Bringing deep learning to the surface: A systematic mapping review of 48 years of research in primary and secondary education

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Abstract

Deep learning is a key term in current educational discourses worldwide and used by researchers, policymakers, stakeholders, politicians, organisations and the media with different definitions and, consequently, much confusion about its meaning and usage. This *systematic mapping review* attempts to reduce this ambiguity by investigating the definitions of *deep learning* in 71 research publications on primary and secondary education from 1970 to 2018. The results show two conceptualisations of the term *deep learning*—1) *meaningful learning* and 2) *transfer of learning*—both based on cognitive learning perspectives. The term *deep learning* is used by researchers worldwide and is mainly investigated in the school subjects of science, languages and mathematics with samples of students between 13 and 16 years of age. *Deep learning* is also a prevalent term in current international education policy and national curriculum reform, thus deeply affecting the practice of teaching and learning in general education. Our review identifies a lack of studies investigating *deep learning* through perspectives other than cognitive learning theories and suggests that future research should emphasise applying embodied, affective, and social perspectives on learning in the wide array of school subjects, in lower primary education and in a variety of sociocultural contexts, to support the adaptation of *deep learning* to a general educational practice.

Keywords: deep learning**,** primary and secondary education, systematic mapping review

Introduction

Since the turn of the last century, policy documents and research reports concerning education have been advocating the need for students to learn and develop skills and knowledge to prepare for life in the rapidly changing society, both in the international (Dumont et al., 2010; Pellegrino & Hilton, 2012) and in the Norwegian (NOU 2014:7; NOU 2015:8) educational contexts. In particular, meaningful learning, digital competence, problem-solving ability, critical thinking and students' ability to transfer skills and knowledge from one context to another have been described as important. Consequently, this has led to an increase in both the development and revitalisation of terms describing these skills and knowledge sets. A frequent term used in this

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regard is *deep learning*. The term has been examined in *academic publications* (e.g., Bransford et al., 1999; Tochon, 2010; Ohlsson, 2011; National Academies of Sciences, Engineering, and Medicine, 2018; Østern et al., 2019), used in *political policy reports and documents* (e.g., Dumont et al., 2010; Pellegrino & Hilton, 2012; NOU 2014:7; NOU 2015:8) and highlighted in mainstream media coverage of education. However, with similar sounding terms like, e.g., *deep learning*, *deeper learning*, *in-depth learning*, *deep learning approach* and *deep level processing* all being part of the discourse, combined with partially overlapping and/or unclear definitions, there is confusion and uncertainty as to what the term *deep learning* actually means, its origin and its empirical support. Adding to the confusion, the term *deep learning* is also prevalent in discourses other than education, e.g., in research on artificial intelligence and machine-learning (Aizenberg et al., 2000; Dechter, 1986)

To obtain an overview of how *deep learning* is understood in research on *education* we made efforts to identify review-articles of *deep learning* in education. The only publication we could find was Beattie, Collins and McInnes' review article published in 1997, which provided an overview of the foremost research groups working with *deep learning* at that time. However, these research groups focused on learning in higher education, and the aim of the review was to provide an overview regarding *deep* and *surface learning* in the *accounting education literature*. We could not identify any publications providing a literature review of *deep learning* regarding *primary and secondary education*. This gap in the research literature is especially relevant since *deep learning* is gaining traction in current international and national education policies and reforms. In the OECD report *The Nature of Learning* (Dumont et al., 2010), *deep learning* is highlighted as an important educational concept to handle the demands of the "knowledge society" (p. 330), The American National Research Council's report *Education for Life and Work* (Pellegrino & Hilton, 2012) emphasises that *deeper learning* is crucial in developing 21st century competencies, while in Norway, the concept of *in-depth learning* has become a key term in the new curriculum (The Norwegian Directorate for Education and Training, 2020). An overview is needed of how *deep learning* and similar sounding terms (e.g., deeper learning, in-depth learning) are defined, which learning theories and perspectives these definitions are based on, and how they have been investigated in primary and secondary education.

Aim of study

In educational discourses there is a focus on changing education to provide children with the skills and knowledge needed to cope with the 21st century's demands, and *deep learning* is described as a key element in this regard. Subsequently, the aim of this article is to provide an overview of how *deep learning* is conceptualised in research on primary and secondary education. Due to the project's time and resource limitations we carried out a *systematic mapping review* rather than a *systematic literature review* (Grant & Booth, 2009), as our focus is to provide an overview of the *definitions* used, the *parts of the world* in which research has been conducted, and the *age ranges* and *school subjects* examined. We extract the definitions used and *synthesise, compare* and *thematise* them to provide an overview of key elements in the definitions as well as the learning theories and perspectives applied. The research questions that guide this *systematic mapping review* are as follows:

1. In what countries, sample age ranges, and school subjects have *deep learning* been investigated?
2. How is *deep learning* conceptualised and defined in research on primary and secondary education?

Theoretical perspectives

According to Beattie et al. (1997), the terms *deep* and *surface*, in relation to learning, were first described by Craik and Lockhart (1972) for investigating cognitive processing. From the 1970s, several research groups around the world worked on the distinction between *deep* and *surface learning*, with the former referring to learning with understanding and the latter referring to more temporary learning (Beattie et al., 1997).

A decisive contribution to the field of *deep learning* in education was Marton and Säljö's study of Swedish university students (1976a), which discovered that what a student intends to get out of learning determines whether a deep or surface approach will be used. The approach the student selects is a response to both a particular task and a particular context, underlining that an individual's study approach is flexible. This is regarded as one of the seminal studies of *deep learning* in education and contributed to the foundation of the theoretical model later known as *Student Approaches to Learning* (SAL).

According to Beattie et al. (1997) a *deep approach to learning* is shown by students who 1) seek to understand the meaning of the teaching materials, 2) relate ideas to their previous knowledge and experiences, and 3) examine the logic of the arguments and relate the evidence presented to the conclusions. Meanwhile, a *surface approach to learning* is characterised by students who 1) memorise parts of the content of the teaching materials and accept the material presented without questions, 2) concentrate on memorising facts rather than distinguishing any underlying principle or pattern, and 3) are influenced by assessments requirements.

After the early and large projects in the 1970s and '80s, the main research focus on *deep learning* in education has been on facilitation and assessment in higher education, while research of a more fundamental nature has been very limited (Beattie et al., 1997).

Tochon, professor in curriculum studies, suggests that *deep learning* (Marton & Säljö, 1976a, Entwistle & Wilson, 1977; Biggs, 1993), together with other perspectives like *deep teaching* (Tochon & Hanson, 2003; Hargreaves & Fink, 2006; Smith & Colby, 2007), *deep politics* (Gitlin, 2005), *deep education and philosophy* (Næss, 1989; O'Sullivan, 1999; Jardine, 2004) and *deep linguistics* (Chomsky, 1965; Lakoff, 1973), points towards 'the deep turning in education' (Tochon, 2010, p. 8). *Deep education* emphasises a holistic perspective including both the student and the teacher, working towards an ecological understanding *of* and responsibility *for* a sustainable future. A key element characterising this is an orientation towards meaning-making and transformative learning, including development of the students' identity.

Tochon (2010) claims that depth in education occurs when both students' and teachers' identities are activated, moved and given opportunity to understand their existence and their own role in relation to society and the world. He problematises that *deep learning* has mainly been investigated and described through *cognitive learning theory* and highlights that *deep learning* 'engages students intellectually, socially, and emotionally' and moves "beyond

temporary gains in achievement scores to create lasting, meaningful improvements in learning" (p. 5).

Dahl and Østern (2019), building on Tochon's (2010) ideas, emphasise the last thirty years of research in modern neuroscience and also questions the emphasis on cognitive perspectives regarding *deep learning*. The neurobiologist Damasio's (1994, 2000, 2010) research shows that when something happens outside of ourselves that we regard as an event, it affects us in an *embodied* way. Our entire body is affected by our brain through pre-reflective processes that affect blood circulation, intestines and muscle apparatus. We are permeated by affects, resulting in feelings that we can capture in words that we connect to the event. Actions are affective and emotionally anchored, and cognition emerges from the intra-action with the affects. As exemplified by Damasio's research, this provides opportunities to expand the understanding of learning beyond the cognitive perspective. He highlights that there are no clear lines separating the cognitive from the affective, social, and embodied aspects of learning. It is the *totality* of these aspects that, like Tochon's (2010) redefinition, that results in *deep learning*.

Deep learning can be understood *both* as students' approach to their learning material and as part of a deep turning in education. However, this does not necessarily mean that researchers investigating *deep learning* adhere to the ideas of the *deep education* "movement". This chapter shows that the theoretical framework purported by the SAL community seems to be the most prevalent theoretical understanding of *deep learning* regarding education, and thus also provides the basic theoretical framework for this mapping review. However, as described above, we are aware that there are variations as to how *deep learning* is understood and applied in the educational discourses worldwide and we will in the subsequent analysis of the data be sensitive as to these variations.

Method

This worldwide review draws on procedures defined in the literature on systematic literature reviews and research synthesis (Grant & Booth, 2009; Moher et al., 2015; Gough et al., 2017). Firstly, we carry out a *systematic mapping review* (Grant & Booth, 2009) with the intention of creating a worldwide *map of the empirical research* that has been undertaken on *deep learning* in primary and secondary education. We extract data elements regarding the geographical prevalence, the age range of the participants and the school subjects investigated and carry out a quantitative analysis of these elements to provide an overview. Secondly, we carry out a qualitative analysis where we *extract*, *analyse*, *synthesise, categorise and thematise* the definitions of *deep learning* to gain overview of the learning theories and perspectives that are prevalent in the conceptualisations. Hopefully, in doing so, we can contribute to inform discussions on what future research might usefully address regarding *deep learning* in primary and secondary education. We provide no formal quality assessment of the publications apart from identifying that they are scientific and peer reviewed. A protocol for the review was developed using the *Preferred Reporting Items for Systematic review and Meta-Analysis Protocols* checklist (Moher et al., 2015) and involved planning and documenting every step of the review process before the actual review was conducted.

Search strategy

Deep learning has become a generic term that covers a range of different component processes undertaken in different contexts for different aims (Dumont et al., 2010; Pellegrino & Hilton, 2012). An initial search for research publications was conducted, and we also examined a selection of central international and national grey literature (Dumont et al., 2010; Pellegrino & Hilton, 2012; NOU 2014:7; NOU 2015:8) to gain an overview of similar terms used in more contemporary publications. This initial search enabled the identification of several focus points and terms considered important for the definition of the core search terms. The authors discussed the initial search and decided to operationalise *deep learning* by including several variations of the term. We also wanted to investigate connections between *deep learning* and other terms and included terms that, in the grey literature, appeared to be closely connected to *deep learning*. The following list of core search terms was used in the search string: *deep learning*, *deeper learning*, *in-depth learning*, *in depth learning*, *deep level processing*, *transfer of learning*, *adaptive expertise*, *21st century skills*, *21st century knowledge*, and *21st century competencies* (see *supplementary material 1 for search documentation*).

Because the possibilities for filtering searches differ among databases, we found it necessary to develop a second search string. This string consisted of core search terms defining the *primary and secondary education* context we were interested in identifying research related to (see *supplementary material 1 for search documentation*). Both search strings were created in cooperation with an educational sciences librarian and were adapted to suit the different database interfaces, but the text words were identical in each search. The search included the text words from the *title*, *subject descriptions*, *key words*, and *abstract*. The search for international articles was conducted in *Education Resources Information Centre* (ERIC), *Education Source* and *Scopus* databases and was limited to peer-reviewed articles published between 1970 and 2018. The search was conducted on in January 2018, and we decided on 1970 as the starting point because according to Beattie et al. (1997), the terms *deep* and *surface*, in relation to learning, were first described by Craik and Lockhart in 1972. The first two databases are disciplinary topic–specific bibliographic databases that focus on education, while the third is interdisciplinary, which enables the identification of key studies of interest published in other disciplines.

Inclusion and exclusion criteria

The inclusion and exclusion criteria are described in *table 1*. When considering the eligibility of publications for this review we had no restrictions regarding the study design or sample size. Due to limited time resources and scope of this review on primary and secondary education both studies with samples from special education and higher education were excluded. Since the method of systematic mapping review does not entail an exhaustive search (Grant & Booth, 2009), we decided to use search terms in the English language only, and an abstract in English was required to be considered for inclusion. Publications that provided an abstract in English but was written in a language neither of the authors were proficient in would if deemed eligible, be considered by a colleague proficient in that language.

Table 1. Inclusion and exclusion criteria

Type of criterion	Criteria	Inclusion	Exclusion
Type of publication	Journal articles	X	
	Conference papers		X
	Reports		X
	Dissertations		X
	Books		X
Access	Online	X	
	Paper	X	
Publication period	January 1970–January 2018	X	
Place of study	Worldwide	X	
Type of study	Empirical investigation	X	
	Literature reviews	X	
	Theoretical studies	X	
Research method	Qualitative	X	
	Quantitative	X	
	Mixed method	X	
Language	English	X	
Education level	Primary education	X	
	Secondary education	X	
	Special education		X
	Higher education		X
Key term in the title or abstract (topic)	Deep learning	X	
	Deep-level processing	X	
	Deeper learning	X	
	In-depth learning	X	
	In-depth learning	X	
	Adaptive expertise	X	
	Transfer of learning	X	
	21st century skills	X	
	21st century competencies	X	
	21st century knowledge	X	
Definition of the key term in full text	Definition in the full text	X	
	No definition in the full text		X

The first search resulted in 812 hits on ERIC, 614 hits on Education Source and 415 hits on Scopus, for a total of 1841 publications (see *supplementary material 1*). After the removal of duplicates, 1303 publications were first assessed for eligibility at the title and abstract levels. Eligibility disagreements were resolved through discussion between the first and second author. As a calibration exercise 100 abstracts were assessed by the first and second author to pilot and refine the criteria. After the calibration exercise both authors conducted independent, blind screenings of the titles and abstracts against the inclusion criteria (Gough et al., 2017). The publications deemed ineligible in the first screening phase were excluded for the reasons shown in table 2.

Table 2: Papers excluded in first screening phase

Total number of publications	**1303**
Not empirical	430
Not on topic	364
Not primary or secondary education	260
Not journal article	14
Total excluded in first screening phase	**1068**
Publications eligible for second screening phase	**235**

In the second screening phase, the full texts of the remaining 235 publications were read, focussing on identifying the definition of the key term in the publication—e.g., *deep learning*,

adaptive expertise, *21st century skills*—and identifying a possible connection between the key term in the study and *deep learning*. If the publication did not contain a definition of *deep learning* or did not describe a connection between the key term and *deep learning*, the publication was excluded. In our preliminary search for relevant key terms, we read several central grey literature publications highlighting *deep learning*. Common to these publications were descriptions of connections or similarities between *deep learning* and terms like *21st century skills*, *adaptive expertise* and *transfer of learning*. We identified 3 studies examining *21st century skills/knowledge/competencies* in the context of primary and secondary education and 3 studies examining *adaptive expertise*. These studies were read in full text, but none of these publications described a relationship between their key term and *deep learning*. Therefore, they were not included in the final categorisation. We identified 60 studies examining *transfer of learning* in primary and secondary education and all were read in full text. Of the 60 studies focussing on *transfer of learning,* only three describe a connection with *deep learning*, and only these three were therefore included. In the second screening phase, 164 of the publications were excluded. We assessed 1303 publications for eligibility in this review and 71 were included. See *figure 1* for an overview of the stages of the eligibility assessment.

Figure 1: Flow diagram illustrating the stages of the eligibility assessment
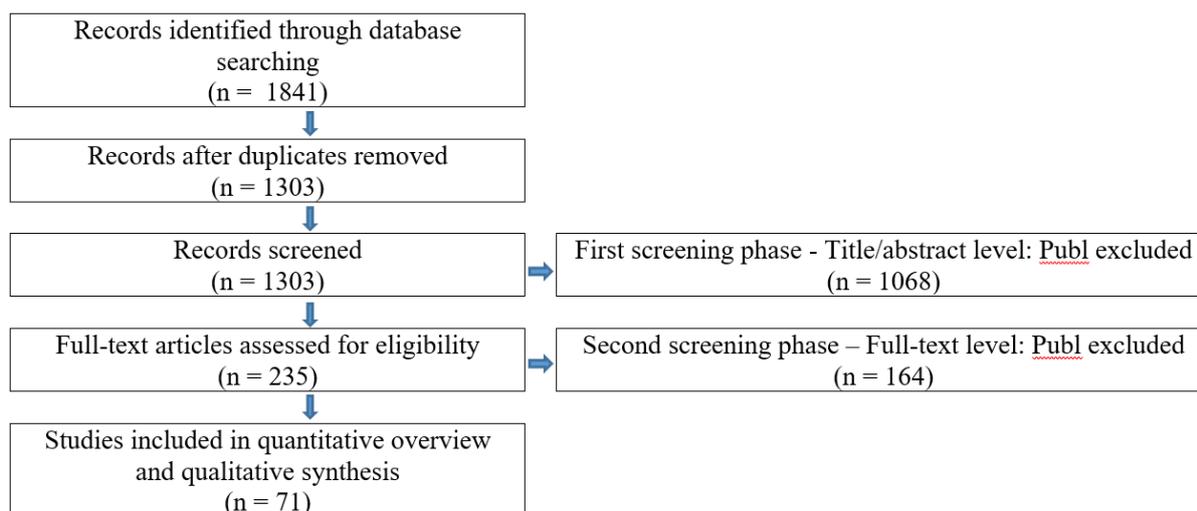
Data extraction and analysis

The analyses of the 71 publications deemed eligible was performed in two steps, both followed by a discussion between the authors. In *the first step*, a coding scheme inspired by the work of Gough and colleagues (2017) and Prøitz et al. (2017) was applied to the included publications. The data were extracted, coded and categorised in QSR NVivo 12, and the included studies were coded with the following descriptive variables: *year of publication*, *first author's country of affiliation*, *age range of the participants*, *school subject* and *definitions of key terms*. *In the second step*, the extracted paragraphs defining and describing the study's definitions of *deep learning* and the possible connections to other terms were analysed to facilitate the qualitative identification and interpretation of patterns in the definitions. Applying a *conventional content analysis* on the extracted definitions, we avoided preconceived categories but relied on

inductive categories with close similarity to the empirical material (Braun & Clarke, 2006). As an example of the analysis, we will use an extracted paragraph from Chin and Brown (2000):

> In essence, the deep approach is associated with intrinsic motivation and interest in the content of the task, a focus on understanding the meaning of the learning material, an attempt to relate parts to each other, new ideas to previous knowledge, and concepts to everyday experiences (p. 110).

In this paragraph we identified three main elements: *intrinsic motivation*, *meaning* and *relating*. The extracted paragraphs of all the included publications were analysed, synthesised and categorised in this way, providing an overview of the key elements in each definition. See *supplementary material 2* for an overview of the key elements found in each publication.

Results

The 71 publications included were published from 1994 to January 2018 and reflect a considerable recent rise in the frequency of publications on *deep learning* in primary and secondary education. No studies were identified in the period from 1970 until 1993, 35 studies were published from 1994 until 2012, and 36 publications were published during the last five years of the study period (2013–2018). *Deep learning* has been investigated in Asia (35), Europe (22), North America (10), Oceania (8), Africa (2) and South America (1). The age range of the participants in the reviewed studies is 8 to 23[2] years, and the mean ages range from 13–16 years. The studies focus on the school subject's *science* (23), *languages* (15) or *mathematics* (13), often in combination, whereas 19 publications focus on students' learning approaches or motivation for schoolwork independent of the school subject. *Social science* (8), *computer science* (4), *art* (2), *vocational subjects* (1) and *religion* (1) are examined by some publications. For an overview of the included studies, see *supplementary material 2*.

The analyses yielded two main categories across the 71 publications based on a synthesis of the definitions of the key word:

- The first and largest category consists of 63 publications defining *deep learning as meaningful learning*.
- The second category consists of 5 publications that define *deep learning as transfer of learning* and 3 publications focussing on *transfer of learning* that describe a connection between *transfer of learning* and *deep learning*.

Deep learning as meaningful learning

This category consists of 63 studies, and three elements comprise the core of the conceptual definition of *deep learning*: 1) *meaning*, 2) *relating*, and 3) *intrinsic motivation*. Moreover, they are often used in combination. All publications contain either *meaning* or *relating* or both, and we chose to name the category *meaningful learning*.

Fifty-eight of the 63 studies in this category refer to one, or several, of the seminal studies of deep learning from the 1970s and 1980s when defining *deep learning*—e.g., Marton and Säljö (1976a), Biggs (1987, 1993) or Entwistle and Ramsden (1983)—clearly highlighting a

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[2] Two publications report participants above the age of 20, Janeiro et al. (2017) report participants age range between 15 and 21 and Wishart & Triggs (2010) report participants age range between 11 and 23.

connection with the conceptual framework of *Student Approaches to Learning* (SAL). Five of the studies included in this category do not refer to any of these publications, but they use the terms *deep learning* (Liem, Ginns, Martin, Stone, & Herrett, 2012; van Aalst, Hing, May, & Yan, 2007), *deep-level learning strategies* (Matos et al., 2017), *deep processing strategies* (Chou, 2017) and *deep cognitive learning strategies* (Şen, 2016). However, the main elements in the definitions in these five publications are clearly similar to the definitions of the 58 other publications in this category. The former are likewise connected to the same conceptual framework and are categorised similarly.

The most prevalent element, which features in 52 of the studies' definitions, is that learners look for *meaning* in the learning material to gain an understanding. In some of the definitions, the meaning element is contrasted with *rote memorising*, which is often described a defining feature of *surface learning*. Dahlin and Watkins (2000) provide a typical example of a definition focussing on how students might approach the learning material on different levels:

> Central to this position are the concepts of a surface approach where the learner focuses on 'the sign', the learning material itself, and a deep approach where the focus is on 'the signified', that is beyond the sign to that to which the material refers (p. 66).

Learners who reproduce, replicate and memorise signs, for example, by learning a piece of text by rote, use a *surface learning* approach. Learners who seek to understand the intention of the learning material use a *deep learning* approach.

Thirty-eight studies describe students *relating* new knowledge to previously acquired knowledge and to their everyday experience as a defining feature of *deep learning*. Chin and Brown (2000) give a typical definition that describes different levels of relating: *"(...) an attempt to relate parts to each other, new ideas to previous knowledge, and concepts to everyday experiences"* (p. 110). Accordingly, students who use a *deep learning* approach strive to attain coherence between the different parts of the learning material, between the new information and what they already know, and between the school context and their experience outside of school.

Twenty-three studies highlight students' *intrinsic motivation* as a main feature of a *deep learning* approach, emphasising a learners' interest in the learning material that is driven by their own interest rather than by an external motivation. Some publications state that the two elements of searching for *meaning* and *relating* should be regarded as *deep learning strategies* and that *intrinsic motivation* is the motivational component of a *deep learning* approach. The definition in Cano's study (2007) is an example in which all three core elements are present with a clear distinction between motivation and strategy:

> By contrast, the motivation of those deploying a deep approach tends to be intrinsic (they strive to understand the author's intent and seek self-fulfilment from the material). Their strategy is more meaningful (searching for meaning, integrating formal knowledge with personal experience, and relating facts to conclusions) (p. 132).

We found some other features of *deep learning* used in defining the term that are worth highlighting (see *supplementary material 2* for overview). Ten of the studies include *critical thinking* in their definitions, but generally without a further explanation of what critical thinking entails. Seven studies add *metacognitive strategies* to their definitions. Six studies include

application of knowledge, four of these specify that the application must be to a novel situation. Four studies describe *long-term retention*, i.e., students' ability to retain knowledge for a long time, as an important aspect. Three studies include *transformation* as part of their definitions, referring to students transforming the learning material.

Thirty-two of the studies in this category investigate pupils attending school in Asia, 21 in Europe, 8 in Oceania, 4 in North America, 2 in Africa and one in South America. The pupils in the studies were mainly between 13 and 16 years of age, with some as young as eight years old and others as old as 23 years old. The school subject contexts of these studies were mainly *science*, *languages* and *mathematics*.

Two publications in this category mention a connection between *deep learning* and *transfer of learning*, i.e., how knowledge or skills acquired from one task or situation can be applied to a novel task or situation. Alkharusi (2013) notes that, from the standpoint of assessment, transferring to authentic tasks demands a higher emphasis on understanding and thus requires *deep learning*. Munowenyu (2007) suggests that *deep learning* also enhances the development of transferable skills. The six studies that include *application of knowledge* in their definitions display clear similarities with the definitions of the term *transfer of learning*; however, they do not explicitly use this term.

Deep learning as transfer of learning

This category consists of eight publications. All publications in this category describe a relationship between *deep learning* and *transfer of learning*. Five of them define *deep learning as transfer of learning*, while three describe *deep initial learning* as a requisite for subsequent *transfer of learning*.

The origin of the term *transfer of learning* dates back to the beginning of the 20th century when seminal studies in the field of educational psychology investigated whether improvement in one mental function would influence the efficiency of other functions (Bransford et al., 1999). For example, studies tested the doctrine of "formal discipline", e.g., if practicing and learning Latin or other difficult subjects had broad-based effects, such as developing the general skills of learning and attention.

First, we report on the five publications using *deep learning* as a key term, and second, we report on the three publications that focus on *transfer of learning* that suggest a connection between *deep learning* and *transfer of learning*.

We synthesised the content of the definitions of the five publications using *deep learning* as *the learning process leading to transfer of learning to a novel situation*. These publications explicitly refer to research on *transfer of learning* when defining *deep learning*. Two of the publications, Grover and colleagues (2015) and Nehring and Szczesiulc (2015), use the term *deeper learning* and define it by referring to a United States Research Council report (Pellegrino & Hilton, 2012): '*the process through which an individual becomes capable of taking what was learned in one situation and applying it to new situations*' (Nehring & Szczesiul, 2015, p. 332). Both studies describe how the skills and knowledge needed to transfer learning from one situation to another can be divided into three domains, namely, the *cognitive*, *interpersonal* and *intrapersonal*, and these skills are referred to as *21st century competencies*. The *cognitive domain* includes critical thinking, information literacy, reasoning and argumentation, and

innovation. The *interpersonal domain* includes teamwork, collaboration and leadership. The *intrapersonal domain* includes intellectual openness, work ethic and conscientiousness, and positive core self-evaluation. These competencies are described as the blend of knowledge and skill that create an individual's capacity to understand how, why, and when to apply domain-specific knowledge.

Three publications in this category, Parker and colleagues (2011; 2013; 2017) describe *deep learning* as learning for *adaptive transfer*:

> …a kind of deep learning that we call adaptive, flexible or transferable. Following Bransford and Schwartz (2000) and Hatano and Inagaki (1986), we take an understanding to be deep when it is both complex and adaptable; that is, when it is differentiated (composed of diverse cases or problems) and elaborated (much can be said about each case), yet integrated (coherent, it all hangs together) and flexible (is useable in novel problems later) (Parker et al., 2017, p. 255).

According to this quote, *deeper learning* means that students' understanding is differentiated, elaborated, integrated and flexible.

The remaining three publications in this category investigate *transfer of learning* in primary and secondary education but describe a connection with *deep learning*. All three studies underline that *deep initial learning* is necessary for the subsequent transfer of learning to a novel context (Pugh et al., 2014; Schiff & Vakil, 2014; Grotzer et al., 2015).

The eight publications in this category were published between 2011 and 2017. Six of the eight studies investigate pupils attending school in United States, while one study reports on schools in Northern Ireland and one on schools in Israel. The pupils were between 8 and 18 years old, and the school subject contexts included *science*, *computer science*, *social science* and *mathematics*.

In all, 10 of the publications included in this review mention a connection between *deep learning* and *transfer of learning;* 8 in this category and two in the *meaningful learning* category. However, this connection is not emphasised by the majority of the studies investigating *deep learning*.

Discussion

Our systematic mapping review of *deep learning* in primary and secondary education shows that the term is conceptualised in two main ways: 1) *deep learning as meaningful learning* and 2) *deep learning as transfer of learning*.

Conceptualisations of deep learning

The publications defining *deep learning as meaningful learning* refer to research on *Student Approaches to Learning* (SAL) and show a clear connection between the publications using this definition and the seminal studies of *deep learning* from the 1970s and 1980s. In general, we find a large degree of similarity in the literature review published by Beattie et al. (1997) and our review regarding how *deep learning* is characterised in the publications. We find that two of the elements, *meaning* and *relating*, either individually or together, feature in the majority of definitions of *deep learning* in our review. However, the third element Beattie and colleagues (1997) highlights, the examination of the logic of the arguments, is not found to the

same degree in our review, although some of the publications mention *critical thinking* as a characteristic trait.

The second conceptualisation of *deep learning* identified in our review is through *deep learning as transfer of learning*, defined as "*the learning process leading to transfer of learning to a novel situation*". All five publications using this definition are published after 2009, indicating that this conceptualisation of *deep learning* is fairly new in the field of primary and secondary education. The term *transfer of learning* has been part of the field of education since the beginning of the 1900's, when Woodworth and Thorndike (1901) investigated the *transfer of learning* between an original learning context and a novel situation, disputing the idea of *formal discipline*. However, the conceptualisation of *deep learning as transfer of learning* might be understood as a development or re-emergence of the term *transfer of learning*.

We find it difficult to establish if the publications that define *deep learning* as *transfer of learning* and the publications that claim that *deep learning* is a requisite for transfer share the same understanding of the relationship between the two terms. We suggest that the relationship between *deep learning* and *transfer of learning* should be investigated and elaborated on in future research.

This review finds that both conceptualisations of *deep learning* in research on primary and secondary education—1) *meaningful learning* and 2) *transfer of learning*—are defined from perspectives related to *cognitive learning theory*. This finding supports Tochon's (2010) argument that research on *deep learning* has mainly focused on it as a cognitive phenomenon. However, Tochon outlines a much broader, multi-disciplinary turn concerning depth in education, highlighting that *deep education* concerns the whole person and implies a sense of purpose and deep transformational learning, affecting identity and how students see their role in relation to the world, especially regarding ecological understanding and the responsibility for a sustainable future, which is of the utmost importance in the global society. He argues that there is a need for research that incorporates embodied, affective and social aspects of learning to expand how *deep learning* is conceptualised. Dahl and Østern (2019) suggest that the way out of a too-narrow cognitive focus on *deep learning* might be, contrary to expectation, by directing attention to recent developments in cognitive sciences, especially *neurosciences*. Damasios' (1994, 2000, 2010) studies on the connections between emotions and rationality (*somatic marker hypothesis*); Kandel's (2006) studies on the physiological basis of memory storage in neurons (*synaptic growth*); and Rizzolatti and Singaglia's (2008) studies of the connections between perception, memory and action (*mirror neurons*) all point to learning as a process that fundamentally involves embodied, affective, social and cognitive aspects. These aspects should all be considered when investigating *deep learning* in the context of primary and secondary education in future research.

Deep learning in different sociocultural contexts

We found that studies of *deep learning* investigate pupils all over the world and apply similar definitions across different sociocultural contexts. However, Chan (2008) pinpoints that, from a Western viewpoint, *memorisation* and *understanding* are often investigated as distinctive and polarised constructs, while, from an Eastern viewpoint, these constructs are viewed as intertwined. This disparity results in what she describes as "the paradox of the Chinese learner"

(p. 235), in which Chinese students take a deep approach to learning even though they use memorisation strategies. She also suggests that the psychological constructs used in the West cannot explain Chinese students' performance adequately because teaching and learning need to be interpreted in relation to sociocultural influences and systems perspectives. Future research should consider these perspectives, especially regarding how *understanding* is understood across different cultures and in the transfer and adaptation of research findings regarding *deep learning* across different educational systems.

School subjects examined

This review finds that the majority of the studies focus on examining *science*, *language* and *mathematics*, but only two studies (Dart et al., 1999; Dart et al., 2000) mention a *practical aesthetic subject* (PAS) as part of the study's focus, the subject being *art*. According to Borgen and Hjardemaal (2017), compulsory education internationally makes certain assertions about PAS. The focus seems to be on PAS capacity to improve academic performance in other subjects—like *languages*, *mathematics* and *science*—and to contribute to moral development, health and psychological wellbeing in a life-long perspective. These subjects are not included in the Organisation for Economic Co-operation and Development Program for International Student Assessment surveys or in the empirical research that has examined school performance and learning outcomes. This situation places PAS in the discourse of education both as important subjects and as fundamentally different from other school subjects. One of the main characteristics of PAS is the focus on embodied, affective and social aspects of learning. In PAS—like *Physical Education, Arts and Crafts* and *Music*—the students' application of their bodies, feelings and social interactions are central to the learning outcomes. We suggest that PAS should be included in future research regarding *deep learning* to ascertain a more holistic understanding of the interactions between the embodied, affective, social and cognitive aspects of learning.

Age ranges examined

The seminal studies of *deep learning* from the '70s and '80s focused on students' approaches to learning (SAL) in higher education (Beattie et al., 1997). This review finds that the participants in the studies on *deep learning* in primary and secondary education are, on average, between 13 to 16 years old. Only 4 of the included publications investigate *deep learning* in students that are under 10 years old. This result begs the question whether *deep learning* primarily is understood as a concept relevant for children above this age. Dahl and Østern (2019) point out that the aims of higher education and those of general compulsory education differ. Moreover, they note that the adaptation of *deep learning* from the context of higher education to that of general education, e.g., in the recent Norwegian curriculum reform, entails a 'twist' (p. 47). *Deep learning*, a concept that has been developed in relation to adults' learning of theoretical knowledge (Beattie et al., 1997), has now, seemingly without resistance, been placed as central to children's and youths' learning (Dahl & Østern, 2019). Consequently, the lack of research on *deep learning* in the lower age ranges of primary education needs to be addressed.

Concluding remarks

Our study show that two main conceptualisations of *deep learning* have emerged around the world during the last five decades of research on primary and secondary education: *meaningful learning* and *transfer of learning*. The first is conceptualised as students' approach to learning with the intentions to understand the *meaning* of the learning material and to *relate* new ideas to previous knowledge, driven by an *intrinsic motivation* to learn. The other is conceptualised as students' ability to *transfer skills and knowledge* to a novel context.

The current educational discourse highlights a need for a change in the educational system that can provide students with the skills and knowledge needed to cope with the demands of the 21st century, and *deep learning* is proposed to be an important feature. Our review finds that research on *deep learning* in primary and secondary education conceptualises *deep learning* as a cognitive phenomenon investigated among teenagers in relation to a few school subjects. However, applying a concept that has been investigated with such a narrow scope as a key feature in in the curriculum of compulsory education might result in an understanding of *learning* simply as *cognitive learning* among politicians, policymakers, school leaders, teachers, students and parents. This might lead to a focus on facilitating a teaching practice based solely on this understanding. As highlighted by researchers like Tochon (2010), Dahl and Østern (2019) and Damasio (1994; 2000; 2010), *embodied*, *emotional* and *social* aspects of learning are fundamental and need to be considered together with the *cognitive* aspects. Biesta (2010) describes a prevalent trend in education focussing on educational practice. He accentuates that a possible consequence of focussing solely on practice, is that the overall aims and purposes of education and its guiding values is neglected by favouring a focus on 'what works' (p. 493). We see a similar tendency in the discussion concerning *deep learning* and which skills and knowledge are needed to cope with the 21st century. In policy documents there seems to be a heavy focus on implementing practices like *deep learning* to facilitate, e.g., *critical thinking*, *problem-solving* and *transfer of learning*, without necessarily revising the content and direction of education overall. Are the current aims and purposes of education sustainable for a future where phenomena like globalisation, digitalisation, climate change and pandemics affect our way of living in unforeseen ways? We believe that Tochon's (2010) idea of *deep education* is an interesting starting point for discussions regarding the direction of education in the 21st century. Future research on *deep learning* should apply a broad range of perspectives, including embodied, emotional, social and cognitive aspects of learning, and investigate *deep learning* in all age ranges and all school subjects. In addition, the perceived differences between Eastern and Western educational contexts should be considered, and the relationship between *deep learning* and *transfer of learning* should be elaborated.

Acknowledgements

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