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ORIGINAL PAPER

Adaptive Expertise Development during Work-Based Learning in Higher Education: A Realist Review

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Abstract

Higher education institutions are challenged to educate students for an uncertain future. Adaptive expertise (AE) is needed to thrive in an uncertain future: the ability to respond successfully to altered situations and changing circumstances. Work-based learning (WBL) environments would allow students to develop AE. However, knowledge about how WBL contributes to AE development in higher education is scarce. This paper reports on a realist review to understand and explain how, why and in what circumstances WBL leads to AE development. Three narratives illustrate how working in challenging conditions, interacting with others and stimulating a willingness to learn were associated with AE development through WBL as a result of shifts in perspective and thinking. Five work-based learning elements for AE development were identified: integrative challenging contexts, reflective practice, interacting with others, guidance and learner characteristics. Future research should focus on how working in challenging situations, interactions with others and guidance interact to stimulate AE development in different types of WBL environments.

Keywords Adaptive Expertise · Adaptive Performance · Workplace Learning · Higher Education · Realist Review

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Introduction

Rapid societal and technological developments ask professionals to respond successfully to changing circumstances. They need to become adaptive experts that can cope with novel, unfamiliar situations, while at the same time maintaining high levels of performance (Hatano & Inagaki, 1986; Schwartz & Bransford, 2005). Consequently, higher education programmes are challenged to design education that supports adaptive expertise (AE) development and acquaint students with innovative professional practices. Previous studies (Pelgrim et al., 2022; Kua et al., 2021#; Bohle Carbonell et al., 2014#) suggest that being confronted with challenging, ill-structured, real-world problems in safe learning environments supports AE development. In many higher education programmes, learning at an educational institution is combined with learning in the workplace (Kyndt et al., 2021), varying from internships to hybridisation models (Bouw et al., 2019). Work-based learning environments offer opportunities for students to work on challenging, real-world problems and thus have the potential to foster adaptive expertise development. However, despite differences in how learning across work and educational contexts is organised (Perusso & Wagenaar, 2021), the question of how (adaptive) expertise develops as part of work-based learning (WBL) in higher education (HE), and how this is or should be supported remains open.

In an overview article, Ward et al. (2018) presented six principles for promoting AE: flexibility-focused feedback, concept-case coupling, tough case time compression, case-proficiency scaling, complexity preservation and active reflection. Although these principles are sound and promising, they must be translated into concrete learning practices. Further, it is still unclear how learner and context characteristics interact and contribute to AE development in work-based learning contexts and, thus, for whom and in what contexts certain practices are effective. Adaptive expertise has been studied in various contexts and among students and professionals with diverse backgrounds. The current review contributes to creating a foundation for theory development, integrating perspectives across different professional domains and uncovering areas that need more research.

Adaptive Expertise

Expertise is consistent peak performance and can be acquired through deliberate practice (Ericsson et al., 1993) in a particular domain. Experts perform tasks more effectively and efficiently than novices (Ericsson et al., 1993). They refine their professional skills by constantly elaborating on new professional cases (Boshuizen et al., 2020). However, experts might not always be aware of the limitations of the context-specificity of their knowledge (Bohle Carbonell et al., 2014#). High levels of automation and routine expertise may impede creativity and adaptability, leading to functional fixedness (Gube & Lajoie, 2020#; Kua et al., 2021#).

The term adaptive expertise was coined by Hatano and Inagaki in 1986 (Hatano & Inagaki, 1986). AE is recognizing when familiar skills and knowledge are

insufficient for a novel, complex, or uncertain situation and adapting accordingly by innovating or refining one's approach (Hatano & Inagaki, 1986; Schwartz & Bransford, 2005). Adaptive performance is the visible behaviour of adaptive expertise (Pelgrim et al., 2022) and, according to Pelgrim et al. (2022), is regularly considered as an interrelated concept and often used interchangeably with AE. AE involves balancing efficiency and innovation, learning from experience, and expanding one's problem-solving repertoire (Hatano & Inagaki, 1986; Schwartz & Bransford, 2005). AE is a combination of several skills and traits (Bohle Carbonell et al., 2014#). This means that AE consists of different constructs and, thus, is not unambiguous. Changing circumstances that can be new for the professional, the work field, or even society trigger adaptive performance in professionals with AE (Pelgrim et al., 2022). The novelty of the situation forces someone to reassess how and why they apply a particular skill (Bohle Carbonell & van Merrienboer, 2020#; Bohle Carbonell et al., 2014#). In these situations, professionals with AE seek to learn from experience (Barnett & Koslowski, 2002; Chi, 2011), critically reflect on their actions, integrate diverse perspectives, and navigate uncertainty by experimenting with new methods and solutions (Bohle Carbonell & van Merrienboer, 2020#; Kua et al., 2021#; Ward et al., 2018). Confrontation with open-ended, challenging or ill-structured problems in an educational or workplace setting seems to be associated with AE development (Pelgrim et al., 2022).

Adaptive Expertise Development and Work-Based Learning

WBL environments allow students to develop AE by acquainting them with challenging, ill-structured real-world problems. Work-based learning in higher education is an intricate interplay between the educational programme and practice, and should therefore be designed in unison. However, how work-based learning (WBL) is designed varies greatly, from alignment models in which students switch from one context to the other (e.g., dual education programmes); to incorporation models whereby school is brought to the workplace or vice versa, and hybridization models whereby both contexts are merged into one new learning site (Bouw et al., 2019). According to Tynjälä (2008), "integration of formal and informal learning is an essential prerequisite for developing the kinds of expertise needed in response to the changes taking place in working life." (p. 130). Incorporating professional practice into educational programmes steers students' learning activities, eliciting new forms of professional development. However, there is a lack of empirical studies showing *how* students can be supported in developing AE through WBL in higher education programmes (Kua et al., 2021#; Pelgrim et al., 2022).

Realist Review Rationale

Previous reviews (Bohle Carbonell et al., 2014#; Kua et al., 2021#; Pelgrim et al., 2022) primarily focussed on conceptualising AE and identifying AE-related aspects, omitting causal explanations of how and why AE was developed. Further, these earlier reviews did not specifically focus on the relationship between WBL and AE development.

Therefore, a realist review could offer a deeper understanding of what happens during WBL in relation to AE development, as realist reviews are especially suited to synthesizing complex processes (Wong et al., 2013). It helps us to understand and explain how, why, and in what circumstances and contexts complex interventions lead to intended, unintended, desired and undesired outcomes. To understand how outcomes (O) come about, we need to understand the underlying mechanism (M) that connects the context (C) with the outcomes (Pawson et al., 2005). These CMO configurations lie at the heart of the realist approach. In this paper, we conceptualise WBL in its different modes as a complex intervention to stimulate AE. Therefore, the scope of the current study is broad, and we interpreted WBL interventions in various contexts, such as formal learning activities, as contextual factors. Mechanisms are the underpinning generative force that leads to outcomes (Dalkin et al., 2015; Jagosh et al., 2011). In line with Dalkin et al. (2015) and Barry et al. (2019), we define mechanisms as the learners' underlying responses, processes, or manners of reasoning that operate in particular contexts. These mechanisms are usually hidden and not the designable elements of WBL environments (Dalkin et al., 2015). Mechanism-resources refer to what the WBL environment *triggers* among learners. Mechanism-responses refer to the learners' *responses*, all of which suggest a change in learners' minds or actions (Jagosh et al., 2011; Thijssen et al., 2022). We define contextual factors at the individual level (e.g., work experience or prior knowledge) and the environmental level (e.g., workplace characteristics, WBL environment or formal learning activities). The contextual factors are related to pre-existing structures, cultural norms or geographic locations (Jagosh et al., 2015). Outcomes are either intended or unexpected outcomes of WBL in relation to AE development as a result of the learners' responses.

Research Aim and Question

The current study seeks to understand how WBL in higher education contributes to AE development. Our primary research question is: *How, for whom, why and under what circumstances does work-based learning contribute to the development of adaptive expertise?*

In this paper, we describe causal explanations using CMO configurations in one or more middle-range theories to answer our research question. These middle-range theories are more abstract explanations for specific contexts, explaining how categories of factors and activities work in types of contexts, than granular explanations for specific settings, and are used to guide programme theory development (Shearn et al., 2017).

Methods

Study Design

We followed the key steps in a realist review proposed by Rycroft-Malone et al. (2012). We used the RAMESES publication standards for realist syntheses (Wong et al., 2013) for reporting this study.

In line with the iterative realist approach, we (the authors) discussed the results from each step in the current review with three groups: 1) our research team (the authors), 2) our advisory panel (members selected from our network of WBL experts), and 3) the research consortium (representing stakeholders from eleven higher education institutions in the Netherlands). These iterations aimed to progressively focus the breadth and depth of the review, explore different perspectives, and delve deeper into the possible causal explanations within and across different studies. See Fig. 1 below for an overview of our realist review approach.

Stage 1: Clarify the Scope of the Review

To clarify the scope of the review and design an analytical framework, the research team selected, reviewed and discussed several publications about (adaptive) expertise development and WBL (Cangialosi et al., 2020; Cutrer et al., 2018; Harteis & Goller, 2014; Markauskaite & Goodyear, 2017; Sessa et al., 2011; Steenhof, 2020; Trede & Jackson, 2019). Additionally, MG and ME wrote a short theoretical background paper on AE development in relation to WBL to stimulate group discussions within the research team and with the advisory panel. These discussions resulted in the further refinement of the review's scope and led to refining the research question: *how does work-based learning in higher education, either in the workplace or in an authentic, simulated workplace with the student in a professional role, contribute to developing adaptive expertise?*

We decided to include in our search all learners involved in WBL during their training in HE programmes (see our inclusion criteria for a detailed description). In line with the purpose of a realist review, the variations in settings and learners will contribute to gaining insights into working mechanisms in developing AE through WBL.

Development of an Initial Framework

The next step was finding and articulating the initial programme theories (e.g., Wong et al., 2010). Given the complexity of AE and the variety of WBL programmes, we followed a similar approach to those of Mertens et al. (2018) and Walshe and Luker (2010) and developed a broad initial analytical framework instead of one programme theory. We conducted a literature screening and gathered information about conceptualisations of AE and descriptions of WBL contexts from a survey sent to other stakeholders in our national network consisting of practitioners and researchers involved in AE development projects. We discussed the outcomes with our advisory panel to explore how WBL could contribute to AE development in HE.

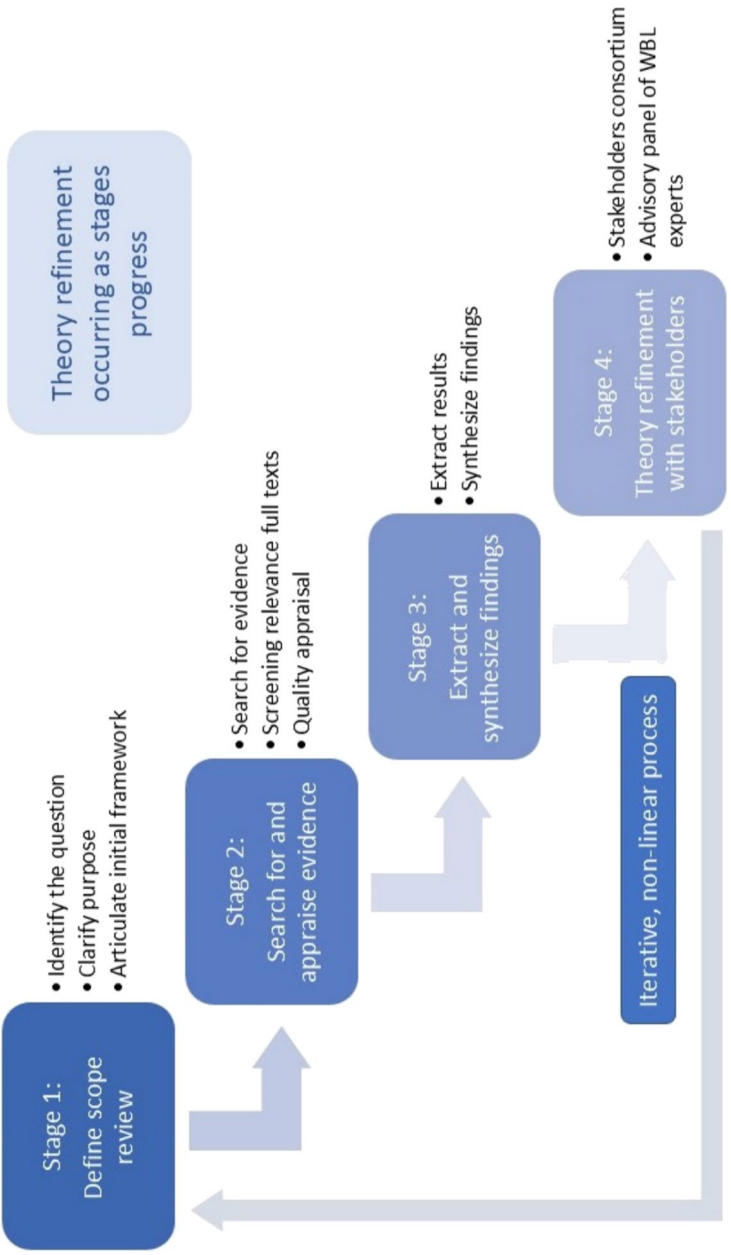

Fig. 1 Overview of the realist review approach (based on Rycroft-Malone et al., 2012)

Furthermore, we selected five key review publications available at the time of this study[1] on (adaptive) expertise development to build our initial framework: 1) Kua et al. (2021#), 2) Bohle Carbonell and Van Merriënboer (2020#), 3) Bohle Carbonell et al. (2014#), 4) Gube and Lajoie (2020#) and 5) Wallin et al. (2019#). We extracted elements related to AE and AE development from the reviews but did not specify the causal relations between those elements.

Our resulting initial framework consisted of five elements and associated sub-elements: 1) meaningful variation and complexity preservation, 2) reflective practice, 3) collaborating, 4) guidance, and 5) learner characteristics. See the first column of Table 1 for the elements and their sub-elements.

Stage 2: Evidence Collection Steps

Search Strategy

We conducted our search on AE and WBL in the following databases: the Web of Science Citation Indexes (Core Collection), Scopus and Education Resources Information Center (ERIC). The initial search took place in March 2021. We searched for English and Dutch language papers only and limited our search from 1986 (marking the publication of the seminal paper by Hatano and Inagaki) to 2021. We conducted a second search on adaptive *performance* and WBL in the same databases in May 2021 based on insights from the review of reviews by Pelgrim et al. (2022), which was performed at the same time as our study and part of the Adapt at Work project. With this second search, we aimed to include papers from the human resource management and human resource development domains missed in our first search by focusing solely on AE. In June 2022, we updated both searches and retrieved additional documents for analysis. See Appendix 1 for the two search strategies.

Inclusion and Exclusion Criteria

Eligible studies were those that included WBL of students enrolled in HE or postgraduates from HE programmes in relation to AE development or adaptive performance, including i) HE bachelor's or master's students, ii) professionals enrolled in a HE professional development programme and iii) professionals working together with HE students in the workplace. Studies included were those that 1) reported WBL, 2) reported outcomes related to AE or concepts related to AE and 3) were based on empirical data or described empirical data. In addition, studies were included that described a simulated workplace or working on simulated authentic tasks that allowed students to experience their professional

[1] To enhance readability, the authors' names and the articles' year of publication have been number-coded (in brackets). In the tables, these numbers are provided together with names and years. In the reference list, the articles which are part of the initial framework are indicated by a hashtag (#) and the review studies by an asterisk (*).

Table 1 Elements of the initial framework related to work-based learning and adaptive expertise development

Elements of work-based learning for AE development[a]	Studies included in the initial framework [1–5]	Studies included in the search [6–15]
Meaningful variation and complexity preservation		
Context of work	[1] Kua et al. (2021[#])	[6] Kawamura et al. (2020[*])
	[2] Bohle Carbonell and Van Merriënboer (2020[#])	[7] Baldinger & Munson (2020[*])
	[3] Bohle Carbonell et al. (2014[#])	[9] Langdon (2017[*])
	[4] Gube and Lajoie (2020[#])	[10] Van den Berg & Schulze (2014[*])
	[5] Wallin et al. (2019[#])	[12] Stutsky & Spence Laschinger (1995[*])
		[14] Regan et al. (2022[*])
		[15] Grunefeld et al. (2022[*])
Connecting formal and informal learning	[1] Kua et al. (2021[#])	[7] Baldinger & Munson (2020[*])
	[2] Bohle Carbonell and Van Merriënboer (2020[#])	[8] Gallo-Fox & Stegeman (2019[*])
		[9] Langdon (2017[*])
		[10] Van den Berg & Schulze (2014[*])
		[11] Drewery et al. (2016[*])
		[13] Hains-Wesson & Ji (2021[*])
		[14] Regan et al. (2022[*])
		[15] Grunefeld et al. (2022[*])
Reflective practice		
Reflecting on experiences and errors	[1] Kua et al. (2021[#])	[6] Kawamura et al. (2020[*])
	[2] Bohle Carbonell and Van Merriënboer (2020[#])	[8] Gallo-Fox & Stegeman (2019[*])
	[3] Bohle Carbonell et al. (2014[#])	[10] Van den Berg & Schulze (2014[*])
	[4] Gube and Lajoie (2020[#])	[13] Hains-Wesson & Ji (2021[*])
	[5] Wallin et al. (2019[#])	[14] Regan et al. (2022[*])
		[15] Grunefeld et al. (2022[*])
Promoting reflective practice	[1] Kua et al. (2021[#])	[9] Langdon (2017[*])
Refining and constructing mental models	[5] Wallin et al. (2019[#])	[6] Kawamura et al. (2020[*])
		[7] Baldinger & Munson (2020[*])
		[8] Gallo-Fox & Stegeman (2019[*])
		[9] Langdon (2017[*])
		[10] Van den Berg & Schulze (2014[*])
		[14] Regan et al. (2022[*])
		[15] Grunefeld et al. (2022[*])

Table 1 (continued)

Elements of work-based learning for AE development[a]	Studies included in the initial framework [1–5]	Studies included in the search [6–15]
Collaborating		
Organisation of collaboration	[5] Wallin et al. (2019[#])	[6] Kawamura et al. (2020[*])
		[7] Baldinger & Munson (2020[*])
		[12] Stutsky & Spence Laschinger (1995[*])
		[13] Hains-Wesson & Ji (2021[*])
		[14] Regan et al. (2022[*])
Learning from each other	[1] Kua et al. (2021[#])	[6] Kawamura et al. (2020[*])
	[5] Wallin et al. (2019[#])	[7] Baldinger & Munson (2020[*])
		[8] Gallo-Fox & Stegeman (2019[*])
		[11] Drewery et al. (2016[*])
		[15] Grunefeld et al. (2022[*])
Perspective making and taking	[5] Wallin et al. (2019[#])	[7] Baldinger & Munson (2020[*])
Guidance		
Responsive guiding	[1] Kua et al. (2021[#])	[6] Kawamura et al. (2020[*])
	[2] Bohle Carbonell and Van Merriënboer (2020[#])	[7] Baldinger & Munson (2020[*])
	[3] Bohle Carbonell et al. (2014[#])	[8] Gallo-Fox & Stegeman (2019[*])
	[4] Gube and Lajoie (2020[#])	[12] Stutsky & Spence Laschinger (1995[*])
	[5] Wallin et al. (2019[#])	
Guiding discovery learning	[1] Kua et al. (2021[#])	
	[4] Gube and Lajoie (2020[#])	
Promoting contextualisation	[1] Kua et al. (2021[#])	
	[4] Gube and Lajoie (2020[#])	
	[5] Wallin et al. (2019[#])	
Supportive work climate	[3] Bohle Carbonell et al. (2014[#])	[14] Regan et al. (2022[*])
	[4] Gube and Lajoie (2020[#])	[15] Grunefeld et al. (2022[*])
Broadening beliefs about learning	[3] Bohle Carbonell et al. (2014[#])	
	[4] Gube and Lajoie (2020[#])	
Stimulating creativity	[4] Gube and Lajoie (2020[#])	

Table 1 (continued)

Elements of work-based learning for AE development[a]	Studies included in the initial framework [1–5]	Studies included in the search [6–15]
Learner characteristics		
Knowledge and skills	[1] Kua et al. (2021[#])	[9] Langdon (2017[*])
	[2] Bohle Carbonell and Van Merriënboer (2020[#])	[10] Van den Berg & Schulze (2014[*])
	[3] Bohle Carbonell et al. (2014[#])	[11] Drewery et al. (2016[*])
	[4] Gube and Lajoie (2020[#])	[13] Hains-Wesson & Ji (2021[*])
		[14] Regan et al. (2022[*])
		[15] Grunefeld et al. (2022[*])
Attitude	[2] Bohle Carbonell and Van Merriënboer (2020[#])	[6] Kawamura et al. (2020[*])
	[4] Gube and Lajoie (2020[#])	[9] Langdon (2017[*])
		[10] Van den Berg & Schulze (2014[*])
		[11] Drewery et al. (2016[*])
		[13] Hains-Wesson & Ji (2021[*])
		[14] Regan et al. (2022[*])
Extent of past experiences	[3] Bohle Carbonell et al. (2014[#])	[7] Baldinger & Munson (2020[*])
		[8] Gallo-Fox & Stegeman (2019[*])
		[9] Langdon (2017[*])
		[10] Van den Berg & Schulze (2014[*])

[a]The first column describes the elements and sub-elements of WBL for AE development. The second column describes which elements and sub-elements were extracted from the studies included in the initial framework. The third column describes for which elements we found empirical evidence in the studies included in the search

role, professional autonomy and accountability. Studies were considered for inclusion if they met the inclusion criteria for setting, learn-work context, outcomes and empirical data. All types of study designs were eligible for inclusion. We excluded document types that did not describe empirical data, such as review studies, opinion articles or descriptions of educational products (e.g., a leaflet or website). See Appendix 2 for a detailed specification of the inclusion and exclusion criteria.

Title and Abstract Screening

A subset of 21 titles and abstracts from the initial search performed in May 2021, i.e., three studies from each 5-year period from 1986–2021, were used to test and refine the exclusion and inclusion criteria and calibrate the reviewers' decisions. All research team members were trained and independently reviewed the titles and abstracts of the identified

studies to determine their eligibility for inclusion in the review. If a reviewer had doubts about including a document, a second reviewer was consulted and consensus was reached based on discussion if necessary. Sometimes, the two reviewers could not reach a consensus, and a third reviewer was consulted. We used Endnote (https://endnote.com/) as a reference manager and Rayyan (https://www.rayyan.ai/) to screen and assess papers.

Quality Appraisal

After title and abstract screening, full-texts were screened and inclusion for further data extraction and analysis was determined based on the findings' relevance for contributing to theory development, testing and refinement. The documents included for further analysis were appraised for relevance and rigour, according to the criteria described by Pawson et al. (2003); see Appendix 3. In contrast with other review procedures, methodological rigour was not used as a criterion to exclude studies. Instead, two research team members discussed the relevance, i.e., whether a study contributes to theory development, and rigour, i.e., whether the method used is credible and trustworthy, of each included full-text and together made a ranking of the included documents. This ranking was used in building chains of inference (see Stage 3).

Stage 3: Data Extraction and Synthesis

Data Extraction

Two research team members prepared a data extraction protocol based on the elements identified in the initial framework and CMO configurations. The protocol was tested on two documents and further refined (see Appendix 4 for the codebook). Other team members were trained before the start of data extraction to discuss the procedure, practice with data extraction and calibrate reviewer decisions. These training sessions established an understanding of CMO, how to use the data extraction form, and the annotation and note-taking methods.

Pairs of reviewers were assigned to each full text and conducted the data extraction using ATLAS.ti and an Excel spreadsheet. We resolved discrepancies through review team discussions. Data were extracted as follows: the first and second coders independently coded text fragments related to the research question, discussed the coding and established the final coding at a consensus meeting. Next, the first coder summarised the information in the data extraction form containing general information about the document and extracted one or more CMOs where possible. We only retrieved partial CMO configurations from some studies, as the documents often did not make explicit links between context, mechanisms and outcomes. Also, the first coder made one or more CMO visualisations. The second coder checked the interpretation of the information in the data extraction form and visualisations and proposed adjustments if necessary.

Evidence Synthesis Steps

Data synthesis aims to develop and refine the initial framework for "what works" in AE development during WBL, for whom and why. We interpreted this step of the review process as a method driven by the previously formulated initial framework, aimed at understanding causation, how mechanisms lead to outcomes, and how mechanisms are shaped by the social and institutional context (education, public and private bodies) (cf. Wong et al., 2013). Following Wong et al., we looked for recurrent patterns of contexts and outcomes in the review data and the mechanisms that plausibly explain these outcomes. The reasoning process was structured around the following activities performed independently by the first two authors:

1. Constant comparison of identified context factors, mechanisms (resources and responses) and outcomes resulted in identifying common elements.
2. Build chains of inference, i.e., connections between identified elements, based on the separate CMOs for each document.
3. Constant comparison of identified elements and chains of inference from each document, starting with the document ranked highest for relevance and rigour.

These activities were part of an iterative, retroductive process. The results were refined based on 1) calibration sessions between the first two authors, 2) a discussion of preliminary results with the entire research team, and 3) a comparison with elements from the initial framework. Through retroductive reasoning (Mukumbang, 2023) narratives were constructed to infer the hidden causal relationships and pathways and to refine the initial framework. The initial framework and search studies suggested several potential mechanisms, and we used inductive and deductive logic as well as insights or hunches to best explain the outcomes.

Stage 4: Validation of Findings

In the final stage of the review, we presented the results to the stakeholders from the research consortium during a meeting of the Adapt at Work research project and to our advisory panel. Thus, we received input for synthesizing the data and, at the same time, introduced reasoning in causal chains as part of the realist approach. This resulted in refining our CMO configurations and narratives.

Results

We first describe the studies included in our review. Second, we use CMO configurations from the individual studies to illustrate which contextual factors and mechanisms are associated with our primary outcome, i.e., AE development. Also, we separately describe the different conceptualisations of AE development found. Third, we compare the CMO configurations from the included studies to the elements

identified in our initial framework to show which elements are supported by empirical evidence from our review studies. This allowed us to reinterpret the elements of the initial framework in CMO terms. Finally, we used an evidence-inspired, retroductive approach to integrate the evidence into three narratives and describe the relationships between the contextual factors, mechanisms and outcomes we identified in our review studies to refine our initial framework.

Description of the Studies Included

The initial database searches in 2021 led to 2,816 published English language papers (search AE: 2,668; search AP: 148). After removing duplicates, the titles and abstracts of 2,051 (search AE: 1943; search AP: 108) papers were screened based on the inclusion and exclusion criteria. In June 2022, we updated the original searches, resulting in an additional 774 papers retrieved. After removing duplicates and screening titles and abstracts, the full texts of 8 papers of the 774 papers were identified in the updated search in 2022, of which 3 papers were included, resulting in 10 papers for the final analysis. The flow chart in Fig. 2 illustrates the search results from searches AE (adaptive expertise) and AP (adaptive performance) as well as the updated search in June 2022. As the review progressed, we focussed on peer-reviewed journal publications and excluded dissertations, grey literature and book chapters, among others.

Of the ten papers included for data extraction, analysis and synthesis, six were observational or interview studies, two were studies that analysed written narratives or essays, and two were survey studies. In three studies, multiple methods for data collection were used. All conceptualisations of AE of the included studies were in line with our definition of AE. See Table 2 for an overview of the included studies, their characteristics and theoretical conceptualisations of AE.

Operationalisations of Adaptive Expertise

The construct AE was operationalised in different ways in the included papers. In four papers, AE was only measured at a general level, as an overarching construct or composite measure (Gallo-Fox & Stegeman 2019*; Drewery et al. 2016*; Stutsky & Spence Laschinger 1995*; Grunefeld et al. 2022*). In three papers, AE was measured at a general level and specific aspects of AE (development) were measured (Baldinger & Munson 2020*; Van den Berg & Schulze 2014*; Regan et al. 2022*). In three papers, only specific aspects of AE (development) were measured (Kawamura et al. 2020*; Langdon 2017*; Hains-Wesson & Ji 2021*). The studies we included did not cover the whole construct but mostly elements of it. Notably, in one study, AE development was implied by the researchers rather than observed (Gallo-Fox & Stegeman 2019*) and in another AE development was linked to professional identity development (Van den Berg & Schulze 2014*).

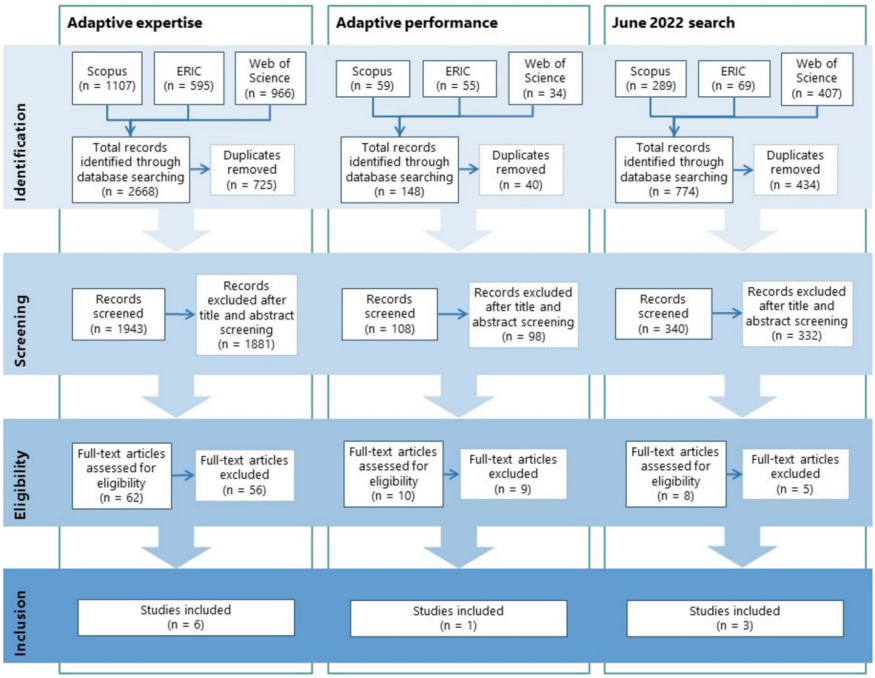

Fig. 2 Publication PRISMA flow diagram

Adaptive Expertise as an Overarching Construct

In seven studies, AE was considered an overarching, single construct (Baldinger & Munson 2020*; Gallo-Fox & Stegeman 2019*; Van den Berg & Schulze 2014*; Regan et al. 2022*; Grunefeld et al. 2022*) or a composite score constructed from a set of questionnaire items (Drewery et al. 2016*; Stutsky & Spence Laschinger 1995*). For example, in the Baldinger and Munson study (Boshuizen et al. 2020), adapting current ways of working and transforming knowledge into ideas for new ways of working was indicative of AE. In the study by Drewery (Drewery et al. 2016*), AE was conceptualised as adaptive performance, i.e., "the extent to which an individual can deal with uncertain work situations" (p. 301).

In one study (Van den Berg & Schulze 2014*), AE development was linked to professional identity development and included shaping identities. Van den Berg and Schulze (Van den Berg & Schulze 2014*) explain that "Adaptive expertise enables teachers to apply knowledge to new problems and develop innovative ways of solving these problems. This, in turn, influences their identities as teachers who can adapt to educational reform." (p. 72).

Table 2 Included papers and their characteristics

Author(s), year and country	Study design	Participants	Characteristics of the work-based learning environment	Conceptualisation of adaptive expertise
Adaptive expertise				
[6] Kawamura et al., 2020*, USA	Constructive grounded theory study using observations and semi-structured interviews	Ten paediatric subspecialty residents in their final years	On-the-job training in a clinical setting where residents predominantly work independently with minimal supervision. They receive indirect feedback from patients and parents, and are encouraged to practice new approaches	Flexible and innovative use of knowledge (Hatano & Inagaki, 1986). Balance between procedural fluency and innovation, based on conceptual understanding
[7] Baldinger & Munson, 2020*, USA	Observational study following a holistic coding approach and systematic observation of discourse patterns and features	Twenty-two in-service secondary mathematics teachers	Teacher educator-led rehearsals were a focal teacher education strategy in a professional development fellowship at a summer institute. Cases in the rehearsals were high-quality mathematical tasks from a problem bank. The in-service teachers were each other's students during the rehearsals. Debrief discussions after the rehearsals provided opportunities for collective sense-making	Balancing efficiency with innovation, where the mastery of procedures is coupled with the capacity to question, modify, and invent ways of addressing multifaceted and non-routine problems (Hatano & Inagaki, 1986; Schwartz & Bransford, 2005). Adaptive expertise is characterised by both the ways people approach a domain and the kind of reasoning they engage in within it

Table 2 (continued)

Author(s), year and country	Study design	Participants	Characteristics of the work-based learning environment	Conceptualisation of adaptive expertise
[8] Gallo-Fox & Stegeman, 2019*, USA	Observational study using an a priori coding scheme and within-case and cross-case analyses	Six coteaching dyads consisting of an early childhood education teacher candidate and a clinical educator	Students complete two nine-week full-time practicum placements. A collaborative teaching model for teacher learning was used during these placements: coteaching. Coteaching places teacher candidates alongside clinical educators to support learning to teach through mutual practice, explication of thinking and decision-making, and shared reflection	Teachers with adaptive teaching expertise are responsive to the diverse needs of children and the local context. Adaptive practice occurs when teachers plan instruction with clear rationales, teach, reflect upon their work, anticipate future action, consider alternative approaches and make necessary adjustments

Table 2 (continued)

Author(s), year and country	Study design	Participants	Characteristics of the work-based learning environment	Conceptualisation of adaptive expertise
[9] Langdon, 2017*, New Zealand	Action research study including document analysis, field notes, taped individual interviews, focus group interviews and transcribed professional conversations	Two mentor teachers	An action research project by each mentor as part of a two-year professional development programme. This included 11 inquiry cycles whereby identification of a practical problem, critical discourse, goal setting, strategic action, observation, data collection, reflection and a revised practical problem were undertaken	Balance between efficiency and adaptive-oriented approaches to learning (Bransford et al., 2005). Movement beyond routine practice towards continuous collaborative engagement in inquiry and theorising, in order to develop responsive, flexible, evidence-informed ways of building and strengthening practice (Timperley, 2011). Moving in and out of routine practice towards adaptive modes of inquiry learning also requires a sense of self and professional agency to continually ask questions to improve learning for all
[10] Van den Berg & Schulze, 2014*, South Africa	Narrative research approach using written autobiographical field texts of experiences at school, at college or university, and as teachers. Four narratives were purposively sampled that had considerable richness and depth	Four practicing teachers with 9 to 26 years of experience as teachers	An Honours programme consisted of five modules of which one module focuses on teaching and learning	Adaptive expertise involves habits of mind, attitudes, and ways of thinking and organizing one's knowledge that are different from routine expertise and that take time to develop. Balance innovation and efficiency (Schwartz & Bransford, 2005)

Table 2 (continued)

Author(s), year and country	Study design	Participants	Characteristics of the work-based learning environment	Conceptualisation of adaptive expertise
[12] Stutsky & Spence Laschinger, 1995*, Canada	An exploratory pre-post comparison questionnaire study	37 fourth-year bachelor nursing students	A preceptorship programme, based on experiential learning theory (Kolb), helps to prepare student nurses to assume their future responsibilities in the 'real world'	Adaptive competencies are the 'congruences between personal skills and task demands' (Kolb, 1984)
Adaptive performance				
[11] Drewery et al., 2016*, Canada	Cross-sectional survey study	1698 university undergraduates	Cooperative education (co-op) programme: co-op students alternate between periods of paid employment and academic study, typically lasting four months long. Cooperative education is a form of work-integrated learning (WIL) for university students	Adaptive performance refers to the extent to which an individual can deal with uncertain work situations, such as emergencies and other stressors (Pulakos et al., 2000). Adapting requires employees to go beyond their normal duties, such as learning new tasks, and handling emergencies, which happen frequently in many organisations (Pulakos et al., 2006)
Search June 2022				
[13] Hains-Wesson & Ji, 2021*, Australia	Case study with mixed methods approach including surveys and focus group interviews	114 university undergraduates	A university-wide short-term, face-to-face, work-integrated learning (WIL) interdisciplinary mobility program	Interdisciplinary skills, including adaptability and flexibility, related to transcending the divide between academic learning, its production, and the use of knowledge outside of a discipline or specific academy, co-creating new knowledge

Table 2 (continued)

Author(s), year and country	Study design	Participants	Characteristics of the work-based learning environment	Conceptualisation of adaptive expertise
[14] Regan et al., 2022*, USA	Focus groups with constant comparison analysis	38 subspecialty residents who demonstrated key attributes of master adaptive learners	On-the-job training in university-based medical centres	Adaptive experts transfer their existing knowledge to solve uncommon or new problems (Hatano & Inagaki, 1986) and those who develop adaptive expertise are primed to be effective lifelong learners
[15] Grunefeld et al., 2022*, The Netherlands	A one-group pre-test post-test design with mixed methods. An instrument to capture adaptive expertise using an authentic and representative task was used and a semi-structured interview	Three mid-level academic educational leaders who excelled on an authentic and representative task in the domain of curriculum design and planning educational change	A professional development program focused on leading educational change. Each participant leads a complex, novel-to-them educational change project in their own department or faculty	To perform well, these professionals need to be able to adapt to changing circumstances and demands (Hatano & Inagaki, 1986). Adaptive expertise allows for easily overcoming novelty and quickly regain a high level of performance

Aspects of Adaptive Expertise Development

Adaptive expertise development was observed at the individual level in most studies. Outcomes differed between studies and in six studies AE development was operationalised as consisting of multiple aspects (Kawamura et al. 2020*; Baldinger & Munson 2020*; Langdon 2017*; Van den Berg & Schulze 2014*; Hains-Wesson & Ji 2021*; Regan et al. 2022*).

In three studies, AE development included *integrating new and existing knowledge* (Kawamura et al. 2020*; Langdon 2017*; Regan et al. 2022*). Kawamura et al. (2020*) described how residents' medical knowledge is situated in a context and how residents integrated this contextual knowledge into their existing medical knowledge. Langdon (2017*) explained that a teacher mentor integrated theoretical and practical knowledge about mentoring beginning teachers. Regan et al. (2022*) explained how residents had more effective retrieval of foundational knowledge.

In three studies, AE development was described as *adapting current ways of working* (Baldinger & Munson 2020*; Langdon 2017*; Hains-Wesson & Ji 2021*). Baldinger and Munson (Boshuizen et al. 2020) illustrated that during group discussions among in-service teachers, strategies and rationales for tailoring a routine approach were suggested. Langdon (2017*) described how a teacher mentor incorporated new, emerging ideas about mentoring practice into her existing perceptions of mentoring practice. Hains-Wesson and Ji (2021) described that higher education students learned to be flexible, open and able to adapt to working in interdisciplinary teams and with industry partners. Baldinger and Munson (2020*) and Langdon (2017*) also described how knowledge was *transformed into ideas about how to perform tasks in new ways* and Kawamura et al. (2020*) showed that this *transformation of knowledge resulted in new ways of working*. In the Baldinger and Munson study (Baldinger & Munson 2020*), learners observing in-service teachers who rehearsed classroom situations collectively co-constructed new ideas around teaching. In contrast, in the Kawamura et al. study (2020*), learners changed the way they performed a particular task. Paediatric physicians-in-training learned to integrate routine efficiencies with flexible approaches and showed new ways to navigate difficult situations.

Developing lifelong learning skills (Langdon 2017*; Regan et al. 2022*) and *performing lifelong learning activities* (Van den Berg & Schulze 2014*)were reported as part of AE development. In the Langdon study (Langdon 2017*), the teacher mentor developed a trifocal approach to mentoring by viewing herself as a learner, similar to the teachers she mentored and students. Regan et al. (2022*) found that residents developed personal learning skills. In the Van den Berg and Schulze study (Van den Berg & Schulze 2014*), performing lifelong learning activities (such as actively seeking feedback from others) was considered part of becoming an adaptive expert.

Comparison of the Initial Theoretical Framework with Results of the Review

The work-based learning elements for developing AE were described in co-existence and relation to each study. CMO configurations were constructed for each study (see Appendix 5) and are referred to when describing the elements of the initial framework

(see Table 1 for the initial framework). We identified similarities and differences when comparing the data extracted from the search studies with the initial framework.

Meaningful Variation and Complexity Preservation

All five studies (Kua et al. 2021[#]; Bohle Carbonell and Van Merriënboer 2020[#]; Bohle Carbonell et al. 2014[#]; Gube and Lajoie 2020[#]; Wallin et al. 2019[#]) from the initial framework highlighted the importance of exposing students to varying situations while preserving complexity (Table 1). Adding variation, exposing students to unfamiliar and risk-full situations, and solving non-routine problems that allow students to make mistakes and stretch their competence stimulated AE development. The search studies did not confirm nor refute that adding variation to work situations stimulates AE development. Intentionally confronting students with complex problems (high-quality problems) was investigated twice in the search studies (Baldinger & Munson 2020[*]; Grunefeld et al. 2022[*]). Most search studies (Kawamura et al. 2020[*]; Baldinger & Munson 2020[*]; Langdon 2017[*]; Van den Berg & Schulze 2014[*]; Stutsky & Spence Laschinger 1995[*]; Regan et al. 2022[*]; Grunefeld et al. 2022[*]) did indicate, however, that an authentic work context contributed to AE development by participating in challenging work (Van den Berg & Schulze 2014[*]; Regan et al. 2022[*]), working in complex situations (Baldinger & Munson 2020[*]) and participating in daily work as usual (Stutsky & Spence Laschinger 1995[*]).

In both initial framework and search studies, connecting formal and informal learning was related to AE development. Intermix training (Bohle Carbonell & Van Merriënboer 2020[#]) (work on learning tasks is intermixed with part-task practice, that is, practicing routines) and participating in scholarly activities (Kua et al. 2021[#]) were mentioned in the initial framework. Search studies included specific programmes, such as a co-op programme (Drewery et al. 2016[*]), a short-term mobility programme (Hains-Wesson & Ji 2021[*]), workshops for learning knowledge and skills (Gallo-Fox & Stegeman 2019[*]; Langdon 2017[*]; Van den Berg & Schulze 2014[*]), an educational leadership programme (Grunefeld et al. 2022[*]), a professional development fellowship programme (Baldinger & Munson 2020[*]) and an induction programme (Langdon 2017[*]), which were related to AE development. In the Regan et al. study (Regan et al. 2022[*]), healthcare professionals in training had review sessions with peers and teacher training sessions that contributed to AE development.

Reflective Practice

All the initial framework and search studies included information about how reflecting on experiences and errors stimulated AE development. Search studies (Kawamura et al. 2020[*]; Gallo-Fox & Stegeman 2019[*]; Van den Berg & Schulze 2014[*]; Hains-Wesson & Ji 2021[*]; Regan et al. 2022[*]; Grunefeld et al. 2022[*]) confirmed the findings of the initial framework, which stated that experiences and mistakes made while working should be reflected upon critically (Kua et al. 2021[#]; Bohle Carbonell and Van Merriënboer 2020[#]; Bohle Carbonell et al. 2014[#]; Gube and Lajoie 2020[#];

Wallin et al. 2019[#]). In one search study (Kawamura et al. 2020[*]), experimenting with new approaches was linked to making missteps and reflecting on those missteps. Another study from the search (Van den Berg & Schulze 2014[*]) showed how reflecting on one's own past experiences resulted in reinterpreting those experiences and learning new lessons from them. In the initial framework, deliberate practice (goal-oriented training with feedback) was mentioned as a mechanism for developing AE (Kua et al. 2021[#]; Bohle Carbonell and Van Merriënboer 2020[#]; Wallin et al. 2019[#]). In contrast, search studies did not mention deliberate practice at all, neither directly nor indirectly.

One initial framework and one search study suggested interventions to stimulate reflection for developing AE. In the initial framework, these interventions were reflective inquiry with reflective prompt protocols, reflective diaries, and self-assessment coupled with timely and specific external feedback (Kua et al. 2021[#]). The search study added interventions for reflective practice with the cyclical inquiry with the help of reflective diaries, self-reflective inquiry, analysing evidence, workshops aimed at conceptual understanding, changing ideas, and promoting a learning climate where reflection and questioning are the norm (Langdon 2017[*]).

Most noticeably, in addition to one of the studies in the initial framework (Wallin et al. 2019[#]), the search studies showed new insights into how learners *refine and reconstruct* mental models during WBL, which was described as promoting epistemic processes to help identify flaws in mental models and help develop flexible imagining. Learners had to switch their perspectives during the work task (Kawamura et al. 2020[*]; Baldinger & Munson 2020[*]; Gallo-Fox & Stegeman 2019[*]; Langdon 2017[*]; Van den Berg & Schulze 2014[*]; Regan et al. 2022[*]; Grunefeld et al. 2022[*]). In the Kawamura et al. study (Kawamura et al. 2020[*]), this was explained as a "shift" in thinking (Kawamura et al. 2020[*]): the situation required learners to switch their perspectives during the conversations with families and patients, which is a "shift" that characterises the flexible approaches of residents developing effective communication skills (Kawamura et al. 2020[*]). In the Regan et al. study (Regan et al. 2022[*]), residents exposed to specific case experiences developed and used mental schemata to organise foundational content necessary for clinical decision-making.

Collaborating

Studies from the initial framework and the search connected learning in interactions with others, specifically through collaborating, to developing AE. However, initial framework studies described conditions for collaborating while the search studies also presented how collaborating promoted AE learning processes. One study from the initial framework (Kua et al. 2021[#]) stated that AE development started in practice during co-construction and co-designing, specifically in the planning phase, where a surprise is identified as novel and which the learner can use as a learning opportunity. Conditions for developing AE were critical dialogue, discussions and conversations (Kua et al. 2021[#]; Wallin et al. 2019[#]) while retaining university and workplace perspectives (Wallin et al. 2019[#]). This should happen in safe learning environments (Kua et al. 2021[#]) where professionals are challenged to solve problems collectively (Wallin et al. 2019[#]).

Search studies showed collaborations between learners and preceptors (Stutsky & Spence Laschinger 1995*; Regan et al. 2022*), consultations with colleagues (Kawamura et al. 2020*) and interactions in rehearsal or peer groups (Baldinger & Munson 2020*; Hains-Wesson & Ji 2021*; Grunefeld et al. 2022*). Collaborative affordances were equitable participation (Baldinger & Munson 2020*), collaborative responsibility (Gallo-Fox & Stegeman 2019*), inviting another to share ideas (Gallo-Fox & Stegeman 2019*), moving in and out of different professional roles (Baldinger & Munson 2020*; Gallo-Fox & Stegeman 2019*), and social acceptance and integration in the workplace (Drewery et al. 2016*). Processes of learning from each other were seen in interactions (Baldinger & Munson 2020*; Gallo-Fox & Stegeman 2019*; Grunefeld et al. 2022*), through the preparation of work with others (Kawamura et al. 2020*), sharing ideas and changes (Baldinger & Munson 2020*), and during collaborative problem-solving (Baldinger & Munson 2020*). The processes and affordances triggered understanding a problem from different perspectives (perspective making and taking), changing perspectives (Baldinger & Munson 2020*) and using important theory, methods and/or examples from other participants (Grunefeld et al. 2022*).

Guidance

Overall, it is worth noting that guidance was a more prominent element for developing AE in the initial framework compared to the search studies. The studies in the initial framework described guidance coming from various persons, such as a mentor (Kua et al. 2021#; Wallin et al. 2019#), a supervisor (Bohle Carbonell et al. 2014#), and/or peers (Bohle Carbonell et al. 2014#), and described more elaborately how they responded to a learner's learning experience by, for example, providing feedback in response to an experience (Bohle Carbonell and Van Merriënboer 2020#), promoting inquiry-based learning through hypothesis testing and problem-solving guidance (Kua et al. 2021#), providing opportunities for choice and discovery (Gube and Lajoie 2020#), supporting students when they fail and showing them ways to learn from their mistakes (Gube and Lajoie 2020#), and encouraging students to take sensible risks and act independently (Gube and Lajoie 2020#). The initial framework also promoted supporting contextualization by helping learners to transform theoretical knowledge into practice (Wallin et al. 2019#), facilitating the integration of conceptual ideas with existing knowledge (Kua et al. 2021#), connecting formal and informal learning (Wallin et al. 2019#), and playing with concepts to infer patterns through inductive learning (active learning) (Gube and Lajoie 2020#). In addition, a safe learning climate through supportive superiors and peers was encouraged (Bohle Carbonell et al. 2014#; Gube and Lajoie 2020#) and students' creativity was stimulated by providing opportunities for students to use their imagination while learning (Gube and Lajoie 2020#) and working with a more game-like or playful approach (Gube and Lajoie 2020#). To conclude, the initial framework indicated that guiding AE development requires the professional/supervisor to broaden their beliefs regarding learning and to have an eye for transformational teaching (Gube and Lajoie 2020#), demonstrate a belief that teachers should go beyond imparting

simplistic and factual knowledge (Gube and Lajoie 2020[#]), refrain from premature assessment of students' ideas (Gube and Lajoie 2020[#]) and encourage guiding professionals/supervisors to take on new tasks outside of their current job descriptions (Bohle Carbonell et al. 2014[#]).

In the studies from the search, we found that mentoring and guiding debriefings were conducive to developing AE during WBL and that a guiding professional/supervisor functions as a resource and model for learners (Kawamura et al. 2020[*]; Stutsky & Spence Laschinger 1995[*]; Regan et al. 2022[*]) or as a facilitator who stimulates reflective discussions (Baldinger & Munson 2020[*]). In addition, two studies showed how a supportive work climate stimulated AE development (Regan et al. 2022[*]; Grunefeld et al. 2022[*]). In the Grunefeld et al. study (Grunefeld et al. 2022[*]), it appeared that working with a supervisor who supported innovative projects was especially important. In the Regan et al. study (Regan et al. 2022[*]) entrustment by a senior team member empowered residents' profound awareness of responsibility.

Learner Characteristics

The initial framework suggested that pre-existing domain knowledge (Bohle Carbonell et al. 2014[#]) and metacognitive capabilities were relevant for developing AE, such as the ability to adopt innovative approaches towards atypical or novel cases (Kua et al. 2021[#]), analogical problem solving and abstract reasoning (Bohle Carbonell et al. 2014[#]), relating and synthesizing knowledge, connecting, collaborating, communicating clearly, reflecting, having cognitive flexibility (Gube and Lajoie 2020[#]) and regulation processes (Bohle Carbonell et al. 2014[#]). Metacognitive capabilities such as problem-solving, self-efficacy, cognitive flexibility, integrating theory and innovation were also mentioned in search studies (Langdon 2017[*]; Van den Berg & Schulze 2014[*]; Drewery et al. 2016[*]; Hains-Wesson & Ji 2021[*]; Regan et al. 2022[*]; Grunefeld et al. 2022[*]).

In addition, it seems that specific learner attitudes were important for AE development. In the initial framework, this was described by high intrinsic motivation (Gube and Lajoie 2020[#]), humility (Gube and Lajoie 2020[#]), embracing complexity (Gube and Lajoie 2020[#]), openness to multiple perspectives (Gube and Lajoie 2020[#]) and excitement about novelty (Gube and Lajoie 2020[#]). In the search studies, this was described as an open and responsive attitude (Kawamura et al. 2020[*]), showing commitment (Langdon 2017[*]), being innovative (Van den Berg & Schulze 2014[*]), feeling challenged (Hains-Wesson & Ji 2021[*]), taking ownership (Regan et al. 2022[*]) and having confidence (Langdon 2017[*]; Drewery et al. 2016[*]). In both the initial framework (Bohle Carbonell and Van Merriënboer 2020[#]; Gube and Lajoie 2020[#]) and search studies (Langdon 2017[*]; Van den Berg & Schulze 2014[*]; Drewery et al. 2016[*]), positive attitudes and mindsets towards learning were related to AE development. The Van den Berg and Schulze study (Van den Berg & Schulze 2014[*]) made this specific by expressing learning intentions and engaging in lifelong learning activities.

Lastly, the initial framework stated that having past work experiences helps learners to deal with unpredictable situations (Bohle Carbonell et al. 2014[#]) for AE development, which was confirmed by search studies (Baldinger & Munson 2020[*]; Gallo-Fox & Stegeman 2019[*]; Langdon 2017[*]; Van den Berg & Schulze 2014[*]). One study from the search related being competent (Langdon 2017[*]) to AE development, while the Drewery et al. study (Drewery et al. 2016[*]) found that no previous relevant work experience or excellent academic score is necessary for developing AE during WBL.

Narrative Synthesis

Following an evidence-inspired, retroductive approach, we integrated evidence from the search studies with our insights into narratives. In these narratives, we infer the possible relationships between the pieces of evidence. The narratives illustrate how the elements identified in the initial framework and the factors identified in the search studies stimulate AE development. A shift in thinking was identified as a recurring mechanism in most of the search studies. The three narratives are described below and visualised in Figs. 3, 4 and 5. When we refer to specific CMOs, these can be found in Appendix 5.

Narrative 1: Working in Challenging Conditions

This narrative was based on six studies (Kawamura et al. 2020[*]; Baldinger & Munson 2020[*]; Langdon 2017[*]; Van den Berg & Schulze 2014[*]; Regan et al. 2022[*]; Grunefeld et al. 2022[*]) and describes how challenging situations or working conditions could result in AE development. Challenging situations could be encountered while performing "work as usual" in the workplace (Kawamura et al. 2020[*]; Langdon 2017[*]; Van den Berg & Schulze 2014[*]; Regan et al. 2022[*]; Grunefeld et al. 2022[*]), or by deliberately switching roles and perspectives while performing authentic tasks in a simulated workplace (Baldinger & Munson 2020[*]). For example, the two studies by Kawamura et al. (2020*) and Regan (Regan et al. 2022[*]) investigated excellent trainees in a similar context, i.e., on-the-job training of residents in hospitals. These studies showed how trainees learned from taking care of patients, but also that different mechanisms were associated with learning from these experiences. In the Kawamura et al. study (2020*) the challenging conditions were part of the usual work, such as difficult conversations with patients and caretakers (CMO_1, CMO_2), whereas in the Regan et al. study (Regan et al. 2022[*]) the unstructured learning environment posed significant challenges (CMO_2, CMO_5). In the Regan et al. (2022[*]) study, a strong sense of responsibility combined with memorable clinical examples resulted in more effective retrieval of foundational knowledge and more learning from these experiences (CMO_1). In the Kawamura et al. (2020[*]) study, these challenging conversations were an opportunity to try out new approaches where they could experiment and refine their approaches resulting in new ways of navigating in difficult situations (CMO_2).

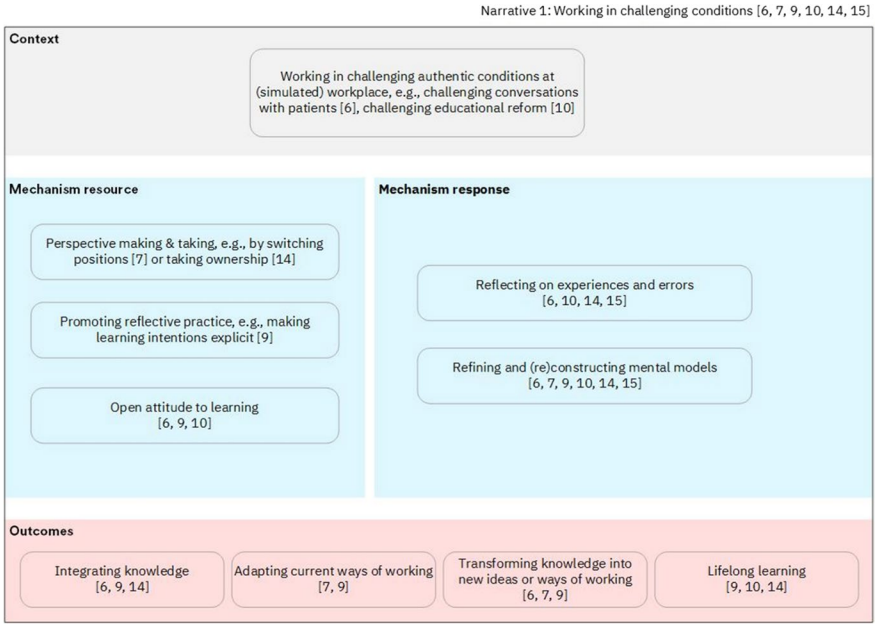

Fig. 3 Narrative 1: Working in challenging conditions

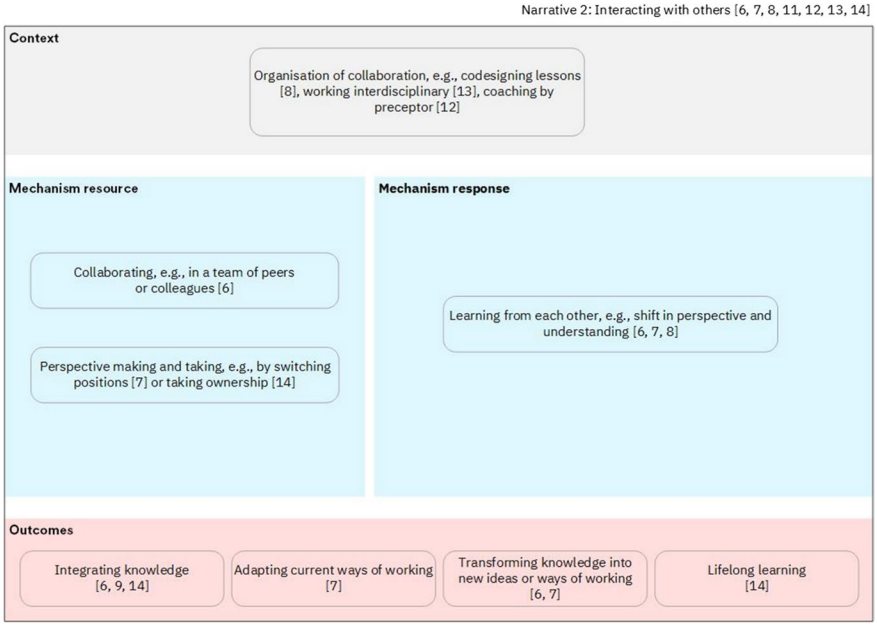

Fig. 4 Narrative 2: Interacting with others

Fig. 5 Narrative 3: Stimulating the willingness to learn

Narrative 2: Interacting with Others

Seven studies (Kawamura et al. 2020*; Baldinger & Munson 2020*; Gallo-Fox & Stegeman 2019*; Drewery et al. 2016*; Stutsky & Spence Laschinger 1995*; Hains-Wesson & Ji 2021*; Regan et al. 2022*) described how interactions with others stimulated AE development in terms of adapting current ways of working, developing new ideas about practice and developing AE competencies in general. These studies show that interaction was stimulated by the organisation of collaboration or was often interwoven with the interventions implemented in these contexts. Collaboration was evident in all these interventions: teachers in training codesigning their lessons in dyads with their supervisor (Gallo-Fox & Stegeman 2019*), preparing specific situations together with a more senior colleague or supervisor ((Kawamura et al. 2020*) CMO_1), or with peers ((Baldinger & Munson 2020*; Regan et al. 2022*) CMO_3), solving problems collaboratively (Baldinger & Munson 2020*), working interdisciplinary ((Hains-Wesson & Ji 2021*) CMO_1, CMO_2), or being coached by a preceptor during work (Stutsky & Spence Laschinger 1995*).

Two studies dealing with learning through interaction during daily work (Kawamura et al. 2020*; Stutsky & Spence Laschinger 1995*) and during peer-to-peer moments (Baldinger & Munson 2020*; Hains-Wesson & Ji 2021*) illustrate how interacting with others can contribute to the development of AE. The Kawamura et al. (2020*) and the Stutsky & Spence Laschinger (1995*) studies show that students and practitioners learn by observing staff ((Kawamura et al. 2020*) CMO_3). The staff and observation experiences provide them with inspiration or new ways

of working which helps them to develop adaptive expertise competencies. In the Baldinger & Munson (2020*) study, in-service teachers were stimulated to switch between different roles and take the perspective of the other person while practicing classroom situations in a simulated workplace, which resulted in mechanisms of meaning-making, forward reasoning and shifting perspectives. This led to new key ideas and strategies for teaching. In the Hains-Wesson & Ji (2021*) study it was mentioned that working together on an industry-linked project with peers from other disciplines made students feel challenged and the need to dig deep and understand the difficult complex situation which led to them being flexible, open and adaptable to working with others (CMO_1).

Narrative 3: Stimulating the Willingness to Learn and Lifelong Learning

Seven studies (Kawamura et al. 2020*; Langdon 2017*; Van den Berg & Schulze 2014*; Drewery et al. 2016*; Hains-Wesson & Ji 2021*; Regan et al. 2022*; Grunefeld et al. 2022*) described the role of the willingness to learn or to engage in (lifelong) learning activities as a mechanism-resource for AE development. A willingness to learn and/or engage in (lifelong) learning activities interacted with the context, e.g., how work and WBL were characterised. These contextual characteristics and mechanism-resources subsequently influenced mechanism-responses from learners: they were making mistakes and learning from them ((Kawamura et al. 2020*) CMO_2), learned to deal with uncertainty and complexity ((Hains-Wesson & Ji 2021*) CMO_2), became empowered by a profound awareness of responsibility while taking care of patients (Regan et al. 2022*), reflected on their role perceptions, assumptions and actions ((Langdon 2017*; Van den Berg & Schulze 2014*; Grunefeld et al. 2022*) CMO_1), or thought differently about their role in the workplace or a team (Drewery et al. 2016*).

Associated contextual characteristics were that learners were confronted with challenging situations in five of the seven studies, i.e., navigating difficult conversations with patients and caretakers [6 CMO_1, CMO_2], navigating an unstructured learning environment while transitioning from school to training on-the-job ((Regan et al. 2022*) CMO_5), coping with a constantly changing, resource-limited school environment (Van den Berg & Schulze 2014*), leading complex change projects ((Grunefeld et al. 2022*) CMO_1) or adjusting to a new workplace with limited or no guidance ((Regan et al. 2022*) CMO_2), all while performing work as usual. In the Regan et al. (2022*) study, coping with an unstructured learning environment (CMO_5) challenged learners to direct their learning and at the same time entrustment they received from senior colleagues (CMO_3) was associated with taking ownership in decision-making (CMO_3) which led to empowerment of a profound awareness of responsibility (CMO_3). These mechanisms were associated with personal learning (CMO_3) and learning to adapt (CMO_5). Similarly, in the Drewery et al. (2016*) study, students in a co-op programme worked in organisations with limited time and resources to train these students and the students' willingness to learn, self-efficacy and lifelong learning skills positively influenced their adaptive performance in such a setting.

In these different contexts, several interventions were implemented to support learners, e.g., by stimulating reflection or preparing challenging situations together.

The level of relevant (work) experience of the learners varied between the studies, ranging from undergraduate (Drewery et al. 2016*; Stutsky & Spence Laschinger 1995*; Hains-Wesson & Ji 2021*) to over 15 years of experience on the job (Langdon 2017*). This suggests that learners at any level of experience either needed the willingness to learn as a context factor (learner characteristics) to adapt to a challenging and changing environment or that learners' willingness to learn enriched their perceptions of their professional role and performance.

Discussion

This realist review showed that work-based learning contributes to adaptive expertise development by exposing individuals to challenging, integrative workplace conditions that require them to integrate and transform knowledge, adapt current ways of working, and develop new approaches. A shift in perspective and thinking was identified as a recurring mechanism-response, which can be prompted by working in challenging, integrative environments and by interactions with others, such as fellow students, mentors, and team members. Furthermore, the willingness to engage in lifelong learning stimulates AE development, as ongoing reflection and openness to new perspectives sustain professional growth. We focused our review on a broad range of professional domains and a broad range of learners in the higher education context because there is an urgent need for higher education institutions to prepare students for an uncertain future (Barnett, 2004; Mylopoulos et al., 2018). We identified context factors related to job demands, learner characteristics, collaborating with others and mechanism-resources related to responsive guidance, learner characteristics, reflective practice and interacting with others.

The review results reflect our initial framework's five work-based learning elements (Table 1): meaningful variation and complexity preservation, reflective practice, collaborating, guidance and learner characteristics. We propose a slightly different emphasis for two elements based on our results. We propose *integrative challenging contexts* instead of *meaningful variation and complexity preservation* because in the search studies we saw that AE was mainly developed in challenging work conditions where formal and informal learning moments are alternated or interwoven, which is inherently meaningful and complex. We also suggest using *interacting with others* during WBL instead of *collaborating* because we noticed that mechanisms for AE development mainly involved working together at the interaction level with peers, colleagues, supervisors and teachers in actual work-based settings. This results in five work-based learning elements for AE development: integrative challenging contexts, reflective practice, interacting with others, guidance and learner characteristics.

The results also show how the work-based learning elements appeared in co-existence and in relation to each other. This became especially clear when comparing the CMOs across the studies. Below, we discuss how the three narratives forming our middle-range theories expand and refine the literature on AE development. Specifically, we discuss how empirical findings from our review support the elements of

AE development from the literature and enrich the literature with implications for AE development in WBL environments.

First, working on challenging and authentic problems in a complex work context contributes to the development of AE. Based on our review, we propose that arranging for a (simulated) work context, in which students work on challenging and authentic problems and weave in formal and informal learning activities, stimulates mechanism-responses associated with AE-development. The importance of challenging and authentic problems to stimulate AE is also stressed by Ward et al. (2018) and Mylopoulos et al. (2018). Furthermore, according to Mylopoulos et al. (2018) this also involves risk-taking on behalf of the learner. This aligns with our finding that AE development is associated with contexts where learners are encouraged to make mistakes and experiment with alternative actions. The study by Barnett and Koslowski (2002) also supports the idea that variability in the type of problems is related to AE development. They posited that experience with working on a wider variety of problems resulted in a different reasoning style and a more theoretical understanding of the domain. Our review showed that students who are encouraged by others to reflect on their experiences in cycles through self-inquiry learn to revalue their competencies to address the problem, make a conceptual change and apply forward reasoning. This (guided) reflection process results in developing new ways of working for oneself and/or for the workplace. Ward (2018) also proposed active reflection as an effective principle for training AE. In daily practice, this reflective problem-solving process can be supported by observing a peer (colleague) deal with similar problems and/or by embedding workshops systematically in the reflection cycle with the help of a supervisor, coach or teacher, and explicit reflection moments, e.g., taking the form of assignments, diaries, etc.

Second, interactions with others in a challenging and complex work context contribute to AE development among higher education students. Barnett and Koslowski's (2002) study also showed that differences in role and social context might explain differences in AE. They hypothesised that working in a team means that feedback from others is available, there is a need for justification of actions towards other team members and brainstorming of ideas is common, all of which are important for building AE (Hatano, 1982). According to Otte et al. (2018) team reflection is important for team functioning and expertise. For team reflection to occur, they argue that available performance feedback, a psychologically safe environment and empowering leadership are necessary. Our findings showed that exchanging experiences and ideas, viewing and evaluating problems from different perspectives, and switching roles can result in re-interpreting experiences, joint negotiation of meaning and developing new ways of working. Based on our review, we propose that these processes of AE development can be supported by having students work closely with a (more experienced) colleague but also by initiating interactions among peers, such as debriefings, or by integrating formal learning moments in daily work with explicit attention to joint responsibility, respect for everyone's input, group dynamics, and learning to work, plan and set goals together.

Finally, students' learning skills also contribute to AE development in a higher education context. These are metacognitive skills, e.g., coping with new or unexpected problems, cognitive flexibility, innovation and attitude aspects, e.g., a

positive attitude and mindset towards learning and lifelong learning intentions. In their review of reviews, Pelgrim et al. (2022) noted an abundance of individual characteristics reported in the literature associated with AE. They conclude that there is currently no consensus on which characteristics should already be present in a student, such as the internal motivation to master a subject, enjoying solving challenging problems, or the belief in one's abilities, or that a challenging and complex work context can also foster them. Based on our results, we conclude that these contexts can also inspire students' motivation or agency and students' learning skills can be examined through (guided) reflective inquiry.

The included studies provide remarkably little information on how guidance can be used to support AE development. Especially in WBL, teachers, workplace supervisors and other stakeholders work closely with students. There is limited empirical evidence from the studies included in our review on how they fulfil their roles and how they collaborate with each other and with the students to stimulate AE development. A review study by Ceelen et al. (2021) on pedagogic practices to support students' workplace learning stresses the importance of demonstrating activities, stimulating participation and trusting students to perform activities independently. This was also observed in two studies included in our review where senior colleagues either demonstrated activities (Kawamura et al., 2020*) or trusted trainees to perform activities independently (Regan et al., 2022*). Wiese et al.'s review study (2018) argues that effective guidance is a two-way process by supervisor and student, which requires leadership from both. Our study results also emphasise the importance of responsive guidance, and based on our initial framework we would argue that supervisors can support AE development by encouraging students to share their ideas and learn from their mistakes, providing a safe learning climate, and having students work on challenging tasks just outside their comfort zone.

Although our studies included a broad range of learners with varying experience levels, most learners were in the later stages of their education or already working as professionals. This suggests that these learners are familiar with working more or less independently and developed routine problem-solving approaches, e.g., as seen in the study of Van den Berg and Schulze (2014*). The role of conceptual knowledge as part of AE development, as emphasised by Bohle Carbonell et al. (2014#) and Hatano and Inagaki (1986), was not examined for these particular learners in the studies included in our review. Thus, it remains unclear how the balancing between efficiency and innovation develops and when learners should be exposed to these challenging, integrative environments, when they would benefit most from interacting with other disciplines and perspectives and when to offer learners specific guidance.

Furthermore, the work-based settings in our review studies vary considerably. We adopted a broad perspective on WBL and also included studies with a simulated workplace (Baldinger & Munson, 2020*) and studies where professional development programmes with workshops, lectures or inquiry cycles are integrated into the work setting (Langdon, 2017*; Van den Berg & Schulze, 2014*). Most of the settings in the included studies are based on alignment, in which students switch from one context to the other, or incorporation, whereby school is brought to the workplace or vice versa (Bouw et al., 2019). Our search did not find any studies with settings that are based on hybridization, i.e., in which both contexts are merged into one new learning site (Bouw et al., 2019).

Hybrid learning environments require different didactics and pedagogy from those used in workplace learning (Khaled et al., 2021). Our results show how work-based learning elements are related and this can be used to design hybrid learning environments in higher education that stimulate meaningful learning experiences.

In this realist review, we used CMO configurations to explore and describe the relationships between context factors, mechanisms and outcomes. Adding more explanatory factors, and thereby expanding our CMO configurations to CIMO (including interventions (I)), ICAMO (also including the actor) or SCMO (including the strategy) could potentially lead to more detailed insights in what specific aspect (Context, Intervention, Actor, Strategy) activates the mechanisms (see De Weger et al., 2020). However, this is only of added value if these components are very well defined and distinguished, which is hard to achieve when dependent on secondary information, as in a realist review. Moreover, WBL often does not depend on a single intervention or actor but is a complex orchestration of those. Therefore, this realist review aimed to form methodologically sound realist causal explanations using CMO configurations (De Weger et al., 2020).

Future Directions

Our review shows the importance of working in challenging conditions for developing AE. However, it is still debated how challenging or ill-structured these conditions need to be and relates to the concept of change described by Pelgrim et al. (2022). Should these challenging conditions reflect changes in task environment that are new for specific learners or should they reflect changes that are new to the entire world? Knowledge about this is needed for designing WBL environments aligned with learners' needs at different stages of their education.

Furthermore, both hybrid learning environments and learning environments aimed at AE development require a rethinking of how we design curricula. Task and learner characteristics, as well as the changing role of supervisors and guidance, necessitate further studies examining how these new WBL environments influence students' learning in these complex contexts.

In addition, our review shows that learners develop AE through interactions with others. Future research is needed to gain more in-depth knowledge about how these interactions shape AE development and how we can facilitate these interactions. To what extent do team composition, boundary crossing or learner characteristics influence these interactions?

Strengths and Limitations

The strength of a realist review is that the complexity of an intervention, in our case WBL, and heterogeneous sources of information can be considered. Our review reflects this by including qualitative and quantitative studies from various domains and learn-work contexts. This way, our review provides a comprehensive and in-depth understanding of how WBL and AE development are related. Further, we used the

RAMESES guidelines for carrying out and reporting a realist review (Wong et al., 2013) to guide the review and writing process.

However, our review also has limitations. A common thread among our studies was the focus on individual-level outcomes. All studies reported outcomes for individual learners, although we expected to find team- and organisational-level outcomes. AE is not a clear construct and consists of different aspects (Hissink et al., 2025), which is reflected in the different operationalisations of AE across studies. This made it difficult to specify which context factors and mechanisms contributed to a particular individual, team, or organisational outcome.

Furthermore, we viewed WBL as a complex intervention; however, in a number of studies, affordances were described within these learn-work contexts (e.g., discussing ideas with others, collaborative problem solving) that were specifically designed as interventions within a learn-work context in other studies (e.g., in workshops, on a co-teaching program). This resulted in considerable difficulty in unambiguously delineating context factors from mechanism-resources while constructing the CMO configurations. We frequently discussed this delineation within the research team and decided that the chain of reasoning was leading.

In addition, we only included peer-reviewed journal papers in English, resulting in a small number of papers for analysis. This might bias our results as important causal factors that could have informed theory development might be missed. However, we included a broad range of domains and learners and focused on empirical studies. The small number of empirical papers included in the analysis, despite a large number of titles and abstracts retrieved in the search, indicates that there clearly is a gap in the literature on how WBL contributes to AE development in a higher education context. The current review provides a starting point for future studies to further explore how WBL can contribute to AE development in higher education.

Conclusion

This study demonstrates how AE development among higher education students can be stimulated in learn-work contexts. It offers guidance for curriculum designers, teachers and students. Making a ‘shift’ in thinking was identified as a recurring mechanism associated with adapted ways of thinking and working, potentially distinguishing adaptive expertise development from routine expertise development. This shift was prompted by challenging WBL environments and interacting with others. Our review shows a clear need for future research and an apparent need for more rigorous and valid measurement of AE in WBL settings. This would accelerate empirical

investigation of the relationship between work-based learning elements and AE development. Furthermore, students work intensively with one another and with teachers, supervisors, and other stakeholders in many learn-work contexts. Our review shows a clear need for more in-depth knowledge of how challenging and ill-structured work situations for the learner need to be, how guidance and support should take shape, and how working together with others can promote AE development.

Appendix 1

Search Strategies

Search strategy 1: adaptive expertise and work-based learning

Scopus	((TITLE-ABS-KEY((expert* OR learner OR professional OR student OR resident* OR intern* OR novice OR worker OR employee OR scholar) W/3 (adaptiv* OR adapta* OR flexib*)) AND PUBYEAR > 1985) AND (TITLE-ABS-KEY (learn* OR develop* OR train* OR educat*) W/3 ("workplace" OR "work-based" OR "work-based" OR "practice-based*" OR "practicebased" OR "on-the-job" OR "professional" OR "challenge-based*" OR "project-based" OR "projectbased" OR "problem-based" OR "practice-oriented*" OR "authentic" OR "life-long" OR "lifelong" OR "work-integrated" OR "work integrated" OR "work-related" OR "work related" OR "job-related") OR ("apprenticeship" OR "internship" OR "ongoing-education" OR "work-placement" OR "field-placement" OR "practice-placement" OR "clinical placement" OR "authentic tasks" OR "authentic context" OR "authentic environment" OR "authentic setting")))
ERIC	((expert* OR learner OR professional OR student OR resident* OR intern* OR novice OR worker OR employee OR scholar) N3 (adaptiv* OR adapta* OR flexib*)) AND ((learn* OR develop* OR train* OR educat*) N3 ("workplace" OR "work-based" OR "workbased" OR "practice-based*" OR "practicebased" OR "on-the-job" OR "professional" OR "challenge-based*" OR "project-based" OR "projectbased" OR "problem-based" OR "practice-oriented*" OR "authentic" OR "life-long" OR "lifelong" OR "work-integrated" OR "work integrated" OR "work-related" OR "work related" OR "job-related") OR ("apprenticeship" OR "internship" OR "ongoing-education" OR "work-placement" OR "field-placement" OR "practice-placement" OR "clinical placement" OR "authentic tasks" OR "authentic context" OR "authentic environment" OR "authentic setting")) [Boolean/Phrase; Limiters 1986–2020; do not apply equivalent subjects]
Web of Science	TS = ((expert* OR learner OR professional OR student OR resident* OR intern* OR novice OR worker OR employee OR scholar) NEAR/3 (adaptiv* OR adapta* OR flexib*)) AND TS = ((learn* OR develop* OR train* OR educat*) NEAR/3 ("workplace" OR "work-based" OR "workbased" OR "practice-based*" OR "practicebased" OR "on-the-job" OR "professional" OR "challenge-based*" OR "project-based" OR "projectbased" OR "problem-based" OR "practice-oriented*" OR "authentic" OR "life-long" OR "lifelong" OR "work-integrated" OR "work integrated" OR "work-related" OR "work related" OR "job-related") OR ("apprenticeship" OR "internship" OR "ongoing-education" OR "work-placement" OR "field-placement" OR "practice-placement" OR "clinical placement" OR "authentic tasks" OR "authentic context" OR "authentic environment" OR "authentic setting"))

Search strategy 2: adaptive performance and work-based learning

Scopus	((TITLE-ABS-KEY (learn* OR develop* OR train* OR educat*) W/3 ("workplace" OR "work-based" OR "workbased" OR "practice-based*" OR "practicebased" OR "on-the-job" OR "professional" OR "challenge-based*" OR "project-based" OR "projectbased" OR "problem-based" OR "practice-oriented*" OR "authentic" OR "life-long" OR "lifelong" OR "work-integrated" OR "work integrated" OR "work-related" OR "work related" OR "job-related") OR ("apprenticeship" OR "internship" OR "ongoing-education" OR "work-placement" OR "field-placement" OR "practice-placement" OR "clinical placement" OR "authentic tasks" OR "authentic context" OR "authentic environment" OR "authentic setting"))) AND (TITLE-ABS-KEY ((adaptiv* OR adapta* OR flexib*) W/3 (performance)) AND PUBYEAR > 1985)
ERIC	((learn* OR develop* OR train* OR educat*) N3 ("workplace" OR "work-based" OR "workbased" OR "practice-based*" OR "practicebased" OR "on-the-job" OR "professional" OR "challenge-based*" OR "project-based" OR "projectbased" OR "problem-based" OR "practice-oriented*" OR "authentic" OR "life-long" OR "lifelong" OR "work-integrated" OR "work integrated" OR "work-related" OR "work related" OR "job-related") OR ("apprenticeship" OR "internship" OR "ongoing-education" OR "work-placement" OR "field-placement" OR "practice-placement" OR "clinical placement" OR "authentic tasks" OR "authentic context" OR "authentic environment" OR "authentic setting")) AND ((adaptiv* or adapta* or flexib*) N3 (performance)) [Boolean/Phrase; Limiters 1986–2021; do not apply equivalent subjects]
Web of Science	#1 TS = ((adaptiv* or adapta* or flexib*) NEAR/3 (performance)) #2 TS = ((learn* OR develop* OR train* OR educat*) NEAR/3 ("workplace" OR "work-based" OR "workbased" OR "practice-based*" OR "practicebased" OR "on-the-job" OR "professional" OR "challenge-based*" OR "project-based" OR "projectbased" OR "problem-based" OR "practice-oriented*" OR "authentic" OR "life-long" OR "lifelong" OR "work-integrated" OR "work integrated" OR "work-related" OR "work related" OR "job-related") OR ("apprenticeship" OR "internship" OR "ongoing-education" OR "work-placement" OR "field-placement" OR "practice-placement" OR "clinical placement" OR "authentic tasks" OR "authentic context" OR "authentic environment" OR "authentic setting")) #1 AND #2

Appendix 2

Inclusion and Exclusion Criteria

Inclusion Criteria

1. Work-based learning is reported. This also includes incorporation of workplace characteristics (such as individuals, environment or task characteristics). Work-based learning could include a higher education learning environment, provided that professionals from the workplace are actively involved.
2. The outcome is adaptive expertise or a related concept, including but not limited to: (cognitive) flexibility, growth mindset, flexecution, transformative learning/teaching, creative thinking/behaviour, reflective learner/professional/practitioner, reflexivity, innovation/innovativeness, boundary crossing, agency, adaptability, adapt to change, adaptive performance, meta-cognitive skills, self-regulation/self-regulative knowledge, navigating complexity, critical thinking, unlearning.

3. Work-based learning takes place in a higher education context. This includes bachelor or master students from higher education programmes, professionals who are involved in work-based learning together with students from higher education programmes (e.g., supervisors, team members), and learning by professionals who are following a higher education professional development programme in the workplace. It should be explicitly about the learning processes of either students or professionals in relation to AE development.
4. Documents are based on empirical data or empirical data is described.
5. Documents in which a simulated workplace or working on authentic tasks is described, AND the student is placed in or experiences the professional role.
6. Documents describe more than *if* something works, without a rationale, they also provide information about *why* something works. Assumptions (about the mechanisms of why something works) about AE development are studied.
7. Language is English or Dutch.
8. Peer-reviewed journal publications are included.

Exclusion Criteria

1. If any of the inclusion criteria 1 to 4 is not met, the document is excluded.
2. Other document types, such as case descriptions, opinion/perspective articles, products (such as: flyers, leaflets, brochures, instruction manuals, etc.).

Appendix 3

Full Text Appraisal of Relevance and Rigour

1. First, full texts are assessed using the in- and exclusion criteria for the screening of titles and abstracts.
2. Second, relevance is assessed using the following questions: does this document help in answering our research question? Is there enough information in the document in terms of outcomes and descriptions of a) adaptive expertise (development) and b) work-based learning?
3. Third, rigour is assessed using the following questions: are the (research) methods used credible and trustworthy? Are the (research) methods suitable for answering the research question in the document? Does the conclusion of the original authors have sufficient 'weight' to give a methodologically sound contribution to testing our initial programme theory?

We used a tool to assess rigour derived from Pawson and Barnes (2003):

- Transparency – is it open to scrutiny?
- Accuracy – is it well grounded?
- Purposivity – is it fit for purpose?
- Utility – is it fit for use?
- Propriety – is it legal and ethical?

- Accessibility – is it intelligible?
- Specificity – does it meet source-specific standards?

Relevance and rigour are considered dimensions, i.e., more or less relevance and rigour, and there is a grey area. For example, a document can fulfil the inclusion criteria, be relevant in answering our research question, and information is described in a transparent way, but not be useful or specific. The final assessment of whether the (research) methods are credible and trustworthy is in part a subjective judgement: "… standards do not replace judgement. They are part of an appraisal process, providing a reference point for judgements and a context against which to explain why and how judgements are made." (Pawson & Barnes, 2003, p. 3).

Appendix 4

Codebook for Data Extraction in ATLAS.ti

Code name	Explanation
Outcomes	Outcomes refer to intended or unexpected intervention outcomes. The result of how people react to the mechanisms. *Outcomes must indicate AE (development) or related concepts*
Context-infrastructure	Context includes the pre-existing organizational structures, the cultural norms and history of the community, the nature and scope of pre-existing networks, and geographic location effects with a specific focus on what contextual factors shape the work-based learning of the case/study. What characterises the (work-based) environment? What tools are used, e.g., real or simulated patients, software used?
Context-actors	Individuals who partake in the programme, including its characteristics and/or roles or positions (e.g., prior knowledge, self-confidence, job satisfaction of facilitator, coach)
Context-artefacts	What tools are used to support the learning and working of the participants?
Context-time	When did learning take place? Temporal aspects, such as available time, timing, speeding up or slowing down task performance, in relation to the work tasks to be performed

Code name	Explanation
Context-cross-boundary teaming	How do workplace and educational programme actors work together in designing the work-based learning environment? What interactions are described and how is collaboration organised?
Context—task complexity	What type of task is reported? Is a complex, authentic professional task described (e.g., providing care for the elderly) or a partial task (e.g., applying a bandage)?
Context—problem solving—unfamiliar problems	Participants have to solve unfamiliar problems – problems just outside the scope of the domain of expertise of the participants, but that experts are able to solve based on acquired strategies to understand the problem and assess potential solutions
Context—problem solving—ill-structured problems	Participants have to solve ill-structured problems. Ill-structured problems can be characterised by an incomplete problem definition, an unknown strategy to solve the problem, the goal is not clear or there is not one optimal solution to the problem
Context—problem solving—wicked	Participants have to solve wicked problems. Wicked problems are social or cultural dilemmas, or problems that are hard to explain or by nature impossible to solve. They are not more difficult problems, but problems at a different level of abstraction, e.g., hunger in the world or climate change
Context—intervention(s)—general	Characteristics of work-based learning specifically/intentionally designed or enacted to influence or stimulate (development of) AE or related concepts
Context—intervention—problem solving strategies	What is done to help solve the problems
Context—intervention—reflection	What is done to stimulate reflection by the participants
Context—intervention—error learning	Participants can learn from making mistakes
Context—intervention—boundary crossing	What is done for participants to learn from crossing school and work boundaries
Mechanism(s)—resource	The mechanism that is triggered by the intervention, in a certain context, by indicating why the intervention produces a certain outcome. It can be their ability (resources) to put the intervention into practice

Code name	Explanation
Mechanism(s)—response	The mechanism that is triggered by the intervention, in a certain context, by indicating why the intervention produces a certain outcome. It can be an explanation of the cognitive processes (reasoning) that actors use to choose their response to the intervention. The response is everything that suggests a change in people's minds and actions

Appendix 5

Visualizations of the CMO Configurations for each Study

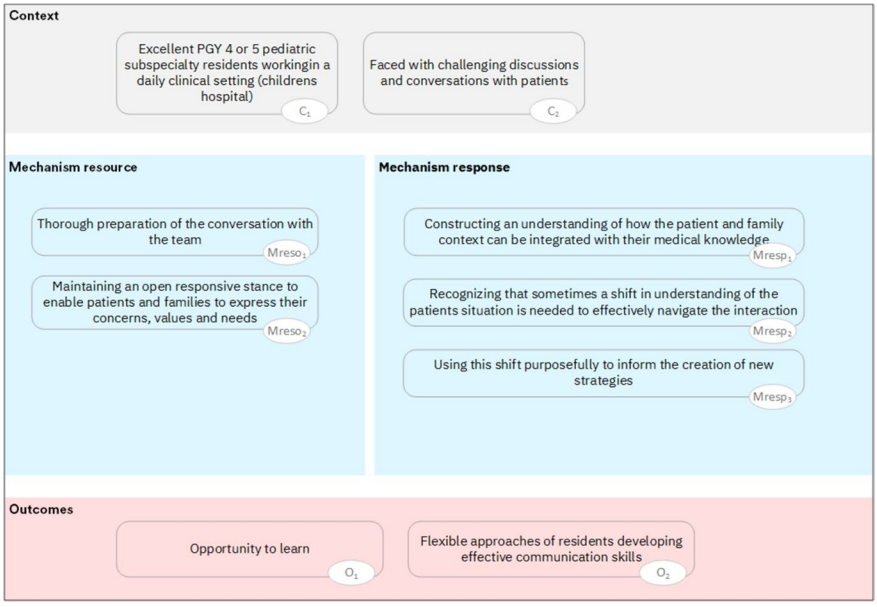

Fig. 6 Kawamura et al. (2020*) CMO_1

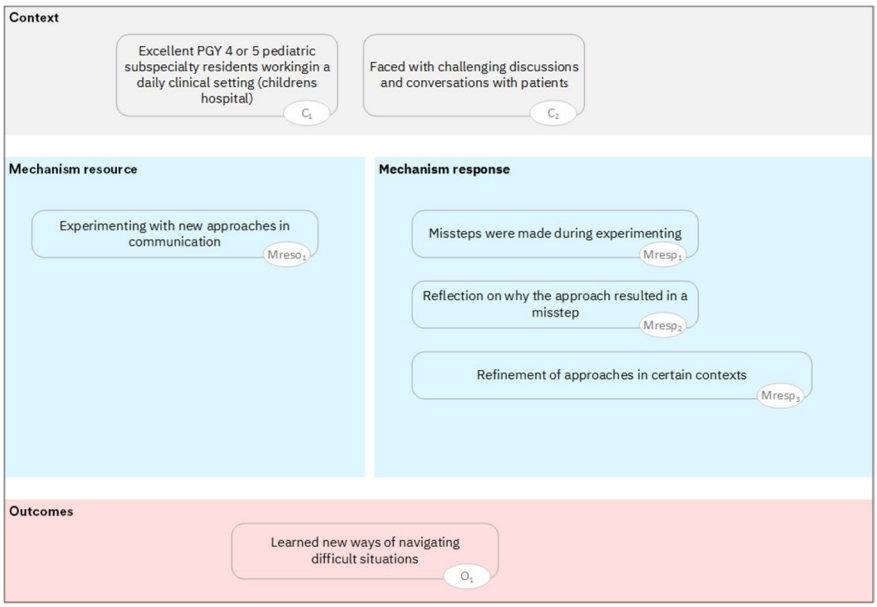

Fig. 7 Kawamura et al. (2020*) CMO_2

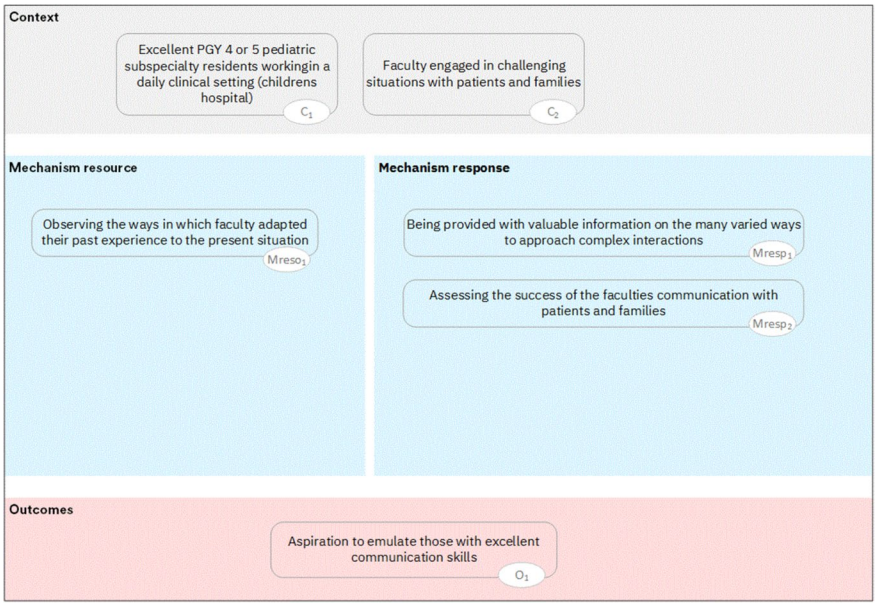

Fig. 8 Kawamura et al. (2020*) CMO_3

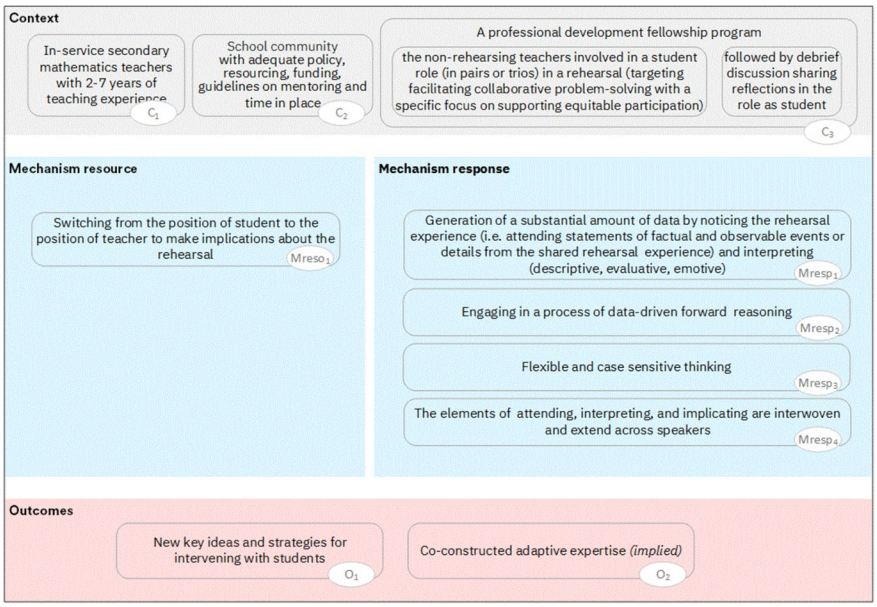

Fig. 9 Baldinger & Munson (2020)*

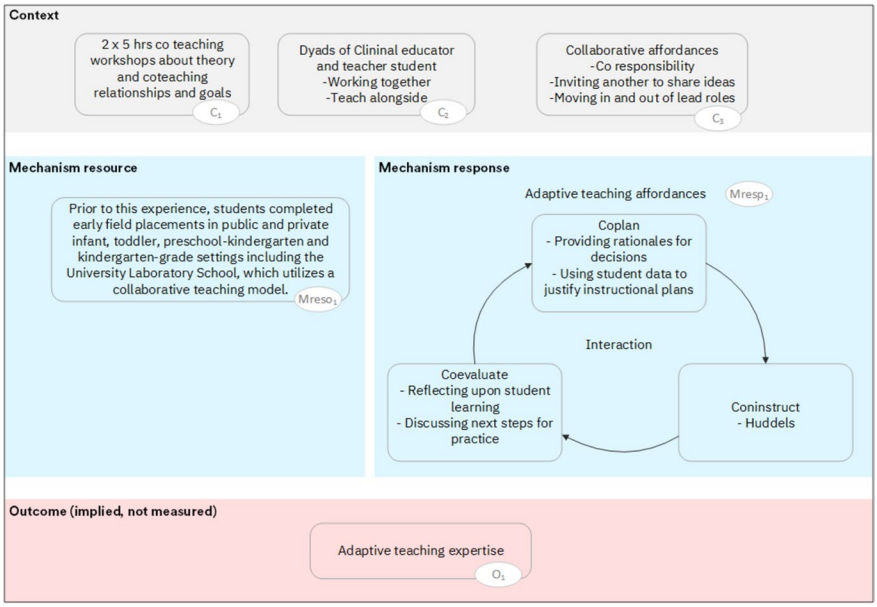

Fig. 10 Gallo-Fox & Stegeman (2019*)

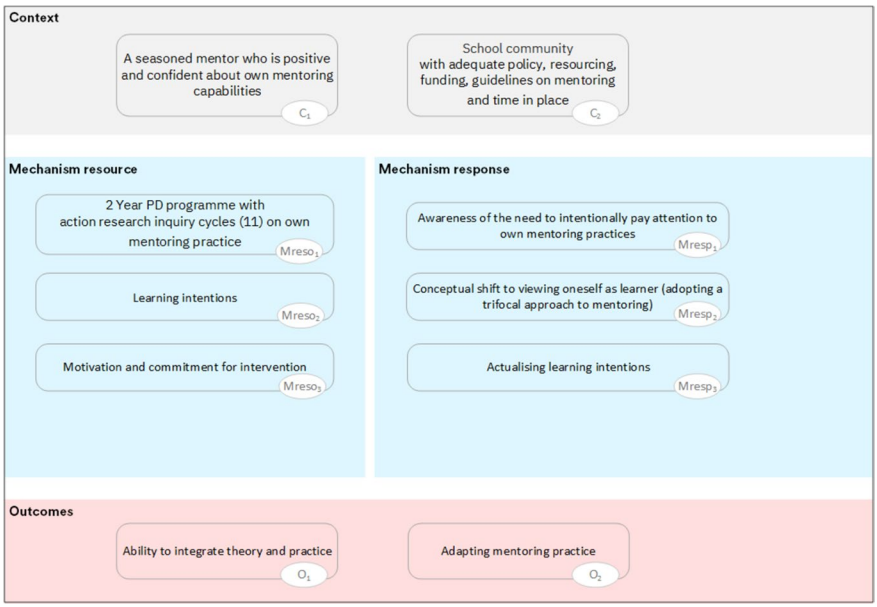

Fig. 11 Langdon (2017*)

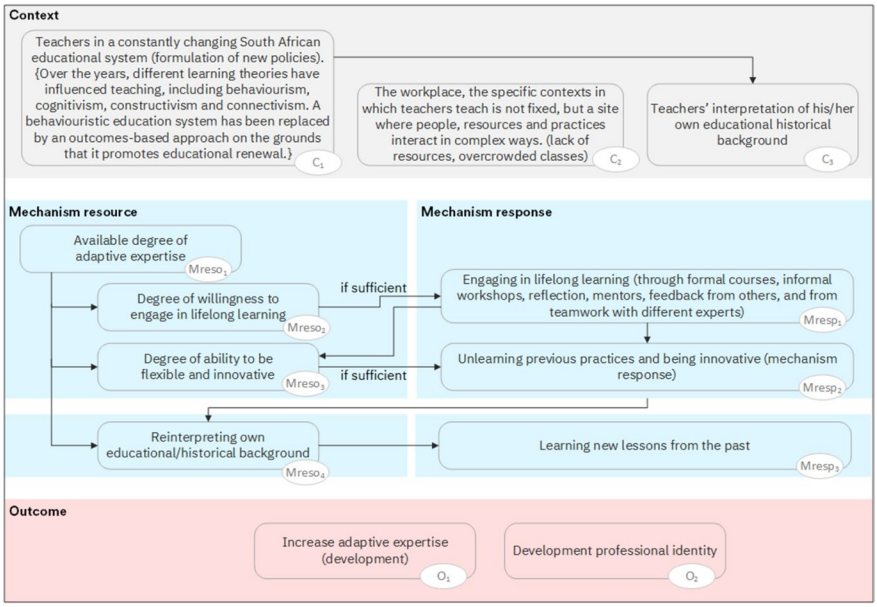

Fig. 12 Van den Berg & Schulze (2014*)

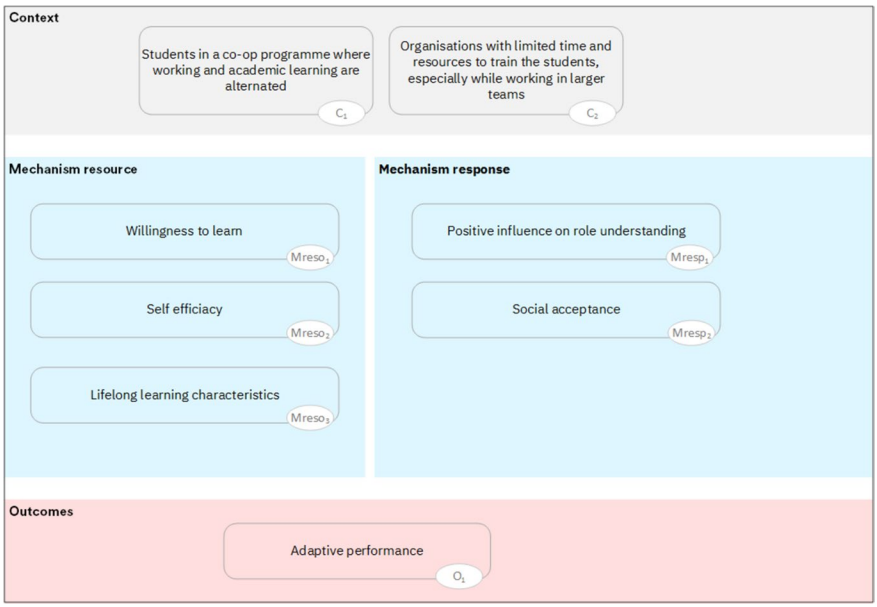

Fig. 13 Drewery et al (2016*)

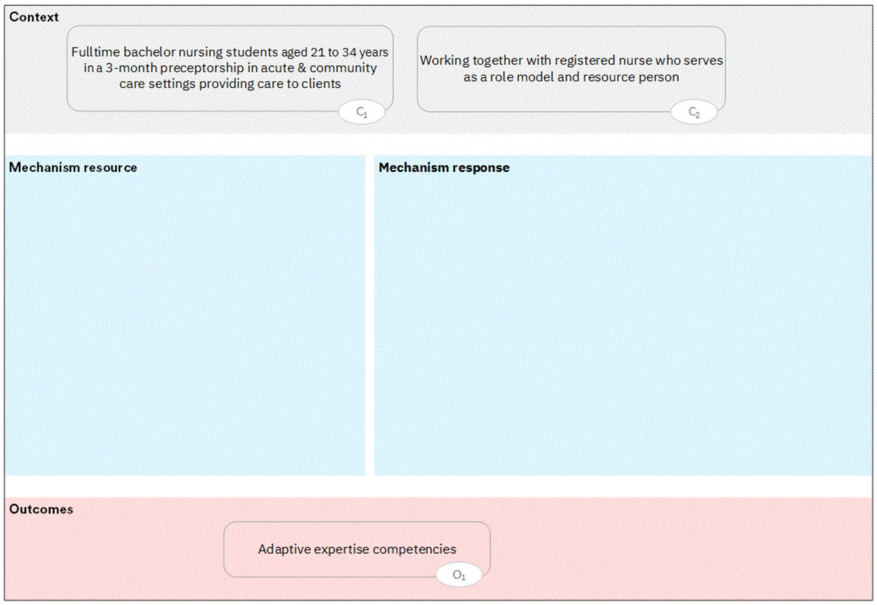

Fig. 14 Stutsky & Spence Laschinger (1995*)

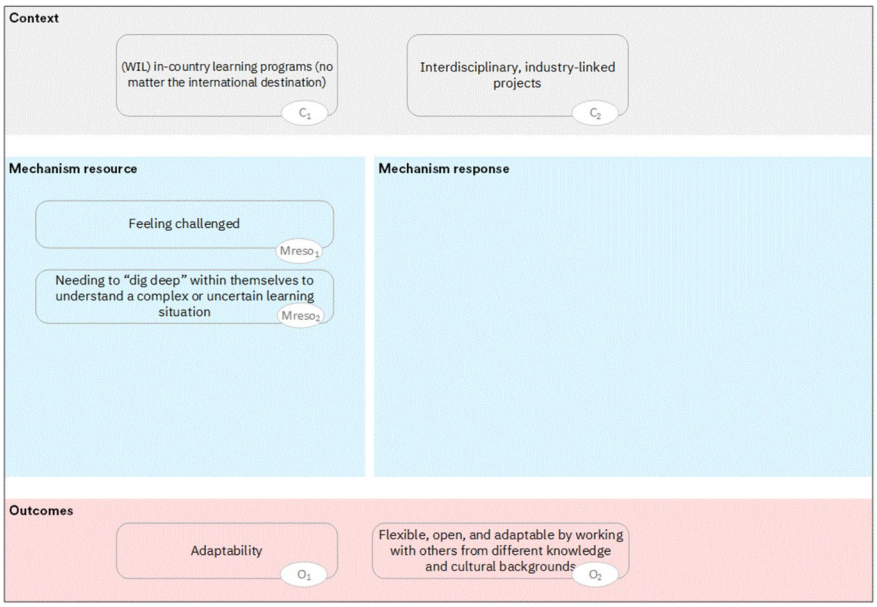

Fig. 15 Hains-Wesson & Ji, (2021*) CMO_1

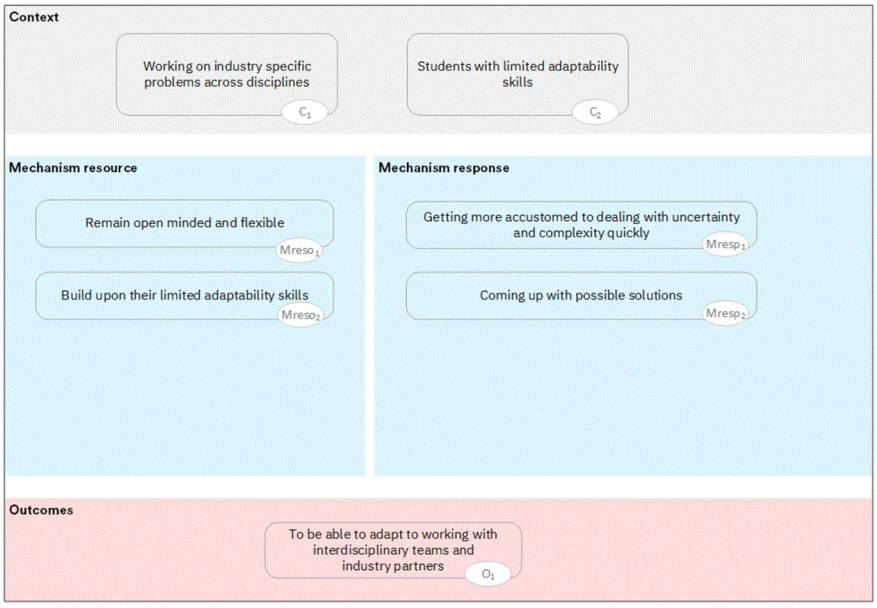

Fig. 16 Hains-Wesson & Ji, (2021*) CMO_2

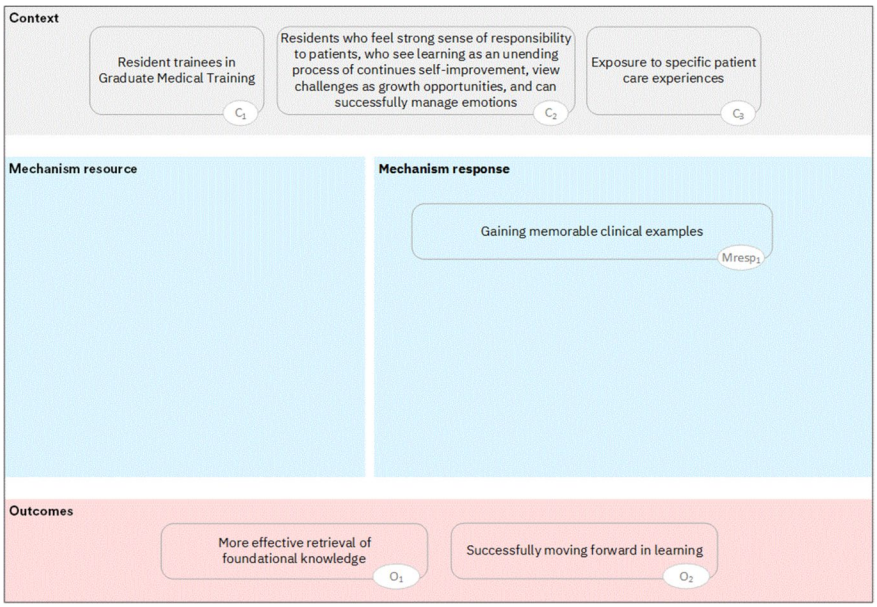

Fig. 17 Regan et al., (2022*) CMO_1

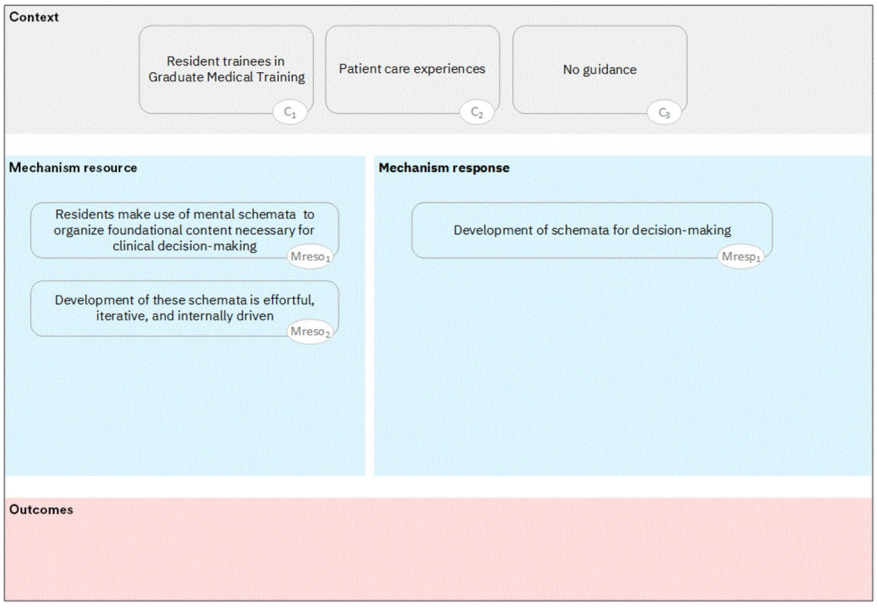

Fig. 18 Regan et al., (2022*) CMO_2

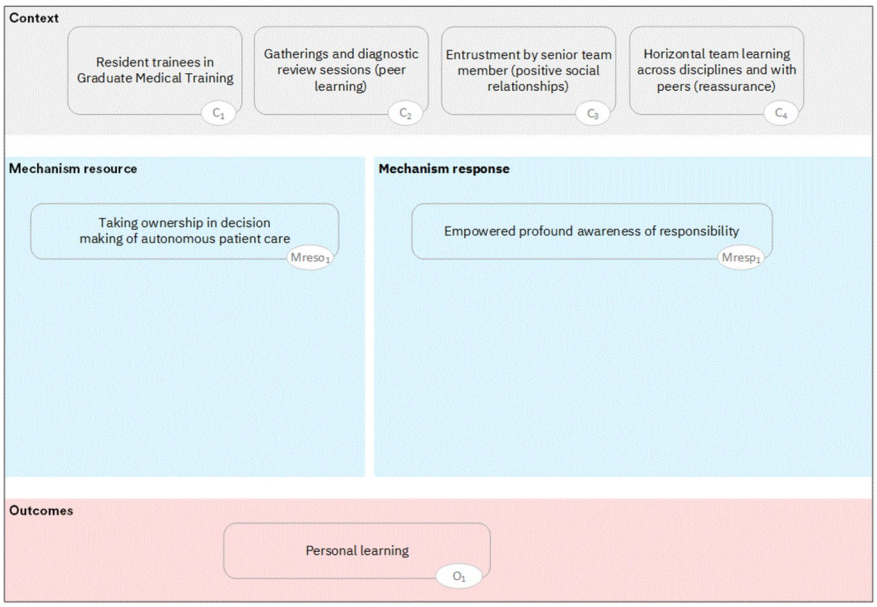

Fig. 19 Regan et al., (2022*) CMO_3

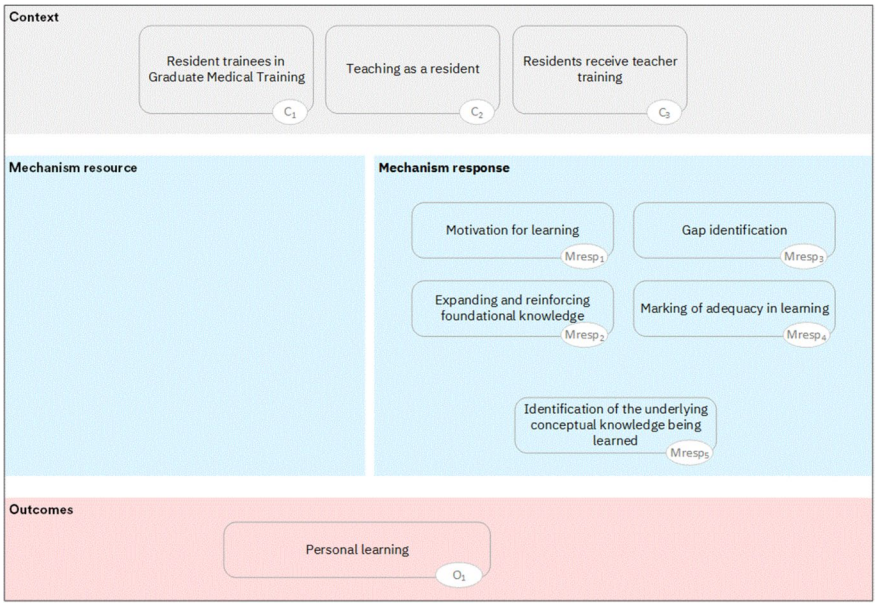

Fig. 20 Regan et al., (2022*) CMO_4

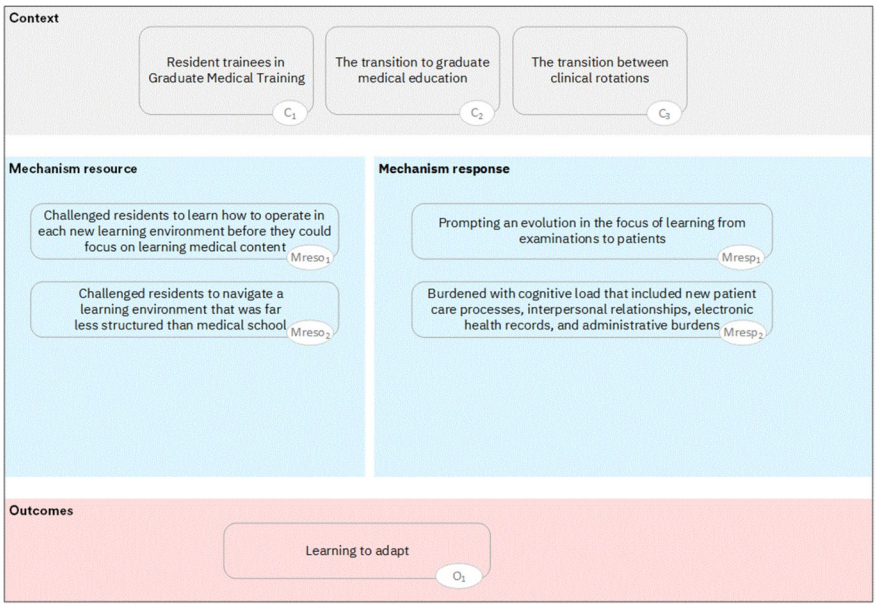

Fig. 21 Regan et al., (2022*) CMO_5

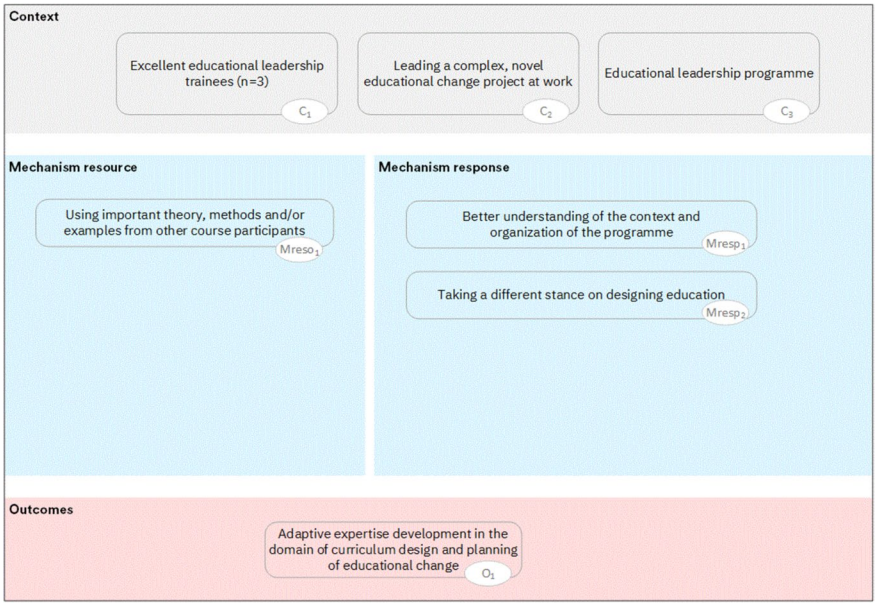

Fig. 22 Grunefeld et al., (2022*) CMO_1

Fig. 23 Grunefeld et al., (2022*) CMO_2

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Declarations

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