophy as a critical inquiry". A philosophy of science education, and by extension, any philosophy of STEM-subject education, should not therefore be abstract or removed from practice, but should make some positive contribution to the way in which that discipline is taught and assimilated.

Another point raised by Schulz (in the context of science education) is the need for a "guiding metatheory" for the practice of education and its relationship with the disciplinary educational philosophy. The term metatheory is taken over from Aldridge et al. [15] and denotes a worldview or paradigm which gives a "big picture" of a subject, so providing an encompassing framework under which multiple theories of development or learning are classified together based on their shared view of human nature. A metatheory "seeks to formulate a coherent account of, and prescriptions for, a given range of phenomena within its specified conceptual framework; it has pre-established criteria for empirical interpretation and judgments, and it directs research efforts along given lines within scientific or scholarly communities" [16]. Aldridge suggested that there were four psychological metatheories which have been applied to education, each of which presented a different view of the subject, based on some characteristic underlying metaphor. These were the biological or organismic view, the mechanistic view, the dialectic view, and the contextual view. The biological or organismic view, associated with Piaget and fellow constructivists, sees educational development occurring through a sequence of discontinuous stages, much like the development of some biological organisms. Reese and Overton [17], suggested that the biological nature of the metaphor should also be understood as emphasising development in holistic, or at least integrated, terms. They contrast this with the reductive, mechanistic model which derived primarily from behaviourist psychology, which sees the process of learning in terms of inputs, provided by the learning environment and teacher amongst others, and outputs in terms of modified behaviour. As expected, the primary metaphor is the mechanism. By contrast, the dialectic metatheory, based on the theories of Marx, Hegel, and Soviet theorists such as Vygotsky, focuses on contradictions and conflict in the individual's dynamic interaction with the environment, which are taken to be primary determinants of development. Finally, the contextual metatheory is derived from pragmatic philosophers such as Pierce, James, and Dewey, and based on the idea that human activity does not develop in a social vacuum but is rigorously situated within a sociohistorical and cultural milieu. To these four metatheories describing psychological development, Aldridge et al., and Schulz add what they see as a specifically educational cognitive-cultural metatheory which looks particularly at educational, rather than psychological, development. Based on Egan's cultural-linguistic metatheory [18], it sees human cognition evolving through distinct stages that use a set of cognitive tools to shape the ways in which individuals understand and make meaning of the world. These are not fixed stages of development but rather represent different ways of thinking and understanding that can coexist in individuals of different ages and abilities. An effective education should provide opportunities for students to engage with these cognitive tools and move between them, fostering a more comprehensive and imaginative understanding of the subject matter. The metatheory, therefore, provides a lens through which the profession or community of practice views itself and the subject. It provides meaning and conceptual order for the ontological basis of the discipline by giving value to certain methodological prescriptions about what constitutes knowledge and what methods would be appropriate to arrive at it. Wherever the arguments for or against understanding a subject through the perspective of a particular metatheory, it seems clear that the analysis of the arguments themselves is not simply based on empirical data but upon reasoning about the kind of things that are under study, the way that knowledge about them is accessed and the values that are important when considering science education, i.e., on elements of the philosophical categories of ontology, epistemology, and axiology. Consequently, the analysis of such metatheories falls under the remit of the philosophy of education, and when applied to a specific discipline, the philosophy of disciplinary education.

Turning to the recent development of the philosophy of engineering education as an independent academic discipline, e.g. [19], we see a number of fundamental problems emerging. One of these is the discrimination issue, i.e., whether there is a philosophy of engineering education that is distinct from a general philosophy of education on the one hand, and more established philosophies of disciplinary education (such as the philosophy of science education or the philosophy of mathematics education) on the other. If this is so and the distinction can be made, then the second problem emerges, i.e., to identify the characteristic questions and methods that arise within the subject area. Finally, there is the issue of what relevance the answers to the previous two questions have for the discipline, i.e., how a philosophy of engineering education would impact upon the engineering curriculum.

The discrimination problem for engineering education is dependent on a similar problem for the subject of engineering as a whole, in that, for there to be a distinct philosophy of engineering education, it is necessary to be able to discriminate engineering as a discipline from (primarily) applied science. This is usually done by observing that the process of rational engagement with engineering as a subject is different to that which takes place in modern science, and leads to a focus on the contingency of engineering knowledge and praxis, and its relation to design [20]. Dias [21] characterises this problem as resting on the establishment of engineering identity. Specifically, he claims that engineers are currently facing three "identity crises", each of which, from the perspective of this paper, can be viewed as an issue in one or more of the three intrinsic philosophical categories discussed earlier. Firstly, there is the epistemological crisis concerning whether engineering knowledge is theoretical or practical. The second, ontological, question concerns the role with which engineers identify - that of scientist, designer, or manager. The third, axiological, question relates to how the engineer interacts with the outside world through ethical issues and the aesthetics of design. All three crises have implications for engineering education as the tension between the different poles of opinion lead to different perspectives on what engineering is, and how it should be taught. Pawley [22] reports three different but common conceptions of the subject amongst a small group of engineering teachers - that of applied science, technological problem-solving and artefact-making. Ontological questions are themselves reflected in epistemological ones: if engineering is primarily applied science, then this, presumably, would mean that the appropriate methodology to use would be the scientific one. Yet, as pointed out by Goldman, "Engineering is contingent, constrained by dictated value judgements and highly particular. Its problem solutions are context sensitive, pluralistic, subject to uncertainty, subject to change over time and action directed." This suggests that a philosophy of engineering should be as much Pragmatic as Platonic (if not more so), and, consequently, this should be reflected in its educational approaches and methods. This is not to say that engineering and engineering education can be divorced from science and mathematics - both subjects clearly provide a vast array of theoretical and practical tools to address questions within the engineering domain - but more that engineering cannot be reduced to their application as, fundamentally, the subjects lie in different knowledge domains with different ontologies, methodologies, value systems, i.e., they have different philosophical bases.

5 TOWARDS A PHILOSOPHY OF COMPUTING EDUCATION

What implications does the previous sets of discussion have for outlining a philosophy of computing education? On the one hand, it is clear that the subject area is not independent of the problems and methodological concerns that it shares with its neighbouring STEM disciplines. The need for a coherent educational metatheory, issues about the ethical frameworks for professionals, the incorporation of notions of contingency and risk and within the curriculum, these all apply to computing education as well as other STEM subjects. We can therefore draw some insight about the importance of the philosophical issues in computing education from considerations in other STEM-subject education. Matthews [23] remarks that "A teacher's epistemology or theory of science influences the understanding of science that students retain after they have forgotten the details of what has been learnt in their science classes... this ought to be as sophisticated and realistic as it is possible in the circumstances. [Unfortunately] a teacher's epistemology ... is largely picked up during his or her science education; it is seldom consciously examined or redefined". The situation with computing education is probably significantly worse. While science has a widely accepted methodology which can serve as a coherent basis for epistemology within the subject, there is often substantive disagreement among computing educators, whether constructivist, instructivist or neither, on fundamental approaches to pedagogy as well as other important issues.

Computing education, along with other STEM-subject education, also requires a coherent metatheory to provide a clear narrative to students. Indeed, this is, perhaps, more urgent because of the place the subject holds, sitting across science, technology, engineering, and mathematics, each of which seems to tell a different story about its own practice, and where the narratives that emerge are often defined in opposition to the other STEM-subjects. It is likely that an explanatory narrative for computing will engage with the metatheories in science and engineering, but, as Schulz points out, the analysis, evaluation and possible synthesis of different metatheories will be a philosophical project requiring philosophical tools to make progress. This shared inheritance and content from the more established STEM disciplines also contributes to the problems under philosophical examination. For example, if we consider the computing subdiscipline of software engineering, it shares many of the epistemological and methodological concerns of physical engineering. Software systems often operate in uncertain and evolving environments, where requirements can change, and new information can emerge over time. This uncertainty and incompleteness make it difficult to achieve a complete understanding of a system, leading to potential gaps in knowledge and hence failures in design. Such systems can exhibit emergent behaviour, making them difficult to fully understand and raising questions about the limits to which a formal specification can be made. Software development often involves choices between different design approaches, which have sets of requirements which cannot all be optimised simultaneously, with different stakeholders having different interpretations of system requirements or priorities, leading to varied and contradictory interpretations of the specification. Software development, as a professional process, relies not only on explicit, codified knowledge but also on implicit and tacit knowledge, which is difficult to articulate or transfer to others. The expertise and intuition of experienced software engineers play a crucial role in capturing and transferring this knowledge. Clearly, many epistemological and methodological questions arise, but it would be possible to replace the phrase "software system" with "physical engineering system" and the text would be equally correct, showing that similar philosophical considerations apply to teaching both physical engineering and software engineering. The introduction of new and potentially revolutionary AI technologies presents its own challenges. Given the pace of development in computing, and the changing environments to which computing and information technology is applied, a superficial and unreflective appreciation of the importance of philosophical issues will inevitably cause problems when teaching about the big issues that emerge. A strong philosophical basis for the subject would promote the conceptual clarity that allows the fundamental assumptions of the subject is based to be examined, and viewed in comparison with similar concepts and methodologies in the educational practice of other STEM disciplines. A comparison between the ethical issues faced, say, by artificial intelligence researchers and those engaged in the natural sciences reveals that both share concerns about research accountability and transparency, e.g., the black-box nature of some machine learning algorithms that make it difficult to understand and explain how the outputs of experiments are causally connected to given inputs. In their study of the ethics in scientific research, Weinbaum et al. [24] identified ten ethical principles divided into three categories - ethical scientific inquiry, ethical conduct and behaviour of researchers, and ethical treatment of research participants - that would be normative in scientific research. While the third category would not generally be applicable in AI research, the first two are clearly important and this provides yet another example of shared philosophical concerns among educational research in STEM subjects.

There are however differences between computing and other subjects. We would argue that what distinguishes computing from its neighbouring STEM disciplines is its focus on the representation, manipulation, and application of abstract information to the real world. Any high-level conceptual analysis of this, be it in the context of programming, information systems, machine learning or whatever, will lead to ideas about the process of abstraction and the essential nature of information and how it can be transformed from one medium to another. This lends a specific flavour to any philosophical discussion which is not found in other disciplines and which should inform the practice of the philosophy of computing education as well as its expression within the computing curriculum. This is a substantial and significant issue, and much more could be said about it. For example, the low-cost reproducibility of abstract information has profound implications for the ethical and aesthetic basis of the subject.

Finally, one definitional question that may be asked concerns the relationship between the philosophy of computing education and the subject denoted by "Computing Education Research" (CER), e.g. [25–27]. We take CER to be an inclusive term which encompasses the rigorous study of computing education from a number of perspectives. These would include the philosophy of education, as well as the empirical study of educational topics in the field through the methods of the natural, cognitive, and social sciences. There are significant questions about how the sense-making terminology of CER, in particular, those associated with use of words such as theory, grand theory and paradigm relate to what has been described here as metatheory, as well as the general term philosophy. Probably the most influential definition of theory in the context of CER is that of Malmi et al [28] which defined theory "to mean a broad class of concepts that aim to provide a structure for conceptual explanations or established practice, and use such terms as 'theories', 'models', and 'frameworks' to describe particular manifestations of the general concept of theory". Investigation of how this kind of definition, which encompasses scientific, empirical investigation as well as conceptual analysis, relates to the activity of "doing computing education" (not just CER) [29, 30], clearly overlaps with some of the philosophical activities discussed previously. Moreover, there are other definitions of theory, e.g., Sfard [31], which also deserve attention when exploring these ideas. It is worth noting, however, that disentangling these definitions and investigating the emphases that underlie these concepts, is exactly the process of conceptual analysis and inquiry that forms the basis of the philosophical method.

6 CONCLUSION

We have argued in this paper that the philosophy of computing education is a subject which should be seen as central to computing education. It provides robust methods for conceptual analysis of the key concepts and serves to identify and clarify problems that lie at the heart of the discipline. Its subject matter lies in the intersection of the philosophy of education and the philosophy of computing, and so draws from both of these subdisciplines. It is informed by the philosophies of the STEM-subjects from which computing, as a discipline, has emerged. While operational questions of the best way of teaching specific elements of the Computing curriculum are most properly addressed using the empirical findings of pedagogy, appropriately informed by results from the cognitive and social science, the justification for the overall narrative of why things are being taught, the motivation for, and priorities of, the curriculum, i.e., the metatheory for computing education, are philosophical issues guided by concepts of value.

Despite a lack of explicit mention, it is clear that there is currently much work being done in the philosophy of computing education. It underlies much of the rigorous work that is currently done under the term "theory" in CER, the methodological analyses of Tedre and Pajunen [25], the analysis of the nature of the Computing discipline [32], attempts to justify the basis of the curricular components described in the CC2020 documents [6], and the pervasive appearance of ethics as part of the standard university curriculum. These all testify to the existence of a robust interest in the philosophical issues that underlies much of the technical work done in computing education.

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