

3 | Enhancing adaptive performance through developing epistemic agency and research competencies

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ABSTRACT In today's dynamic and complex work environment, engineers face continuous changes and new challenges. This chapter explores how adaptive performance can be enhanced through the development of epistemic agency and related research competencies. The case studies of Brice, a vocational-level automotive engineer, and Viola, a master-level research engineer, illustrate how adaptive expertise requires integrating and constructing new knowledge tailored to specific challenges. Epistemic agency, defined as the active and conscious engagement in knowledge creation, enables professionals to identify knowledge gaps, decide how to address them, and create actionable knowledge collaboratively.

The chapter conceptualises epistemic agency through two components: the epistemic aspect, encompassing the acquisition, understanding and creation of diverse knowledge types, and the agency aspect, emphasising proactive, context-sensitive decision-making. These allow engineering professionals to innovate and adapt within their field. Next, this chapter highlights the role of research competencies in fostering epistemic agency and stresses the need for educational approaches that intertwine research activities with professional tasks and practices. Authentic professional tasks, rooted in real-world challenges, are proposed as the foundation for higher education curricula. This pedagogical approach, exemplified by challenge-based learning (CBL), emphasises interdisciplinary collaboration and knowledge creation.

Ultimately, the chapter calls for reimagining engineering education to prioritise epistemic agency and adaptive expertise, ensuring that future professionals can effectively navigate the complexities of modern work environments. These insights are crucial for preparing students like Brice and Viola for lifelong learning and professional adaptability.

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Introduction

Brice is an automotive engineer with a level 4 vocational qualification. He is working at a garage, specialising in Alfa Romeo and repairing classic cars. Consequently, in his daily practice he mainly repairs diesel and gasoline engines. In his vocational training, there was a lot of focus on electric engines but at that time it did not hold his interest. However, due to the current transition from diesel and gasoline cars to electric cars, Brice will have to switch to electric engines soon.

Viola is an engineer with a level 7 master qualification. She is working at a research and consulting firm that helps clients realise broad prosperity. She is currently developing advice for a big city to come to a zero-emission zone in the centre of the city as part of a project team consisting of different kinds of professionals. Her task is to develop a prediction model for the logistic road flows as a part of a framework with guidelines for coming to zero-emission city logistics. Both the subject of the project and working with professionals from very different fields is new to her.

As professionals in the engineering domain, Brice and Viola both face changes in their daily work due to significant shifts in their work environment (transition to electric driving) or new societal issues (sustainability and CO₂ reduction). To remain well-functioning professionals, Brice and Viola should be able to adjust to new uncertain circumstances, changing complexity of job tasks and work methods. Despite the difference in qualification level of their education, they are both expected to show flexibility in the workplace, which is seen as a critical ingredient for success (Van der Heijden, 2002). This flexibility is the main characteristic of adaptive expertise and the corresponding concept of adaptive performance. At its core, engineers like Brice and Viola can successfully meet uncertain, complex and dynamic challenges in their work – new for the engineering domain or themselves – in a creative and flexible way (Bohle Carbonell et al., 2014; Pelgrim et al., 2022). In other words, engineering professionals like Brice and Viola nowadays are expected to perform professional tasks optimally even in changing contexts, to contribute to societal issues and to pursue life-long learning.

Several reviews into what constitutes adaptive expertise and how to develop it, emphasise the importance of cognitive flexibility (Feltovich et al., 1997) and corresponding solid domain knowledge (Bohle Carbonell et al., 2014; Pelgrim et al., 2022). Therefore, as also indicated in the introductory chapter of this book, engineers who act adaptively can come up with creative solutions to new problems because they have access to rich, conceptual knowledge. The more complex and deeper

this knowledge is, the easier it is for a professional to think creatively and critically, enabling them to develop original, well-reasoned, and useful solutions to new problems in the work context (Feltovich et al., 1997).

However, as the scenarios of Brice and Viola show, what could be seen as the solid domain knowledge of an engineer is subject to change as well, due to the inherently dynamic and context-dependent character of domain knowledge. For Brice, this means being able to further extend his solid domain knowledge in diesel and gasoline engines with knowledge about repairing electric engines. For Viola, this means she should be able to integrate knowledge of other professionals into her own domain knowledge to some extent as well. This indicates that to be an adaptive expert, engineering professionals need to continuously determine which knowledge is needed to deliver good work and should be able to create that knowledge in collaboration with other professionals.

So, adaptive experts can balance the efficient use of their previously acquired knowledge with the creation of new knowledge in response to novelty and complexity (Kaffka et al., 2024; Mylopoulos et al., 2018). Knowledge creation therefore seems to be an essential part of fostering solid domain knowledge and ensuring that engineering professionals remain effective and efficient in dealing with the complexity of today's society and challenges in their daily work.

As Markauskaite and Goodyear (2017, p.1) put it: "Working on real-world problems usually requires the combination of different kinds of specialised

and context-dependent knowledge, as well as different ways of knowing. People who are flexible and adept with respect to different ways of knowing about the world can be said to possess epistemic fluency."

In this chapter we zoom in on this aspect of epistemic fluency in adaptive expertise and performance. Building on the work of Damşa et al. (2010) and Heikkilä et al. (2023) we refer to this as *epistemic agency*.

Conceptualising epistemic agency

Epistemic agency refers to the way in which professionals actively and consciously engage in knowledge creation in their daily practice (Damşa et al., 2010; Heikkilä et al., 2023). Based on a systematic conceptual analysis of the literature, we propose that a professional with epistemic agency should be able *to recognise and acknowledge* where adequate (actionable) knowledge is lacking in a specific professional context, *make substantiated decisions on how to deal with the missing knowledge with a thoroughness that is appropriate* to the given context, and make the results *useful* within and for specific professional situations *in collaboration with stakeholders* (Munneke, 2024; Munneke et al., 2023).

To further conceptualise epistemic agency, we will first discuss the meaning of the *epistemic* component and what we mean by knowledge in the context of professional work. We then elaborate on the meaning of the *agency* component in the context of new, uncertain circumstances and the changing complexity of work.

The term *epistemic* in epistemic agency refers to the stance of professionals towards *knowledge* and includes everything related to acquiring, understanding, justifying and creating knowledge. Following research on professional expertise, we use the term ‘knowledge’ in its broadest sense. This includes all contributions to thinking, interacting and performing such as: codified, explicit knowledge; know-how; personal beliefs and understanding; episodic memories; self-knowledge and tacit knowledge (Eraut, 2010). There are many ways these types of knowledge are interpreted by researchers.

However, despite the wide diversity in classifications of knowledge, we can broadly distinguish three different types of knowledge professionals can acquire and use in their work: 1) explicit, formal, explanatory, declarative knowledge (know-that, know-why) such as concepts, models and theories; 2) implicit, informal, procedural, experiential knowledge (know-how) such as skills and dispositions to act in a particular way; and 3) regulatory knowledge that supports ongoing learning and development (Bereiter, 2002; Eraut, 1985; Markauskaite & Goodyear, 2017; Tynjälä, 2008).

Markauskaite and Goodyear refer to the complex constellation of these types of knowledge that professionals need to ultimately deliver quality work, as *actionable knowledge*. They stress that creating actionable knowledge involves much more than developing formal, declarative knowledge, because it requires “a combination of intelligent problem solving, engagement with the material and social environment, and perceptual-sensorimotor skills” (p.90).

In conclusion, the epistemic element in epistemic agency is thus a comprehensive concept and involves the integration of different types of knowledge. This holistic approach ensures that professionals are not only well versed in theoretical concepts (formal, declarative knowledge), but also adept at acquiring and applying existing knowledge as well as creating new knowledge in, with and for practical situations (Schön, 2002). This ultimately leads to continuous professional growth, high-quality work and the innovation needed in that work.

While knowledge construction often occurs as professionals react to specific changes, uncertainties, or problems, *agency* denotes their proactive involvement in shaping how they respond (Biesta & Tedder, 2007; Kusters et al., 2024). In essence, epistemic agents are not passive recipients of information; they critically assess and contribute to the knowledge they encounter. The definition of epistemic agency we gave earlier in this chapter suggests that this response could take place, for example, at the level of deciding *how* to acquire new knowledge (Greve et al., 2018).

It refers to the ability to make conscious, substantiated decisions about what is appropriate given the context in which professionals are acting, and recognizing that there may be multiple approaches. This is in line with broader perspectives on agency, which imply that professionals are able to consider different ways of constructing knowledge and make deliberate choices based on what is needed for the given context (Eteläpelto et al., 2013; Lutz et al., 2019).

In doing so it is important that they are aware of different types of knowledge and learn to deal flexible with abstract, contextual and situated ways of knowing to derive actionable knowledge (Guile, 2014; Heusdens et al., 2015). This involves a unique interpretation of what is considered actionable knowledge, while relating this to the shared understanding of the professional community of which a professional is part. In other words, professionals relate to a particular system with its corresponding 'epistemic frame' – i.e., "a system of ideas or ways of understanding that allows us to establish knowledge [...] manners of justifying, explaining, solving problems, conducting enquiries, and designing and validating various kinds of products and outcomes (Perkins, 2006, p.42)".

Finally, it requires the ability to look beyond your own theories and practices, to delve into expertise beyond one's own, to engage in multi- or transdisciplinary collaboration, and learn from other fields (Ninan et al., 2022).

Returning to the cases, how does epistemic agency help Brice and Viola to deal adaptively with the challenges of their daily practice? For Brice, epistemic agency supports the acquisition of new actionable knowledge, as the combination of explicit, implicit and regulatory knowledge enables him to effectively repair and maintain electric engines. Brice will need to engage with the latest information and technologies related to electric engines. In his case, this means revisiting the concepts he learned during his vocational training and updating his knowledge base to include recent

advances in electric vehicle technology. Brice's ability to understand and justify the new knowledge is crucial. He needs to understand how electric engines differ from diesel and gasoline engines, not only in terms of mechanics, but also in terms of their environmental impact and efficiency.

This deeper understanding will enable him to justify the transition to electric engines both to himself and to his clients. When he becomes more familiar with electric engines, he can start to innovate and create new solutions tailored to the specific needs of his garage and clients. This could involve developing new repair techniques or customising electric engines for classic cars, combining his expertise in both areas.

In the case of Viola epistemic agency can also assist the acquisition and creation of new actionable knowledge necessary to develop a predictive model for zero-emission city logistics in collaboration with professionals from other domains. In her case, acquiring new knowledge means Viola must actively seek out new knowledge related to zero-emission zones and logistics road flows. This involves researching current best practices, understanding the latest technologies, and learning from case studies of other cities that have implemented similar initiatives. She also needs to be able to delve into the knowledge of other professional domains of the professionals she works with (e.g. urban planning, environmental science).

To some extent, she will have to learn to speak the language of fields that were previously foreign to her. Viola needs to deeply understand the principles behind zero-emission logistics and be able to justify her

predictions and recommendations. This involves not only grasping the technical aspects of her prediction model but also understanding the broader environmental and social impacts of zero-emission zones. In her own specific context, she will likely encounter unique challenges and opportunities. Epistemic agency enables her to innovate and create new solutions tailored to this context. This could involve developing new algorithms or integrating diverse data sources to improve the accuracy of her model.

While both Brice and Viola use epistemic agency to adapt and innovate in their fields, there are notable differences between their cases. Brice's work is more focused on a specific technical domain, while Viola's work spans multiple domains. Brice integrates new technical knowledge into his existing skill set, whereas Viola must synthesise knowledge for various fields to create a comprehensive solution in interdisciplinary collaboration with other professionals. By understanding these differences, we can see how epistemic agency is applied uniquely in each context on different levels, enabling both Brice and Viola to respond adaptively to the specific challenges in their context.

Fostering epistemic agency in engineering education through developing research competencies

What are the implications of this conceptualization for teaching and learning epistemic agency in higher education? To start with, Markauskaite & Goodyear (2017, p.553) state: “we claim that well-designed tasks for professional learning are simultaneously professional

(actionable, situated), conceptual and epistemic. Such tasks involve the weaving of epistemic games that are played in professions and a dynamic – embodied and embedded – assembling of actionable concepts. These tasks stimulate discourse that integrates generic (formal) and situated (functional) kinds of knowledge and formal and functional ways of knowing. They involve knowledge that is both coherent and contingent, structured and experiential and explicit and tacit”.

Firstly, this statement makes it clear that authentic professional tasks are the starting point when designing higher education to develop epistemic agency. In doing so, Markauskaite and Goodyear indicate that a variety of more or less (ill)structured and (in)stable tasks are needed throughout the curriculum that enable meaning-making and action. This is consistent with an important pedagogical principle from the 4C/ID model: increasing complexity of authentic professional tasks (Van Merriënboer, 1997; Van Merriënboer & Kirschner, 2013).

In an increasing number of professional practices, the complexity of the issues that professionals are facing is growing. This means that these issues for which adaptive performance is needed should also be incorporated into the curriculum, and students must gain sufficient experience with these complex problems in addition to more routine professional situations. Therefore, students should not only be challenged to grow into a profession and gain more expertise in it, but also to contribute to the issues and challenges in that profession, which are increasingly multidisciplinary in nature.

Secondly, the statement of Markauskaite and Goodyear focuses on the importance of ‘playing epistemic games’ as an educational approach. This approach is rooted in the work of Shaffer (2006) on how to master an epistemic frame of a specific profession. While research is a crucial component of an epistemic game, it often becomes the dominant element in higher education (Greve et al., 2018). Although developing students’ research competencies is essential for creating knowledge and fostering epistemic agency, it is equally important to maintain a strong connection to professional practice. In other words, the focus must not solely be on research competencies for the sake of conducting research, but on producing actionable knowledge for professional situations and problems.

So, research competencies can be seen as supportive and valuable for developing epistemic agency (e.g. Heikkilä et al., 2023; Markauskaite and Goodyear, 2017). Despite the necessity for professionals in practice to find answers in situations of not-knowing through more iterative and pragmatic methods, contemporary higher education often places students in the role of researchers. This frequently results in a unilateral approach with a strong focus on technical research skills, expecting students to conduct research systematically and methodically following the research cycle to acquire knowledge (Greve et al., 2018). However, when it comes to educating future professionals for certain domains this approach is not always the suitable epistemic game for developing actionable knowledge in professional contexts.

Instead, higher education should aim to cultivate professionals that develop epistemic agency and are able to deploy research competencies

to truly benefit the profession. Professionals should know how to act in complex situations and help to evolve the professional field, which goes beyond just teaching technical research skills and providing students with opportunities to take on a researcher role. Still in many educational contexts the development of research competencies often occurs disconnected from future professional tasks in practice.

Instead of pursuing the ‘quality of knowledge creation’ as professional researchers do, the focus should be on the ‘quality of work’ (Ruijters & Simons, 2020). The standards of what constitutes good work should therefore be the determining factor, which in turn redefines the concept of research competencies.

Thus, research competencies are supportive in developing epistemic agency and should be closely linked to ‘good work’ in the future daily practice of professionals. This implies that a broader didactic approach to developing research competencies to foster epistemic agency is needed, beyond merely conducting research. Instead, it should focus on producing professionals capable of handling the dynamics and complexity of professional practice.

In conceptualising epistemic agency, we referred to our definition arisen from a systematic conceptual analysis of the literature. This same conceptual analysis also helped to identify five dimensions of research competencies, each with its own constellation of knowledge, skills, and attitudinal aspects (Table 1, p.43).

TABLE 1 DIMENSIONS OF RESEARCH COMPETENCE

DIMENSION	DESCRIPTION/DEFINITION	EXAMPLES OF KNOWLEDGE, SKILLS AND ATTITUDES
Conceptual <i>What is it about?</i>	Epistemic agency cannot be expressed if there is no knowledge of the subject or situation. The richer the cognitive, conceptual schema of a topic/domain, the better one can assess what they do and do not know, and the easier it is to arrive at new knowledge (Feltovich et al., 1997).	- Conceptualising - Concretizing - Information literacy
Epistemological <i>What are our values and norms when it comes to knowledge?</i>	Every domain has its own peculiarities when it comes to the value and assessment of knowledge. Professionals are initiated into that tradition with its own focus, views, norms and values. This makes this dimension normative at its core.	- Scientific and epistemological beliefs - Common research methods or practices (e.g. action research or design research)
Procedural - technical <i>What are our ways of working?</i>	To answer a knowledge question systematically and methodically with appropriate rigor, one needs to be able to go through a research cycle and master the corresponding technical research skills. Which these are, is closely related to the epistemic dimension.	- Concepts of reliability, validity - Methods of data gathering and - analysis - Operationalizing variables
Affective-motivational <i>What does it evoke emotionally?</i>	The words 'research' or 'not-knowing' evokes emotional responses such as uncertainty, fear and pleasure in many people, motivating them more or less to want to 'research'. Being able to deal with these emotions in a good way contributes to epistemic agency. How, for example, could uncertainty be productive?	- Dealing with uncertainty - Perseverance in the face of frustration and complexity - Awareness of added value of research for own professional practice
Social-communicative <i>How to create relevant and usable knowledge collaboratively?</i>	How to collaborate well with others in answering questions so that the answer is useful to more people than? That includes being able to communicate clearly about answers to a knowledge - question, and being able to convince others about the validity of those answers.	- Argumentation skills - Writing skills - Collaboration skills - Presentation skills

This table illustrates the versatility of developing research competencies and, consequently, epistemic agency. Instead of the current predominantly one-sided emphasis on the procedural-technical dimension, attention must also be given to the other dimensions. It is important to keep considering that students are being prepared for specific professional practices. Therefore, starting with ‘not knowing’ or knowledge gaps that occur in concrete tasks within that particular practice is key. This highlights the importance of focusing on authentic professional tasks (Van Merriënboer & Kirschner, 2013).

Discussion

Higher education seems to be increasingly embracing the idea of focusing on authentic professional tasks. This is reflected, among other things, in the emergence of various forms of education in which there is close collaboration with partners from practice and society. In these educational approaches, epistemic agency becomes a shared endeavor, with subsequent questions about what is considered as valuable knowledge within a group (Damşa et al., 2010). This poses new challenges with implications for educational practice. Below, some of these challenges will be discussed through the lens of the widely adopted educational concept of challenge-based learning (CBL) in higher education.

CBL is a promising approach that emphasises the importance of focusing on authentic professional tasks. In CBL, students tackle real-world and complex challenges within an interdisciplinary team (Gallagher & Savage,

2020; Malmqvist et al., 2015; Van den Beemt et al., 2022).

First, CBL provides students with important learning opportunities in terms of epistemic agency, as they can contribute to authentic issues and challenges in the profession through knowledge creation. In addition, however, it is equally important to focus on their professional growth and expertise when shaping CBL. Especially since the educational concept of CBL, at its core, focuses on both personal and professional development of students (Maya et al., 2017; Membrillo-Hernández & García-García, 2020). Therefore, CBL, which involves students collaborating on mission-driven projects around complex tasks, requires careful design and alignment with their stage of professional development and current level of professional knowledge.

Viola’s story illustrates that she is not only collaborating with professionals from various fields for the first time, but she is also deepening her expertise in her own profession. She is acquiring more complex professional knowledge through new professional tasks such as developing prediction models and constructing guidelines for zero emission city logistics. This is where Viola’s epistemic agency and underlying research competencies are needed as they allow her to actively engage in knowledge creation both at the substantive and collaborative level. Engineering education could have prepared Viola for these kinds of situations by taking professional practice and the subsequent tasks and products as a starting point, and by centering education around these specific professional tasks that require particular competencies.

By doing so, it is then important to give explicit attention to the major 'knowledge questions' that arise in those tasks and the methodologies in a profession itself to answer those questions (Greve et al., 2018). Specifically, in educational approaches such as CBL, this means it is important to closely integrate research activities with professional tasks, rather than asking students to first conduct research to develop knowledge and then apply that knowledge. With this many programmes in higher education thus place a one-sided emphasis on the thoroughness of research and maintaining a critical distance from practice, rather than focusing on solving practical problems and students' professional actions *in* and *with* their own professional practices.

Consequently, this often leads to the complaint that students' knowledge creation through research has little value or relevance to the original problem in practice to be solved (Greve et al., 2019). Therefore, the knowledge created should also be connected to daily practice to prevent that interdisciplinarity in working on professional challenges become disconnected from growing into that profession and gaining expertise.

Second, even within CBL the challenge remains how to collectively create knowledge in a meaningful way. In higher engineering education, as well as in other domains, there is a strong focus on knowledge sharing and construction, what (Bereiter & Scardamalia, 2014) refer to as the 'belief mode'. In this mode, students mainly engage in learning activities focusing on evaluating, questioning, accepting or rejecting knowledge

claims and primarily concerned with truth or falsity of ideas and beliefs. Students are stimulated to assess known knowledge or to create knowledge that is deemed necessary to achieve for educational purposes. In contrast, to what Bereiter and Scardamalia describe as a design mode which involves creating and improving ideas and solutions.

However, guiding them towards creating *new* knowledge and fostering innovation remains a challenge (Van Aalst, 2009). Here, CBL appears promising, but it still originates from the educational objectives. Initiatives are therefore evolving, reflected in the emergence of so-called hybrid learning environments like living labs (Zitter & Hoeve, 2012).

In these living labs, providing education to students is not the sole purpose. Instead, societal issues are at its core and students are – together with teachers, researchers and practice partners – working on knowledge creation. These hybrid learning environments, where education, practice, and research converge towards a higher societal goal, are difficult to causally design or shape in advance based on pedagogical-didactic principles (Carvalho & Goodyear, 2018).

More research is needed in these contexts to shed light on, for instance, 1) the development of both individual and shared epistemic agency, 2) ways to achieve this in collaborations between education, research and practice and 3) capabilities of higher education teachers in their new roles, for instance their ability to ask the right epistemic questions and stimulate knowledge creation of students.

Conclusion

In this chapter, we have discussed the importance of developing epistemic agency and related research competencies to enhance the adaptive performance of (future) engineering professionals. We emphasised the importance of knowledge creation in order to be able to foster sufficient domain knowledge and subsequent flexibility in the workplace – both of which are considered imperative for adaptive performance.

In conceptualising epistemic agency, we highlighted the importance of an agentic stance in creating (actionable) knowledge. Research competencies support the fostering of epistemic agency but currently are addressed in higher education with a focus on procedural-technical aspects and the epistemic game of research, rather than the production of knowledge for knowledgeable action in professional contexts.

We stress the importance of embracing versatility in developing research competencies closely connected to professional practice students are educated for – in other words, the right epistemic game should be pursued. Furthermore, new initiatives in which education is strongly connected to both research and practice bring about their own set of challenges.

Circling back to Brice and Viola, this means that Brice should be able to identify where he lacks actionable knowledge in the context of electric engines, striving for creative solutions for this new context

by expanding his actionable knowledge. For Viola, this means that she should be able to determine what knowledge she needs to act professionally in a multidisciplinary team.

The actions of both Brice and Viola accentuate the importance of epistemic agency and underlying research competencies to perform adaptively, which is necessary on all qualification levels. In designing engineering higher education, it is therefore essential to provide students like Brice and Viola with authentic professional tasks that vary in structure, stability and predictability, and to intertwine knowledge creation with these professional tasks, rather than teaching students to do research ‘separately’.

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