

# Context, Competency and Authenticity in STEM Education

Roger McDermott  
School of Computing  
Robert Gordon University  
Aberdeen, United Kingdom  
roger.mcdermott@rgu.ac.uk

Mats Daniels  
Department of Information Technology  
University of Uppsala  
Uppsala, Sweden  
mats.daniels@it.uu.se

**Abstract**—This Research Full Paper presents work which links a consideration of the concept of context with that of learning competency and that of educational authenticity in STEM subjects. The word "context" is very familiar in both everyday language and in educational settings. However, because of its ubiquity, it is often taken for granted that both educators and students know what it means, and how it is being used. This paper reviews the concept of context, using the typology developed by Dohn et al. We draw attention to the way in which this can be applied to the notion of competence, specifically, the competence framework developed by Frezza et al, and consider how the concept underlies the idea of authentic learning. We argue that a clear understanding of authenticity depends critically on both students and academics being able to discriminate between the different types of contexts that occur in authentic assessment processes, such as projects based on real-world scenarios. We also consider contextual categories when describing the different ways in which learning can be transferred.

**Keywords**—context, competency, authenticity, judgement

## I. INTRODUCTION

In his 2015 paper, "What is Education For? On Good Education, Teacher Judgement, and Educational Professionalism" [1], the educational philosopher, Gert Biesta, made the bold statement that "the point of education is NOT that students learn". He went on to clarify this somewhat counterintuitive claim by saying that "the point of education is that students learn SOMETHING, that they learn it for a REASON, and that they learn it from SOMEONE" [our capitalisation]. While his essay raised a number of interesting points about what he calls the "learnification of education", it also draws attention to the fact that context appears to be an irreducible factor in the experience of learning.

The notion of context is itself a controversial one in Higher Education. While much of the work on situated learning suggests that all learning is context-dependent, to some degree, but many of the aims of university education appear to reflect a desire to overcome context, e.g. when speaking about the development of skills in a particular subject, the transfer of competencies between different domains, or even the ability to abstract from a specific context altogether. The fact that there is a lack of unanimity on what the term means is surprising given the significance of the concept and the impact it has on a huge range of issues, e.g. see [2]. These range from curricular discussions of domain-specificity versus the generic nature of skills, through issues surrounding the authenticity and relevance of so-called "Real-World" activities in university courses, the assessment of informal learning in the workplace, to transferability of technical and professional competencies and whether this is actually possible. They also have an impact on high-level social and educational policy issues such as the globalisation of

university education and the teaching of students within unfamiliar cultural settings. These are substantial issues that go to the heart of the student learning experience and the pedagogical basis with which this is delivered.

It is an interesting exercise for the reader is to take a passage of text which discusses practical aspects of learning and teaching, and which considers the concept of context, and try to rewrite it without using the word. A few synonyms may present themselves – environment, setting, circumstances – but we suspect that very soon, the reader will start to be dissatisfied with the simple act of replacement of these words because of a perceived reduction of meaning. There is certainly no single word, or indeed collection of words, that does the same job. This linguistic problem is indicative of a wider issue, namely that the concept of context is actually very complex and admits a deep substructure which is often neglected in both common language and educational discourse.

There are many reasons why educators would wish to understand the role of context more deeply but, in this paper, we touch upon three of them. The first is the role it plays in competency theory, and especially the dimensions of competence outlined in competency frameworks. The second is the role of practical judgement in the development of professionalism in STEM subjects. We focus on computing and engineering in this paper, but the same arguments could be articulated for learning in all STEM subjects. Thirdly, we look at the issue of authenticity in learning and the role that context plays in determining authentic learning experiences. When viewed through the lens of context, these three issues can be seen as facets of the same problem of how to support student learning when faced with ill-defined problems.

In this paper, we explore some of these issues, especially in relation to the typology of context categories given by Dohn et al. We seek to clarify the notion of context as it appears in the curricula of science and engineering subjects, using competency theory as the primary example. Specifically, we draw on the CoLeaF model described in the work of Frezza and his co-workers [3], in which a rich and multifaceted conceptualisation of competency as an integrated construct, with knowledge, skills and learning dispositions components, is applied to the curriculum design of computing courses. Here, the idea of contextualisation plays a fundamental part in differentiating the hierarchical levels in which a competence is exhibited, as well as providing a way of discussing the granularity of its description when applied to constructing those competence hierarchies.

The key outcome of this work is to provide an overview of the concept of context so that a deeper understanding can emerge of how it can influence learning and the creation of learning environments in diverse educational settings. This is intended to assist educators in considering how context affects their work and to try and encourage a deeper understanding of

the varieties of meaning that arise from its use. It is hoped that the review will provide insights into the role that context can take, will be useful for individual teachers when creating educational settings in individual courses, as well as for curriculum designers and those constructing educational policies at an overarching level.

We also consider the link between context and contingency and the wider issues of authenticity within university education and the transferability of competencies. This is an important one which goes to the heart of the debate about the extent to which learning can be transferred, and so to fundamental issues of curricular design. This can be related to the idea of models of applied competence and the process of developing educational settings in which students can undertake a constructive approach to learning. On a general level, this leads to the need to find formal approaches to capture and describe the context as part of learning outcomes, both for individual course units and degree programmes since, for example, work done on the transferability of competence between different settings often fails to adequately take account of the different aspects of context when describing learning gains. It is hoped that this preliminary paper provides some foundation for such work.

## II. A TYPOLOGY OF CONTEXT

### A. What is Context?

As with so many concepts which are regularly employed in everyday life, we can become overly reliant on familiar definitions and miss the complexity and subtle nuances of the word when using the term “context” in a technical situation. Since educationalists often use adjectives to moderate the word - one might speak of a professional context, a work-related context, an instructional context, indeed an “educational context” - it might be thought that the prepended phrase is moderating an unambiguous or univocal concept. However, this is far from the case and much of the confusion that arises in, say the discussion of learning transfer, can be traced to the semantic ambiguity about the word. The problem is exacerbated by the fact that the concept occurs so often in common discourse that one is hard-pressed to refrain from using general synonyms just to avoid repetition. Unfortunately, this tends to reduce the clarity in a technical discussion. For example, it is difficult to have a constructive discussion of whether a competency is specific to a particular domain or is more generic and can be applied across disciplines without specifying what is meant by “domain”. Similarly it is hard to investigate whether a skill learnt in one situation transfers to another without elaborating on the word “situation”. Such discussions are commonplace, e.g. how university-based “academic” learning relates to vocational or work-place learning, but often lack precision about what context is, assuming, for example, that all academic institutions are the same, and that the learning environment this produces can be meaningfully compared with that found in a “standard” work-based situation.

We therefore spend some time discussing what we mean by context and the way in which this leads into a model of the concept which we can apply to educational issues. For this, we make use of the definitions and classification scheme found in the work of Dohn et al. This builds on earlier work by Säljö [4, 5], and also on that of Halliday and Hager [6], which sought to provide classification of the ways that the concept, and its derivatives, emerge in learning situations.

One important observation about context is that it usually plays a supplementary role in any analysis of the problem, i.e. it is brought in, or added to, consideration of what Dohn calls the focal object, because that object would not have been adequately understood considered in isolation. This means that context is determined relative to that focal object while, at the same time, helping to shape what properties of the focal object are relevant to the discussion. The context is not therefore a neutral part of the background to the object in question. It is organised by its relation to the focal object and precisely what constitutes the context for the object, say, a learning activity, is itself subject to scrutiny and discussion. What are the relevant focal objects for learning? Dohn suggests basic elements such as “task”, “skill”, “knowledge”, “learning process”, “learner” (to which we might add “competency”) but the list is clearly not meant to be exhaustive and depends on the nature of the phenomenon being studied.

### B. Categories of Context

When discussing the context, various aspects of how we conceptualise it often get confused. We therefore use Dohn’s typology to identify a number of different categories that lead to qualitatively different meanings of the word.

- **Location:** This is the physical space where the activity takes place. It can be the geographical location in varying degrees of locality, e.g. Europe as opposed to China, Sweden as opposed to the UK, but can also refer to the institutional framework in which learning takes place, e.g. a high school as opposed to a university, a workplace as opposed to a research institute. The location category appeals to our sense of context as something related to our presence being situated in the physical environment and is one of the most fundamental examples in which the concept is used.
- **Knowledge Domain:** This is a basic category when discussing learning transfer across disciplinary boundaries or when distinguishing specific and generic skills. We will say more about this when discussing learning transfer, but it can be thought of as a quasi-locational category where we consider the phenomenon in relation to other phenomena in some kind of conceptual space rather than a physical one. This allows us, by analogy, to use words like “distance” and “proximity” with regard to ideas, subjects, concepts, etc, and forms the basis of discussions about, say, “near” versus “far” versions of learning transfer [7].
- **Sequence of Occurrences:** The first “chronological” category in the typology tries to capture when the sequential experience of events provides some degree of explanatory grounding for a phenomenon. It naturally applies to processes in which sequence or order is critical. Given that temporality is an inescapable part of the human experience, it is of fundamental importance to learning. Nevertheless, there are two disjoint ways in which this can occur. The first is what Dohn terms “causal construal” in which there is a clear sequence of occurrences where earlier events may causally influence later ones but not vice versa. By contrast, one could also consider sequences of occurrences in which later events, while not causally affecting prior ones, nevertheless give

meaning and significance to earlier events. Examples of both can be seen when considering something like a syllabus. One could describe a situation in which learning follows a hierarchical pattern, with later elements built upon previous elements, requiring their assimilation to make progress, and where there is, perhaps, some kind of partial ordering placed upon the experience due to curricular requirements. Alternatively, one can see later elements of a curriculum as providing greater levels of significance to earlier elements, at a more sophisticated level of understanding. Older knowledge elements or skills do not causally interact with earlier learning elements but provide a firmer grounding for their use or for their incorporation into the curriculum.

- **Activity:** Types of activity, such as lectures, tutorials, assessments, etc, clearly situate learning within a structure which occur in time, while not relying totally on chronology for significance. These activities may exist on a spectrum from single events or short-term engagements to longer-term patterns of interaction. For example, an assessment might take the form of a single summative test versus the construction of an extended portfolio of work. The interpretation of performance measures will depend on how this is set up.
- **Historical Period:** This is another chronological category but one in which phenomena are much more informed and affected by the sociocultural environment in its broadest sense, and may, for example, involve learning to understand decisions or actions taken in a historical setting rather than imposing current analytic or perceptual frameworks on prior events. Modes of examination of competence, and, indeed, the focus of those performance measures that were used in the past could all be different from current assessment practices. What is considered established practices may change with the incorporation of more data or clearer evidence into the underlying explanatory theory.
- **Social Relationship:** A category related to Historical Period, in the sense that it also deals with situatedness within a cultural or social environment, is that of social relationship. Social, here, refers to the way in which communication takes place between, say an agent taking part in some set of studied phenomena and the network of relationships with other individuals under consideration. For example, in a learning process, social relationships may provide a context in which to understand communications between student and teacher, or between an employer and employee in the workplace setting.
- **Individual Set of Experiences:** The final type is that related to the individual circumstances of the learner. It is natural that the personal history of the learner will affect how a student understands a task, the cognitive and dispositional resources that can be brought to bear on a problem, learning priorities, and so on. These experiences may be understood in terms of causal connections with the task in hand, e.g. a personal experience of another country will provide a context for the acquisition of intercultural competences. In addition, the personal experiences may contribute to

the way in which significance is perceived by the individual and so, in some sense, earlier experiences, or at least the recollection of such experiences, are moderated and changed in the light of later events. Dohn talks about a "*horizon of significance where the meaning of each experience is given "in the light of" the whole of the person's experience."*

The purpose of elaborating these different categories of context is to show how varied application of the term can be and how extensive is the range of meaning that is often subsumed into the term. This is important when considering transfer of learning which is often explained as the application of competence between different contexts. We therefore examine this idea in more detail.

### C. Transfer of Learning

Before we look at the subject of Competency Theory, we look at one important area in which context is often mentioned, namely that of Learning Transfer. Here, the notion of context plays a central part when defining transfer and, how it can be recognised and measured. For example, Perkins and Salomon [7] state that "Transfer of learning occurs when learning in one context enhances (positive transfer) or undermines (negative transfer) a related performance in another context." Investigation into the conditions under which transfer occurs and the cognitive mechanisms that enhance and diminish it have proved an interesting research field, raising questions about the different ways in which the phenomenon occurs and the criteria for establishing whether such a process has been successful. To do this, a number of different types of transfer have been defined. For example, "near transfer", i.e. transfer between very similar but not identical contexts, is contrasted with "far transfer", in which learning transfer occurs between contexts that appear, at least initially, to be quite remote from one another.

One obvious question that arises is how these descriptions of different types of transfer relate to the categories of context used by Dohn. It is tempting to say that the use of proximity metaphors for learning transfer allows us to map these onto quasi-geographical kinds of context, say, the location or knowledge domain categories. For example, when considering learning transfer from competences gained in an academic setting to a professional application domain, some form of reference to the knowledge domain category would be reasonable, but so would others such as the sequence of occurrences and activity categories. However, while sensible, it misses the point that, while Dohn's categories are essentially descriptive, based on data on how context is described in educational texts, the use of qualitative categories in learning transfer texts is much more metaphorical. For example, Perkins and Salomon also distinguish between "reflexive", or "low road" transfer and "mindful" or "high road" transfer. Low road transfer occurs in situations where well-practised skills learnt in one domain are triggered by conditions similar to those in the learning context. This is a reflexive practice in the sense that it is based on automatic, instinctive responses rather than conscious translation processes. One example of low road transfer might be undertaking the practice of software development in one programming language having previously learnt a similar one. This contrasts with high road transfer in which deliberate effort is made to abstract useful, relevant practices from one learning situation, or to search for deep-seated connections or homomorphic structures between domains. Again, it is not unreasonable to analyse the word

“context” in this situation and suggest that it reveals a link with, say, the knowledge domain category (as well as with others, such as the activity category), but such connections would be based on more substantial aspects rather than just the similarity of the words.

Perkins and Salomon also differentiate between positive and negative aspects of transfer. Positive transfer occurs when learning in one context improves performance in another; for example, when developers in one programming language find it easier to work with another language within the same paradigm, say OOP, rather than a different one, say functional programming. Negative transfer occurs when learning in one context impacts negatively on performance in another. For example, despite the generally positive contribution that basic imperative coding structures make to learning functional programming, novice learners accustomed to performing iteration through, say imperative-style loops, may find that a desire to accomplish tasks through manipulating state may inhibit progress. This may partly be due to a misunderstanding of appropriate proximity relationships within the knowledge domain category but may also relate to the individual set of experiences category.

It is worth noting that many learning development proficiency frameworks, such as those derived from the SOLO Taxonomy [8, 9], propose that increase in educational competency is accompanied either by an enhanced capacity for abstraction, or an enhanced exhibition of transfer. Still others, which employ a more phenomenological approach coming from the work of Merleau-Ponty [10] on embodied learning, or Dewey work on habit [11], are based on notions of contextualisation. Examples of these include the Dreyfus model of skill acquisition [12], or the model of professional development proposed by Dall’Alba and Sandberg [13]. In one way or another, context is a central characteristic of these models, and the specific relationship between context and proficiency is one that may provide important insights into the nature of competence acquisition and development.

In summary, we see that the typology given by Dohn provides a rich set of categories with which to describe the various facets of context. This scheme is detailed and covers a full range of the linguistic constructs used in the educational literature to be able to differentiate between genuinely different ways in which the concept is used. A nuanced understanding of context would be a central element in a theory of learning transfer but, so far, a comprehensive application of Dohn’s categories to this area has not taken place.

### III. COMPETENCY MODELS

The modern understanding of a competency, structured as an integrated combination of the knowledge and skill components in a particular area, composed with dispositional aspects of the learner, has been influential in attempts to describe higher educational aims and objectives. It also provides the basis for recent attempts to develop a comprehensive Competency Learning Framework [3] as a tool to present and explain important elements of the computing and engineering curriculum.

While there is a considerable degree of evidence that the triadic structure of knowledge, skills and dispositions is important to understanding the exhibition of proficiency within a learning environment, there is still a need to explain the character of the various components and how they relate

to each other. For example, if one considers the knowledge element associated with a competence, it is clear, e.g. from studies of work-based learning competencies, that there are a number of different types of knowledge which contribute to this component. Codified knowledge, as described by Eraut [14], is different from, say, the episodic knowledge of Bereiter [15] and both differ from the type of implicit understanding of tasks which relies on tacit knowledge. Alongside this categorisation of knowledge, we can also see a taxonomy of skills, e.g. [16].

Another issue that requires clarification concerns the dispositional aspect, which, while generally considered vital for the exercise of a competence, seems to be of a categorically different kind to the knowledge and skill components. A clearer appreciation of the relationship between the dispositional aspect and those of knowledge and skills is important when trying to understand the integrated nature of competency, over and above it simply being a convenient term for a simple aggregate of its components, which could be studied separately. For example, it would be useful to consider the main dispositional sub-components which would improve learner performance and investigate whether there is some operational model for the way in which this happens, e.g. some kind of scale on which a positive attitude is measured. The way in which the Competency Learning Framework could be used to provide examples of decompositions into knowledge, skill and disposition components would shed light on how learning might be reinforced across all aspects of the competency. This work has been started in, for example, the original CoLeaF paper, and its successors and provides a promising path for future research. However, while such an exploration of the notion of competency, its components and their interrelation, is important, it is not the main focus of the present paper. Instead we wish to focus on one aspect of the CoLeaF model which, in some sense, cuts across a discussion of the components themselves and addresses the way in which the model deals with applications of competency, namely its contextual element.

#### A. *What is Competency? Some Basic Definitions.*

In order to discuss some of the issues concerning the notion of competence, it is useful to have an applicable model which at least describes the broad features of the concept. Unfortunately, there is a wide range of terminology used in the literature to describe similar ideas (e.g. competence, competency, capability, capacity, ability...) and a diverse and often incongruent understanding of the nature of the competency is found across multiple subject domains and even geographical locations. For example, the adjective “competent” has a less pejorative tone in Europe, as opposed to Britain, North America, or Australasia. This means that it is difficult to engage in any kind of discussion which clarifies or refines the concept without first defining terms using a model which provides a basic glossary of terms. The Competency Learning Framework, outlined by Frezza et al, views competencies as personal qualities causally related to demonstrated proficiency or accomplishments in an area of work, civic engagement, and social participation. Competencies tell how good one is in a particular line of work, whether in a job, in a profession, or other socially constructed opportunities, such as an interest group, a community-based organisation, or a type of civic engagement.

Following Frezza et al, we will use the word “Competence” to mean “the state of being able, or the generic

capability, which is a necessary requirement to perform, or the set of characteristics which enable performance". This broadly agrees with the definition stated by Armstrong and Lorentzen [17], who distinguish "competence" and "competency", where the former refers to functional areas of proficiency, while the latter is generally reserved for behavioural areas. Thus, competence describes what people need to be able to do to perform a job well, with the emphasis is on "doing" in terms of achieving the desired output, while competency is defined in terms referring to those dimensions of behaviour lying behind competent performance. This is a behavioural description in the sense that it is meant to describe how people behave when they carry out a set of actions more or less proficiently. However, it is symptomatic of the lack of consistency of terminology that, e.g. Woodruff [18] has used the single word competency to describe both the functional aspects of work – the proven ability to perform a job to the standards required in employment – as well as the behavioural characteristics that person must display in order to perform the appropriate work tasks. In a similar way, Gherardi [19] differentiates between a number of commonly used meanings of the term, competence. For example, there is competence as a prerequisite (e.g. the specific educational requirements needed to be allowed to practice within a particular occupation; there is competence as outcome, (i.e. performance to a set standard) and competence as a capability exercised in accomplishing specific tasks, (i.e. competence as practical accomplishment).

#### B. Competencies within the Competency Learning Framework (CoLeaF).

The CoLeaF framework follows Mulder et al [20, 21] in defining a professional competence, that is, the amalgamation of knowledge skills and other attributes needed to perform some kind of vocational or professional task as: *"the generic, integrated and internalised capability to deliver sustainable effective (worthy) performance (including problem solving, realising innovation, and creating transformation) in a certain professional domain, job, role, organisational context, and task situation"* [3]. From the perspective of CoLeaF, competency is therefore viewed as an integrated combination of three elements: a knowledge component, a skill component and a dispositional component. These elements manifest themselves in the exercise of the competency, which also depends on the context in which the activity takes place. The *Knowledge* component (episteme, savoir, "know-that") is the propositional knowledge content of the competence and development of this component leads to an increase in the cognitive or intellectual qualities that allow mastery of core concepts within the domain knowledge. *Skills* (techné, procedural or declarative knowledge, savoir-faire or "know-how") are more practical qualities that people develop and learn over time with practice and through interactions with others. This type of knowledge is contextual, and practical. Dispositions (attitudes, savoir-être, "know-why", "know-yourself") are affective capacities which derive from personal habits and manifest in behavioural, and emotional qualities such as motivational intent, the psychological incentive to apply knowledge and skills to solve problems or address issues of personal, social, or workplace-related interest. The exercise of a competence is the integration of these three components within a particular contextual setting related to some activity or aspects of work in which competencies are demonstrated.

#### C. The Integrative Nature of Competence

As stated, a key feature of this framework is the idea that the learning process for all competencies relies upon all three components which cannot practically be disassociated from each other. A competency is, therefore, necessarily an integrative functional unit consisting of a set of knowledge elements, a set of skill elements, and a set of disposition elements. The integration of the three components is crucial to the application of a competency in the particular context, and they therefore should not be seen as separable, autonomous entities within the learning process. In that sense, within any broadly defined educational process, knowledge and skills do not exist independently in the learner. The knowledge component of a competency is not just knowledge of something but knowledge for something, and if learner is required to express that knowledge, there will be some kind of demonstrative process, participation in which can be taken to be an expression of, and lead to further development in, a skill related to that that knowledge component. Similarly, any skill requires a fundamental underpinning in some element of knowledge, even if that knowledge is just the procedure of the demonstration. In both cases, it is not practically possible to separate the contextual demonstration of knowledge, or the exercise of some skill, from the other component. Moreover, the influential work done on the social context of learning by Vygotsky [22] and others, which considers the role of the learner's interaction with others in the learning process, suggests that a simple, purely cognitive view of learning as direct knowledge acquisition, unmediated by social interaction, is fraught with difficulties. In such (social) learning contexts, e.g. professional mentoring situations, the complex nature of knowledge acquisition and demonstration of skill is quite clear.

The skill component is defined in the Competency Learning Framework as the performance of goal-oriented tasks by engaging in practices that are discipline-related. Some terminological differences may exist in the use of the word "practice", instead of skills, but, in a (broadly defined) educational context, the idea that demonstration of some kind, is the primary proxy to gauge the assimilation of knowledge, is difficult to avoid. This emphasis on demonstration can also be seen in the work of Eraut [23] in the area of workplace learning, vocational and professional education and the practice of learning-by-doing and learning-by-interacting with colleagues [24]. The model of Proficiency Development developed by Dreyfus and Dreyfus [12] proposes that the way in which individuals acquire competence in some area is a process of practice and acquired experience, which takes time and effort as the person moves from demonstrating rule-based behaviours as a beginner, to fully embodied, intuitive, and internalised behaviours at mastery level. Thus, there are plausible models for both knowledge and skill development, which are seen to proceed in tandem in the educational process.

The third component in the competency concept is the set of dispositions of the learner. Within any demonstration of competence, the effectiveness of the process of development and assimilation of knowledge, and so the evidence of skill, will depend on the dispositional characteristics of the learner. Consequently, this affective component is also a critical part of the matrix in which competency is exhibited. The CoLeaF definition of disposition draws on Weinert's work [25], which described them as "motivational, volitional, and social readiness and capacity to use" knowledge and skills that

contribute to "solving particular problems" and applying their solutions "successfully and responsibly in variable situations." This corresponds to the identification by Hubwieser and Sentance [26] of "a quite complex disposal of behaviour that can be applied" to carry out goal-oriented tasks or solve problems with real-life relevancy. The claim by Alsop [27], as reported in Frezza et al, is that "*affect and cognition cannot be meaningfully understood as disparate entities*."

This aspect of learning is clearly influenced by a range of psychological factors, both internal to the learner (and not necessarily at the consciousness level) as well as external factors linked to the learning environment. It is therefore tied to the context in which competence is developed. This context-dependence, although not considered an intrinsic structural element, is nevertheless important since it means that an analysis of a competence cannot simply be reduced to the determination of its components. Although, abstractly, it might be possible to study the three components separately, any competency is inevitably grounded in the particulars of how it is demonstrated. As soon as context is introduced, the relationships between the three components become so intertwined that it is simply not constructive to consider them as anything other than parts of an integrated structure.

#### D. Contextual Dimensions of Competency

At least provisional agreement on the definition of fundamental terms is clearly a prerequisite to investigation of the concept but for the framework to be useful, one also needs to establish a generally applicable vocabulary, i.e. way of speaking about the phenomenon which can accommodate how these fundamental definitions are applied, and so discuss how the properties of different competencies are characterised. The Competency Learning Framework does this by adopting a (slightly modified) version of Mulder's "Dimensions of Competence" [21]. In this scheme, competencies can be characterised through a set of more or less independent dimensions according to how it is applied in the world and how it relates to other educational concepts. This is a contextual description of competency and seeks to provide a complete characterisation of the dimensions in which the concept is worked out in practice.

These dimensions used in the CoLeaF paper, based on the original classification of Mulder, are:

- **Centrality:** this is the degree to which a competency is central to a professional who is engaged in some field of work or study. The range of centrality would be from central to peripheral. Central competencies are essential for effective performance and would be used frequently within that domain, whereas peripheral competencies are less important.
- **Specificity:** (which Mulder himself labels "Contextuality") This is the degree to which a particular competency is generic or specific to a particular situation or context. Here, being more specific means being more-or-less related to an individual set of circumstances or a particular content domain. The more generic a competency, the greater its applicability across a wider range of contexts. For example, the competence for programming in a particular language would be more specific than the competence for public speaking. This raises the important issue of the situativity of learning and its role

in the transferability of competency from one domain to another [2].

- **Definability:** This is the degree to which a specific competency can be clearly defined and delineated.
- **Developability:** The degree to which a competency is open to progressive personal development, somewhat in the sense of the idea of a growth mindset (e.g. Dweck, [28]), or is seen as a set of fixed personal qualities.
- **Dynamic nature:** This is the degree to which a competency is triggered by, or expressed in, a certain set of circumstances. The notion of competence is a very general construct and has to accommodate a very wide range of learnt and developed behaviour. Some competencies appear to be a way of dealing productively with the background human condition, whereas others come into action in specific circumstances. An example of the former would be a generic counselling competence, providing good advice, whereas an example of the latter might be the competence to perform a hill-start in a car.
- **Knowledge inclusion:** The theoretical or knowledge component of a competence may be more or less important to its demonstration in an educational context. Knowledge inclusion is the degree to which knowledge is considered to be important to the operation of the competence. Some competencies, especially those drawn from a practical or vocational field, may be based more on implicit or tacit knowledge, drawing on the experience and developed skill of the practitioner. Conversely, in other competencies which are linked directly to the acquisition of theoretical content or facts, the knowledge component is more explicit. An example of the former would be the practical competency to improvise on a piece of jazz music which relies on the tacit skills and previous experience of the musician. An example of the latter might be a competency to solve a set of mathematical equations.
- **Measurability:** The degree to which competencies can be measured on either a suitable qualitative or quantitative scale. Some competencies appear to be directly measurable, such as the competency of singing a particular note. Others appear harder to measure because they involve assessing various proxies which may require significant interpretation or analysis. This, of course is a central issue in the assessment of learning, especially in a vocational or professional work-place environment, where demonstration of competence may be employed but it is not always clear that the behaviour assessed captures the totality of the learnt experience.
- **Mastery:** The level to which a competency can be said to be achieved. Some competencies, such as using a for-loop, can be more-or-less fully achieved after a period of study. Others, such as the competency for abstracting the features of a software model, appear to be more open-ended. To some extent, this depends on the granularity of the competence being examined but it is also related to the irreversibility criterion of threshold concepts.

- **Performativity:** The degree to which a competency relates to performance. This may be linked to measurability if the competency is based on an explicit demonstration but there are some competencies which are less easy to measure but are nevertheless essentially performative, e.g. intercultural competency
- **Transferability:** The degree to which competencies can be successfully applied across a range of professional situations. Again, here we touch on the contextual nature of competence and what is meant by the word "situation".

These dimensions provide a means for considering how statements of competency can be examined and compared. There is no a priori reason that competencies with similar dimensional characteristics should be related in any domain-specific way. However, given their similar external features, it is certainly conceivable that there are transferable operational lessons about how to develop competencies with similar characteristics in different fields. A dimensional analysis of competencies within the overall competency model may therefore help give structure to the practical process of competency development and would certainly provide a vocabulary for descriptive or prescriptive use in statements of competency.

In many of these dimensions, the notion of context plays a vital role. Centrality uses a generalised notion of location to place a competence in a learning landscape. Transferability is something that has been discussed above. Specificity (which Mulder actually called Contextuality) relates the competence to a set of individual circumstances in which is demonstrated. The Dynamic Nature of a competence dimension tries to capture the degree to which the competence depends on a broad or narrow set of circumstances. Performativity relates to the way in which the competence is demonstrated within the context of a performance event. Even with dimensions which are not, at first, clearly dependent on contextual features, such as measurability or developability, we see that the notion of context underlies their practical application. For example, measurement, and assessment in general, usually involves contextual factors, as does the capacity to learn and develop a competence. Therefore, it is the practical implementation of competency development in the learning process where we should look for a link between the dimensions of competency and the difference categories of context. Again, this work has not yet taken place, but we can, as an example, consider how this process works out when we discuss competency development which tries to use authentic learning activities as a vehicle for learning.

#### IV. DISCUSSION: CONTEXT, AUTHENTICITY AND JUDGEMENTS ABOUT CONTINGENCY

The preceding description of context and competency was quite involved but was done to emphasise the impact that the former has in any discussion about the latter. We believe it is clear, even if the learning process is described in more traditional pedagogical language rather than that derived from competency theory, that the notion of context would play a fundamental role. However, the use of the competency framework and terminology does seem to make this more explicit: an important aspect of thinking about learning in terms of competencies, rather than in terms of knowledge units or enhancement of skill, is the belief that a demonstration of learning requires all three components - knowledge, skill

and an appropriate disposition. As we have said, these three parts of a competence are demonstrated in a specific situation and so there is an inherent contextual aspect to this, which is, in some sense, orthogonal to the structural parts of a competence. Given the competency model described above, we can say that knowledge is acquired within a context, skills are demonstrated in a context, and learning dispositions arise out of the habits and "lived"-experience which form the subjective context of the learner. We believe therefore that it would be beneficial to start to apply the differentiated view of context to the description of learning that emerges from these considerations. As an example, we will discuss the concept of educational authenticity from a perspective which tries to make the different modes of context more explicit. Using the categories outlined above, it is possible to articulate more specific questions about which form of context contributes to making learning experiences more authentic. By this we mean the process by which competencies are acquired and developed in an "authentic" manner, i.e. one which provides opportunities for learners to demonstrate skills in the manner of a professional. This approach is linked to a focus on the need for exercising prudential judgement – what has traditionally been called *phronesis*. The exercise of such a faculty for judgement is not something that can be developed in an algorithmic fashion as it necessarily depends for input on the contingent facts available to the one making the decision. Instead, attempts to proceduralise this process result in heuristics which take account of the context in which the judgement is made. These are not just rules-of-thumb but encompass decision-making processes which respond to changes in information and context to optimise the outcome. The use of such a process allows attention to be placed on what form of context is being considered and how learning develops. Such reflective and evaluative judgement, in which there is a need to take contingent factors into consideration in the decision-making process, is an important aspect of higher-order thinking skills [29].

The task of developing such skills through a process of discernment and prioritisation of relevant issues, has been addressed in a number of areas. Bowden and co-workers [30] have examined the problem in the context of Capability Theory and there have been attempts to extend its scope to incorporate the idea of Threshold Concepts [30, 31]. In that work, they stressed the need for a number of elements to be prominent in any learning situation [32]. Firstly, students should have a learning experience which uses open-ended problems to provide situations in which discernment is a necessary requirement of the learning process. Related to this is the requirement that students should engage with real-world problems within their domain of study. There are clearly a range of contextual factors at play here. When discussing open-ended or real-world problems, a range of contingent information is present, and activities usually involve the construction of trial solutions which require students to reflect on the outcomes of these trials in order to develop an understanding of the strengths and weaknesses of different approaches. Teachers provide feedback about the nature and quality of student engagement in the educational processes which includes ideas around reflective judgement such as discernment and diagnosis, as well as the more common elements of the design and implementation of methods of solution. The formal assessment apparatus usually involves the assessment of processes as well as outcomes, in a way that

integrates knowledge and skill acquisition across the curriculum.

This process of emphasising the act of judgement as a central part of the learning process is also found in approaches which aim at providing "authentic" learning experiences for students. The importance of authenticity to learning can be found in the work of Brown, Collins and others, e.g. [33, 34] on situated knowledge and cognitive apprenticeships. From their perspective, in order to enter into the practices of a particular profession or community of practice, the learner needs to assimilate the behaviour and values of that community. This process of enculturation, in which the student appropriates the attitudes and practices of the community by identification with its more experienced and proficient members, depends on the socio-cultural context of the learning experience. Situated learning therefore required the development of knowledge and skills in contexts that reflect the way in which that knowledge will be useful in non-academic settings [30]. This approach, which is also found in the work of Lave and Wenger on the social context of learning, e.g. [35], is similar to that used by Archbald and Newmann [36, 37] in the context of developing and aligning curriculum, teaching and assessment practices with real-world activities. They suggested that authenticity in the learning process arose partly out of this real-world correspondence, but also the way in which learners develop proficiency in the normative process of enquiry within the discipline through the construction of contextual models. This, in turn, builds on the learner's prior knowledge within the subject area in question.

This model of authentic learning was influential in informing subsequent developments, such as the work of Shaffer and Resnick [38], who argued that student perceptions of authenticity were important in motivating learning and were linked to the alignment between the learning process and meaningful elements of the curriculum. These included a learning experience that was personally meaningful to the student, a "real-world" context outside the immediate classroom environment, learning that provides an opportunity for students to "*think in the modes of a particular discipline*", and an operational view of authenticity in which the assessment process reflects the learning process. Shaffer and Resnick argued that this "thick" view of authenticity allowed for a fuller understanding of the nature of authentic learning and by doing so, reiterated views about the context in which authenticity was likely to be perceived.

In both these cases, there is an emphasis on learning using such things as open-ended and/or real-world problems. The argument that a greater appreciation of context is important in these areas depends on the observation that the authenticity of such work depends on the assumption that the student would validly be able to transfer competence from the assessment situation to a professional context. However, this raises the question of what we mean by the context of the real-world situation (as categorised, for example, in Dohn's typology), what we mean by a professional context (from the perspective of an academic institution) and what kind of competencies are being transferred (using the context-dependent dimensions of competence from, say, the CoLeaF paper). Given the complexity of this situation, we cannot simply say that the student is able to transfer learning from the real-world scenario (which are usually heavily constrained to be appropriate for academic assessment anyway). Instead, we need to evaluate what kind of competence is a focus of the

assessment, what its characteristics are in terms of the demonstration of that competence – in terms of knowledge elements, skills and learning disposition – and then try to map which form(s) of context is (are) important within the learning scenario and what their relationship is with the variety of categories which would describe a professional context. A computing student undertaking an internship or placement – something which would generally be accepted as a prime example of an authentic learning experience – might work on a project which requires them to demonstrate being able to think in the modes of the discipline, i.e. as a professional software developer. Nevertheless, despite the existence of professional bodies and things like codes of conduct which seek to provide minimum standards, the lived experience of software engineers is not uniform across the spectrum of different types of context, e.g. in terms of (geographical) location, chronological categories, etc, and so analysing precisely what kind of learning experience a student has and which context it is transferred from and to, becomes a difficult but important task.

However, one way of making the learning experience more meaningful for the student, and potentially more valuable for other stakeholders such as employers, is to try to delineate those categories of context in which the teacher thinks learning transfer should occur. This can be done at a variety of levels, from assessment requirements to the specification of learning outcomes, and can serve to focus on what form of transfer is expected and, to some extent, comment on the mechanism. For example, if we consider computing students undertaking some form of software development placement or internship, teachers and employers would presumably expect them to demonstrate acquired academic competencies in a professional setting, as well as acquire transferrable competencies from a professional knowledge domain, which could be applied in a later academic one, but there is also a general expectation that such an experience promotes the sense-making process in which later experiences gives new meaning to previous ones – something that is characteristic of some of the chronological categories.

## V. CONCLUSION

In this paper, we have attempted to draw attention to need for a more refined view of the concept of context, and the importance that this has for educational theory and practice. We have spent time trying to give an overview of where this impacts directly on the idea of competence, and the notion of authenticity in the learning experience. We noted that the concept itself has a remarkably rich structure, which can be illustrated using the typology developed by Dohn. We have sought to show that the use of this substructure is vital when discussing the dimensions of competence described in the paper by Frezza et al, on competency frameworks within Science and Engineering and to highlight its importance when discussing authentic learning. While this is a preliminary study, we hope that it will lead to further work as described in the text. We believe that a more sophisticated consideration of the contextual categories should have important practical implications for the way that teachers devise activities to promote hypothetical learning transfer in courses, and the way this is specified in course documentation. While examples in this paper have used Computing as the subject example, the issues are relevant to all STEM disciplines.



## REFERENCES

- [1] Biesta, G. J. J., "What is education for? On good education, teacher judgement, and educational professionalism". *European Journal of Education*, 50, 75–87. 2015.
- [2] Dohn, N., Hansen, S., and Klausen, S., "On the concept of context". *Education Sciences*, 8(3):111. 2018.
- [3] Frezza, S.; Daniels, M., Pears, A., Cajander, Å., Kann, V., Kapoor, A., McDermott, R., Peters, Anne-Kathrin, Sabin, M., and Wallace, C., "Modelling competencies for computing beyond 2020: a research based approach to defining competencies in the computing disciplines", *Proceedings companion of the 23rd ACM conference on Innovation and Technology in Computer Science Education*, Larnaca, Cyprus, 2018. pp 148–174.
- [4] Säljö, R. "Learning and sociocultural change". Den Haag: CIP-gegevens Koninklijke Bibliotheek. 1997.
- [5] Resnick, L.B., Pontecorvo, C., Saljo, R. and Burge, B., "Introduction", in Resnick, L.B., Pontecorvo, C. and Saljo, R. (Eds), "Discourse, Tools and Reasoning: Essays on Situated Cognition". Springer Berlin, 1997. pp. 1–20.
- [6] Halliday, J., and P. Hager. "Context, judgement and learning". *Educational Theory* 52, no. 4: 2002. p429–43.
- [7] Perkins, D. & Salomon, G. "Transfer of learning", in: T. Husen & T. Postlethwaite (Eds) *The international encyclopaedia of education* (Oxford, Elsevier/Pergamon), 1994. p6452–6457.
- [8] Biggs, J.B. & Collis K.F. "Evaluating the Quality of Learning: the SOLO taxonomy", New York: Academic Press. 1982.
- [9] Brabrand C. and Dahl B. Using the SOLO Taxonomy to Analyze Competence Progression of University Science Curricula. *Higher Education*, 58, 531–549..
- [10] Merleau-Ponty, M. "The world of perception". (O. Davis, Trans.). (T. Baldwin, Intro.). London and New York: Routledge. 2004. (Original work published 1948)
- [11] Dewey, J. "The place of habit in conduct" (from *Human nature and conduct*). In L. Hickman & T. Alexander (Eds.), *The essential Dewey* (Vol. 2 pp. 24–49). Bloomington, IN: Indiana University Press. 1998. (Original work published in 1922)
- [12] Dreyfus S.E. The five-stage model of adult skill acquisition. *Bull Sci Technol Soc* 24(3) 2004. p177–181.
- [13] Dall'Alba, G., and Sandberg, J. "Unveiling professional development: A critical review of stage models". *Review of Educational Research*, 76, 2006. 383–412.
- [14] Eraut, M. "Knowledge, working practices, and learning". In *Learning through practice*, ed. S. Billett, 2010. 37–58. Dordrecht: Springer.
- [15] Bereiter, C. "Education and mind in the knowledge age". Mahwah, NJ: 2002. Erlbaum.
- [16] National Research Council. "Education for life and work: Developing transferable knowledge and skills in the 21st century". National Academies Press, 2013.
- [17] Armstrong, M. and Lorentzen, J.F. *A handbook of personnel management practice*. 1996. Kogan page, London, UK.
- [18] Woodruffe, C. "Competent by any other name". *Personnel Management* 23, 9. 1991, 30–33.
- [19] Gherardi, S. "Practice-based theorizing on learning and knowing in organizations". 2000. Sage Publications, Thousand Oaks, CA.
- [20] Mulder, M. "Conceptions of professional competence". In *International handbook of research in professional and practice-based learning*. 2014. Springer, Berlin, Germany, 107–137.
- [21] Mulder, M. "Competence Theory and Research: A Synthesis". In *Competence-based Vocational and Professional Education*. Springer, Berlin, Germany, 2017. p1071–1106
- [22] Bruner, J. "Vygotsky: A historical and conceptual perspective". In J. Wertsch (Ed.), *Culture, communication and cognition: Vygotskian perspectives* 1985. p21–34. Cambridge, England: Cambridge University Press.
- [23] Eraut, M., "Concepts of Competence", *Journal of Interprofessional Care*, 12 (2), 1998. p127–139.
- [24] Foray, D. and Lundvall, B. "The knowledge-based economy: from the economics of knowledge to the learning economy", in: OECD, *Employment and growth in the knowledge-based economy*. 1996. (Paris, The Organization).
- [25] Franz Emanuel Weinert. "Concept of competence: A conceptual clarification". In *Defining and selecting key competencies*, Dominique Simone Rychen and Laura Hersh Salganik(Eds.). 2001. Hogrefe and Huber, Seattle, WA, p45–65.
- [26] Hubwieser P., and Sentence, S. "Taxonomies and Competency Models". In *Computer Science Education: Perspectives on Teaching and Learning in School* (1st ed.), Sue Sentence, Erik Barendsen, and Carsten Schulte (Eds.). 2018. p221–242. Bloomsbury Academic, London.
- [27] Alsop, S. "Beyond Cartesian Dualism: Encountering Affect in the Teaching and Learning of Science". Vol. 29. 2005. Springer Science & Business Media, Berlin, Germany.
- [28] Dweck, C. S. "Mindset: How you can fulfil your potential". 2012. London: Constable & Robinson Limited.
- [29] Kitchener, K. S., & King, P. M. "The reflective judgment model: Ten years of research". In M. Commons, C. Armon, L. Kohlberg, F. Richards, T. Gratzner, & J. Sinnott (Eds.), *Adult development: Vol. 2. Models and methods in the study of adolescent and adult thought*. 1990. p. 63–78. New York: Praeger
- [30] Bowden, J., & Marton, F. "The university of learning: Beyond quality and competence in higher education". 1998. London: Kogan Page.
- [31] Bowden, J. A. "Capabilities-driven curriculum design". In C. Baillie & I. Moore (Eds.), *Effective learning and teaching in engineering*. 2004. p. 36–47. Abingdon, Oxon: Routledge Falmer.
- [32] Baillie, C., Bowden, J. and Meyer, J. "Threshold capabilities: threshold concepts and knowledge capability linked through variation theory". *Higher Education* 2013. 65: 227–246.
- [33] Brown, J.S., Collins, A. and Duguid, P. "Situated cognition and the culture of learning". *Educational researcher*, 1989. 18(1), pp.32–42.
- [34] Collins, A., Brown, J.S., & Newman, S.E., "Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics". In *Knowing, learning, and instruction: Essays in honor of Robert Glaser*, 1989. pp.453–494.
- [35] Lave, J. and Wenger, E. "Situated Learning: Legitimate Peripheral Participation". 1991. Cambridge University Press.
- [36] Archbald, D.A. and Newmann, F.M. "Beyond Standardized Testing: Assessing Authentic Academic Achievement in the Secondary School". 1988.
- [37] Newmann, F.M. and Archbald, D.A. "The nature of authentic academic achievement. Toward a new science of educational testing and assessment", 1992. pp.71–83
- [38] Shaffer, D.W. and Resnick, M. "Thick Authenticity": New Media and Authentic Learning. *Journal of interactive learning research*, 1999. 10(2), p.195.