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ABSTRACT **In this discussion chapter of the book, first the concept of adaptive expertise is reflected upon. It is argued that its skills- and task-based nature has particular strengths for the design of education and learning, such as its underpinned and structured nature of approaching complexity. But it also has some limitations or potential risks, such as an under-emphasis on affective processes, the balance and choice for certain tasks or the risk of relying on potentially limited expert views.**

Second, the chapter discusses characteristics of adaptive expertise in practice and its implications for educational design. Such implications include designing for open and meaningful situations, encouraging learner agency and ownership, integrating social, physical and technological contexts and stimulating formative assessment.

Third, the chapter concludes that adaptive expertise and engineering education might form a happy marriage given their focus on complexity, project- and problem or challenge based approaches, and their balance between skills and knowledge.

The chapter ends with some suggestions for future research, such as on the nature, combination and balance of tasks needed in education and its positioning within the curriculum.

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Introduction

This book brings together a nice and contemporary set of papers on the role of adaptive performance in higher engineering education. After an introduction of the concept (Van den Beemt et al., chapter 1), **the chapters in the first part of the book link the concept to underlying mechanisms in different contexts of work-based learning environments** (Groenier et al., chapter 2; Munneke & Ommering, chapter 3; Kaffka & Backhaus, chapter 4 and Jensen & Gamborg, chapter 5)**. In the second part, the authors describe how adaptive performance can be stimulated** (Kaffka et al., chapter 6; Van Bruggen et al., chapter 7)**. Part II describes formative assessment of adaptive performance** by Pennings et al. (chapter 8) and Baggen et al. (chapter 9).

In this discussion chapter, the conceptual background of the concept of adaptive performance will be further discussed. What was or is its conceptual origin, and how do the different chapters in this book adhere to or expand this origin? What can be seen as strengths of the concept in this respect? But also, what conceptual questions does the concept raise, and what does this mean for its use? Next, the main characteristics of the concept will be highlighted, as they come to the fore across the different contributions in this book. What do these characteristics imply for the learning environment, the role of the teacher (and student), and the curriculum? Finally, a reflection will be given on the fact if there is indeed a good marriage or link between the concept of adaptive expertise and engineering education. Finally, some suggestions for future research on the topic of adaptive performance in engineering education are provided.

Reflections on the nature of the concept of adaptive performance

In the introduction chapter of this book, following Ericsson et al (2018), van den Beemt et al. (this book) 'define' adaptive performance as the outcome of the ability to deal with tasks that are complex, uncertain and new, and for which routine and standard operating procedures are not sufficient, based on cognitive structures resulting from experience. Note that the authors do not directly or explicitly provide this definition, but it can be pieced together based on their definition of expertise and their discussion of complex problems in the context of engineering education, which are described as uncertain, unpredictable, ill-structured, abstract and requiring interdisciplinary, authentic, student-centred approaches, such as challenge-based learning. According to the authors, adaptive expertise underlies adaptive performance, which is the actual and successful dealing with uncertainty in complex tasks.

This definition unobscures that abilities are central, and the book highlights several of these abilities, such as (deep) reflection (on content, processes and experiences), creative and critical thinking, self-regulation and metacognition, being able to apply (see for example the chapters of Jensen & Gamborg and Kaffka et al. in this book). These abilities can

be developed through experiences in dealing with tasks. As such, the concept finds its origin in research on intelligence, task performance and the role of processing information as part of this and has a strong cognitive psychology background – suggesting that (complex) tasks trigger knowledge structures or networks in individuals, structures based on prior performance and knowledge.

Obviously, this cognitive and task-based approach has several advantages for the design and setup of learning environments. Tasks can often be analysed in terms of steps, constituting parts and skills, and linked to actual and authentic professional situations. This leads to clear design criteria and structured approaches for training learners. Several other frameworks take such an approach as a starting point and are discussed in this book as well, such as the 4-CID model for complex skills development (van Merriënboer et al., 2002), or theories on self-regulation and meta-cognition (Zimmermann & Schunk, 2011; Zimmermann, 1986; Winne & Hadwin, 2008).

To some degree, more contemporary variants of these approaches, such as challenge-based learning, case-based learning, scenario or design-based learning, also seem to start from authentic situations and tasks, and the skills and knowledge needed in these. Most of these theories and models are well-researched and provide a sound theoretical basis for adaptive performance and its development in learning environments. Also, the concept of adaptive performance seems to align well with contemporary and relevant approaches in engineering education, such as challenge-based learning and workplace learning, and also aligns well with views on engineers of the future, including the T-shaped profile (Tranquillo, 2017) – see also next sections.

Interestingly, the different chapters in this book seem to expand the concept of adaptive performance and its task-based, cognitive origins quite easily to new paradigms and approaches, such as socio-constructivism, socio-cultural theory or boundary crossing. In doing so, they put more emphasis on elements such as the need for collaboration and shared knowledge or expertise, the role of tools and resources, and the role of individual perceptions and meaning making (see for example Kaffka et al., and Munneke & Ommering in this book). Also, such theories seem to advocate a stronger agency and active role for the learner. This expansion brings an interesting tension to the fore within the concept of adaptive performance.

Within this field of research, there is an interesting debate on the interplay between the role of the individual and their characteristics, the role of the task or environment and its characteristics and the social nature of developing adaptive performance (Pelgrim et al., 2022). Most research seems to situate adaptive performance mainly as a quality of the individual, in particular related to its cognitive and metacognitive nature, thereby following the more traditional origins of the concept. However, scholars such as Engeström (2018) debate this and propose that expertise is not a quality of the individual, but resides in activity systems, which consist of a group of objects and tools, and are conducted in a

community of practice. In doing so, they suggest that the task and context element of the concept are perhaps more important than more cognitive oriented scholars would propose. Obviously, putting more emphasis on one of these elements in the interplay between individual, task, and context also has potential consequences for how one conceives the development of adaptive expertise (see next section).

Next to this, the cognitive and task-based nature of the concept of adaptive performance also raises several questions and issues. First, there seems to be a central emphasis on the cognitive and behavioural aspects of learning, and to some degree the metacognitive or regulative aspects of learning; much less attention is paid to the affective or emotional dimensions of learning of tasks, or to the personal side of learning, including professional identity (development), values, ethics or motivations (cf. Vermunt & Verloop, 1999; Zimmermann & Schunk, 2010). Interestingly, uncertainty seems to be a relevant starting point in tasks in most chapters in this book, but uncertainty can have different origins, relating to, for example, a lack of knowledge, knowledge that brings tensions or dilemmas, a lack of process overview, or working with unfamiliar practices (Bohm et al., 2024).

Interestingly, most experts are inclined to focus on cognitive related uncertainty, while many tasks seem to bring emotional and affective uncertainty as well, requiring different types of support (Bohm et al., 2024). While such elements are under-researched in challenge-based learning and engineering education in general, they also seem underrepresented in adaptive performance research, and are only to a limited degree addressed in the contributions in this book as well.

Second, while tasks and experiences are relevant to show expertise and being able to respond well to a variety of situations and problems, the question arises if all situations tasks are equally relevant and suitable to develop adaptive expertise, and if not, which situations and problems should be prioritized, how they should be balanced and placed within a curriculum. Pelgrim et al. (2022) also note this based on their review of the literature on adaptive performance: they refer to work by Ward et al. (2018) who argue that there is no clarity as to how new or large a task needs to be in order to require or develop adaptive expertise. Some tasks may be so new and complex that even experts (including adaptive experts) cannot easily solve them – they refer, for example, to the way people had to deal with the 9-11 or Covid-19 circumstances.

Also, the question as to whether a task needs to require only disciplinary knowledge or also interdisciplinary knowledge, according to them remains unanswered. This brings another interesting question, as to whether an adaptive expert needs to be a disciplinary specialist or an interdisciplinary one. Ward et al. believe that disciplinary knowledge already allows an expert to be flexible, whereas other scholars would argue that interdisciplinary knowledge and expertise are also needed before one can be an adaptive expert.

In this book, most authors and chapters argue that tasks relevant

to adaptive performance are inter- or transdisciplinary in nature. However, the number of disciplines involved in a task and the degree to which these disciplines or domains are more distant or more adjacent to each other differs, and the role this plays in the development of adaptive expertise remains unclear.

Third, the focus on experts and their cognitive structures have the advantage to detect relevant and central concepts or procedural schemes. However, the practical knowledge of experts may also be subject to misconceptions, ill-defined concepts or procedures, narrow viewpoints, and be constrained to a set of situations that is relatively constrained in nature (Brants, 2013; Quirk, 2010). This highlights the importance of theoretical knowledge as well as relevance of involving multiple experts in learning environments.

Ultimately, these issues also raise some more philosophical questions for education. Should every graduate in higher education strive to become or be developed towards an adaptive expert? Are there different types of adaptive experts, for example, more disciplinary and interdisciplinary ones? Is there a stronger need to focus not only on the cognitive and task-based nature in developing adaptive expertise, but also on the personal, affective and social aspects of expertise development, and in doing so expand the development of adaptive performance in higher education beyond a mere qualification function, to also include a socialization and subjectification function (Biesta, 2020).

The concept of (developing) adaptive performance in practice

While the different chapters in this book highlight a variety in contexts and situations and emphasise different types of skills under adaptive performance, there seems to be a common set of characteristics and criteria that underlies the different learning environments discussed.

Characteristics that emerge from the different chapters of the book are:

- Unfamiliar, complex and open-ended tasks or situations, where there are multiple solutions possible or where solutions always have certain advantages and disadvantages.
- Situations or problems that require a variety of disciplines or domains, different types of expertise, and that are sometimes transdisciplinary in nature. Most of these tasks or approaches, therefore, require some type of collaboration, often involving boundary crossing.
- Task performance often requires tools or other resources. Typically, a design-based, research-based or other type of cyclical approach is needed. Due to the often project-based nature, aspects such as pragmatism or an agile approach are also relevant.
- Activities require the performance of a variety of deep learning skills, such as reflection and self-regulation, creative or critical thinking, logical reasoning, application or abstraction.

- The role of the teacher often emphasises coaching, which is focused on a variety of things, such as content, process, emotions and outcomes. Providing timely and flexible stimulating feedback is essential. This requires the ability to be flexible in content, maintain overview and look at learning in a holistic way. But it also requires from teachers to be able to create networks, work with a variety of stakeholders, the ability to create complex tasks.

- Assessment of learning often focuses on both short-term and longer-term processes, has a programmatic nature, emphasises formative approaches, requires feedback literacy, allowing for a variety of potential outcomes, even learning surprises, and needs to be inclusive, distinctive and include elements such as collaboration and self-regulation. In the end, quality of processes and outcomes is more important than efficiency of performance.

The authors of the different chapters emphasise that adaptive performance is central to their approach and can be suitably translated into environments and conditions that are conducive to learning. Also, there seems to be agreement among the central characteristics and elements involved. Overall, the approaches mentioned seem to suggest that deliberate practice is important (see also Bronckhorst et al. 2011; 2014; van Dijk et al., 2023). This implies that education needs to engage learners in tasks that require effort, concentration, that stimulate self-improvement and that repeated practice is needed. In addition, to stimulate the deliberate nature, sufficient attention needs to be provided to the development of theoretical knowledge in learners, linking this theory to existing knowledge structures of learners, and stimulate reflection, also by providing feedback.

This book implies several areas for educational design:

First, the design for complexity in open, meaningful situations. In the cases discussed, students worked on open-ended, often multidisciplinary challenges that forced them to: 1) apply and develop (existing) knowledge, 2) arrive at new insights together with others, and 3) learn to deal with ambiguity, failure and uncertainty.

Second, to encourage epistemic ownership and agency. Several contributions, e.g., Munneke & Ommering, highlight the importance of epistemic agency : the ability and willingness of students to actively and consciously create knowledge, rather than just reproduce knowledge. This requires students to feel co-ownership of their learning process, and to learn to deal with knowledge uncertainty. For education, this requires the stimulation of making your own choices (autonomy), to be able to negotiate goals or success criteria, and to actively reflect on assumptions, perspectives and results.

Third, to weave social, physical, and technological contexts. Several chapters make it clear that learning is not just a mental activity. Instead, it is *ecological, embodied and relational*. Cognition takes place in interaction with people, objects, technologies and spaces. For example: the role of collaboration in agile working methods (Kaffka et al., this book), the

influence of physical actions on learning (Jensen & Gamborg, this book) and the importance of teachers guiding safe and meaningful interactions (Van Bruggen et al., this book).

Finally, making the case for formative assessment. Although adaptive performance is difficult to grasp, the chapters of Pennings et al. and Baggen et al. show that it is indeed possible to make adaptive performance visible. The adaptation of the D-ADAPT instrument shows how perceptions of adaptive capacity can be mapped. The use of generative AI opens new doors: scenario-based simulations generate realistic contexts in which adaptive performance can be evaluated. This implies that measurement instruments should not only focus on the *end product* of adaptive action, but also on the *processes* that precede it: perspective change, metacognition, reflection, and learning process.

Although this agreement on the main elements and characteristics needed for the development of adaptive expertise is helpful, it does not answer questions as to how adaptive expertise needs to be placed within the larger curriculum. Earlier in this chapter, questions were already raised as to whether the curriculum needs to develop everyone into some kind of adaptive expert? Are the approaches mentioned suitable for all learners? If we agree on the importance of developing adaptive performance in higher education, where and how in the curriculum should it be placed? Is it, given its focus on complexity and authentic, work-based situations, and the complex nature of skills involved, the best place at the end of a curriculum?

As mentioned, some suggest that adaptive performance requires a strong disciplinary basis and requires learners to have a strong theoretical basis. If so, how does this requirement, for example, align with the development of broad bachelors' that is occurring at most Dutch universities? How does the holistic, programmatic and quality focused nature of learning and assessment that is mentioned to develop adaptive performance align with the current focus in most universities on grades, efficiency and summative assessment? How to incorporate elements that go beyond the cognitive nature of adaptive performance? How can students be best prepared for adaptive performance, and what could potential learning trajectories look like?

And finally, is the approach painted in the various chapters mainly or uniquely suitable to the context of engineering education, and is it a typical Western concept or approach – note that the vast majority of the authors and their work originate from the Netherlands? This final set of questions nicely brings us to the final topic of this discussion, the fit with engineering education.

Adaptive performance and engineering education: a happy marriage?

The introduction chapter of this book emphasises the relevance of the concept of adaptive performance for the context of engineering education. In their argumentation, the authors mention the fact that many engineering education institutes focus on complex, real-life, societal problems, for example related to sustainability, health, food or energy, that on the one hand require technological expertise, and on the other hand expertise on a variety of other domains. In addition, the authors mention the focus on innovation and creative thinking, and an entrepreneurial mindset, elements that are also central to engineering education. They further refer to elements such as logical thinking, validation, accuracy, but also the need for design based and scenario-based approaches. And they mention approaches such as challenge-based learning, which are highly popular in engineering universities, and that seem to align well with the authentic, work-based approach to tasks and task performance.

The concept of the adaptive expert, who has a well-developed cognitive structure based on their experiences in real-life tasks, and who is able to link this structure to non-routine tasks requiring complex skills, aligns well with the image of the T-shaped and Phi-shaped engineer, an engineer who has specific expertise and knowledge in one domain, but who is able to collaborate with others and link him- or herself to other domains and practices (Tranquillo, 2017). The idea also aligns well with the distinctions that several universities make in potential graduate profiles, and that further stress the development of particular knowledge and expertise, such as that of a technical expert, an entrepreneur, a policy or decision maker, a teacher, and so on.

As can be seen in the above list of characteristics, many elements of adaptive performance and its implementation in higher education are also typical for engineering education, as already indicated in the introduction chapter of the book itself. Think of design-based approaches, systems thinking, creativity, dealing with complex problems, project or problem-based approaches, challenge-based learning, the use of tools and resources, and so on.

That said, some elements of adaptive performance, certainly when approaching it to its full extent, encompassing some of the limitations mentioned earlier on, are less common or perhaps deemed more challenging for engineering education teachers. These elements are, for example, the need to focus more on emotions and the affective side, the need to focus on the personal side, including ethics and personal values, but perhaps also the need for collaboration and the need for inclusivity, including working with less technical domains. One may finally wonder to what degree adaptive performance should be part of the curriculum, and to what degree all teachers at engineering universities should possess all the qualities and characteristics of coaching as mentioned earlier.

Overall, the marriage of adaptive performance with engineering education seems a happy one, although its relationship needs to be further developed in the future.

Future research

This book provides a good starting point for those interested in developing adaptive performance in education, especially in the context of engineering education. It shows that the concept aligns well with contemporary ideas of engineers that need to be prepared for the challenges of the future, and that embracing it to its full extent aligns well with many educational trends that have been picked up in engineering education. The case studies and projects described in this book help to understand its versatile nature and support the empirical knowledge base behind the construct.

As can be seen from previous sections in this discussion chapter, a book such as this only provides a first step, and more research on the concept and its application is needed in the future. These include investigating the relevance and applicability of adaptive performance outside the context of the Netherlands and engineering education. More conceptual development is needed as well: to what extent should the concept evolve beyond its cognitive and task-based nature? Do other frameworks, such as socio-constructivism, help to develop the concept to include elements such as affect and emotions, personal development, and link the more individual cognitive approach to more shared or collective broader approaches?

Finally, much more research is needed to make the concept better implementable in practice. Questions that could be addressed are: what balance should be struck in the curriculum between more routine-based and non-routine-based tasks? Should all graduates be developed towards adaptive experts? What level of (prior) knowledge is needed to develop adaptive expertise and to what degree can or should this knowledge be monodisciplinary or multi- or interdisciplinary? Where in the curriculum can adaptive performance be best developed, and what should learning-lines look like that prepare students towards adaptive performance? What tasks are most suitable to develop adaptive performance, and how complex (or not) should they be in terms of nature and number of domains of expertise involved? What type of assessment is needed? How can we best prepare university teachers for the different nature of coaching and assessment that adaptive performance requires?

Finally, how does adaptive performance and its current nature position itself to other approaches that start to emerge in science, such as regenerative or transformative approaches? Such approaches deviate from the idea of power structure and traditional (often Western) approaches to knowledge and knowledge development, bring whole person development to the fore, and emphasise different outcomes than the technological-economic paradigm.

> *It is exciting to see the developments presented in this contemporary book! Undoubtedly, this book is the first in a line of many to come in the future, as the topic of adaptive performance is just kicking into gear.*

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