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Implementing the four-component instructional design model in professional development programs: a systematic review with a focus on teachers

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The four-component instructional design (4C/ID) model is designed to support complex learning by facilitating the transfer of theoretical knowledge into practice. This study presents a systematic research synthesis on the implementation of the 4C/ID model in training programs with a special focus on teachers. Specifically, we investigate how the four components and 10 steps of 4C/ID are applied in training programs, for which professional fields and real-life tasks it is used, the concreteness of the instructional design, and the effects on learning. A special focus is on the model's implementation in teacher education. A systematic database search following PRISMA guidelines yielded 55 relevant studies, which were systematically coded and analyzed. Surprisingly, we found only a few papers of $n = 11$ on in-service training with 4C/ID for teachers. Our findings indicate that many studies referencing the 4C/ID model lack detailed descriptions of its implementation. To complement our qualitative synthesis, we conducted a quantitative subanalysis, applying a multilevel meta-analysis to estimate the overall effect size of training programs based on pre-post comparisons. The results yielded a moderate positive effect ($g = 0.76$, $SE = 0.31$, $p = 0.014$), suggesting that the 4C/ID model has a meaningful impact on learning outcomes. These findings underscore the need for more structured reporting and further research on the implementation of 4C/ID, particularly in teacher education.

KEYWORDS
4CID, synthesis, in-service training, instructional design, systematic review

1 Introduction

With the growing demands of a globalized world, training at the start of a professional career is not enough to meet the challenges of subsequent professional practice. Especially teachers will face major challenges such as heterogeneity, digitalization, inclusion and individual support in the coming years (Drijvers, 2022). An optimal approach to professional development should combine theory and practice instead of the instruction of isolated knowledge, especially in teacher training courses (van Merriënboer, 2020).

Instructional design approaches have evolved over the decades. One of the earliest and most influential of these is Gagné's (1965) "Conditions of Learning" model, which was published in 1965. This model defines nine steps intended to systematize and structure the learning process. The field has been supplemented and expanded by various other works for example Reigeluth's Elaboration Theory (Reigeluth, 1983). These approaches are now used in many practical fields. Against this backdrop, the Four-Component Instructional Design Model (4C/ID model) (van Merrienboer and Kirschner, 2012) emerged in the 1990s. Rather than breaking down learning processes into small parts, this model presents them as complex, authentic learning tasks. The 4C/ID model incorporates key elements of previous models, such as Gagné's (1965) emphasis on clearly defined learning objectives, and builds upon them with principles from the whole-task approach and scaffolding.

The Four-Component Instructional Design Model (4C/ID model) is designed to facilitate complex learning—in particular, the transfer of theoretical knowledge into everyday life or professional practice (van Merriënboer, 2020). The special feature of the model is that learning takes place in and on authentic contexts (Leuders, 2020). The focus is on authentic learning tasks that closely mimic the demands of real-world professional practice. This allows knowledge, skills and attitudes to be taught in an integrated way (van Merrienboer and Kirschner, 2012).

The 4C/ID model provides a theoretical base for the design of learning environments and training programs. The four components of the model closely align with quality characteristics of good and effective training programs. For this reason, we argue that 4C/ID can be particularly useful in the development of high-quality teacher training programs, especially for in-service training, where professionals already possess both an educational background and personal experience with their specific real-world tasks. In this article, we present a systematic review that examines the use and implementation of the 4C/ID model in such professional development programs in previously published work. We ask how in each case researchers use 4C/ID as a theoretical framework for developing professional development courses in general, how they document 4C/ID in their articles, in which professions 4C/ID is used in professional development, and what is taught in professional development programs. With a focus on the methodological implementation of the four components of the 4C/ID model, we then highlight teacher training programs as a key example, as they are of particular interest in this study.

2 Elements of 4C/ID and their intended purposes

The 4C/ID model can be characterized by its premise to design learning opportunities with a systematic view on real-life tasks, which are the ultimate goals of professionalization. More specifically, theoretical and practical learning opportunities should be linked with the help of the model in such a way that what has been learnt can be applied effectively in practice (Leuders, 2020; van Merrienboer and Kirschner, 2012). To fulfill this challenging requirement, the model proposes four components to support so-called "competence-oriented learning." We summarize the core ideas regarding each component in the following subsections (following van Merriënboer, 2020), since we consider a detailed documentation of how the four components of 4C/ID are implemented as a key quality indicator of a study's instructional design.

2.1 Working in situated environments and on authentic problems: learning tasks

van Merriënboer (2020) described Learning tasks as whole tasks that should promote learning processes. Above all, learning tasks should prepare students for their future work. The aim is learning through doing and concrete experiences. Learning tasks should always be complete tasks that integrate knowledge, skills, and attitudes, which is why these tasks are also referred to as "whole tasks" (van Merriënboer, 2020). To achieve this, learning tasks should be variable, have various levels of complexity, and learners should be guided to solve them. At the beginning of a learning process students should receive support and guidance for difficult and complex tasks and should be led to the next level of complexity if they can solve a task without any help. Support is gradually reduced until students can solve the task themselves. This process of creating a fully support and reducing the support gradually is called Scaffolding (van Merrienboer et al., 2003). Support can take different forms, such as examples of solutions, completing incomplete solutions and finally solving the complete task (Renkl and Atkinson, 2003)—and can also be provided by the instructors themselves or externally through worksheets with guiding questions, etc. For this, learning tasks consist of both routine and non-routine aspects. Routine tasks are always done in the same way. Non-routine tasks require problem solving, weighing up and making decisions (van Merriënboer, 2013). Learning tasks can encompass anything students engage with—such as cases, projects, work assignments, problems, or other activities. Within each complexity level, the tasks should be varied in a similar way as they might vary in real-life tasks, and typically, learning journeys should begin with simple tasks and gradually progresses to more complex ones over time (van Merriënboer and Sweller, 2010).

2.2 Connecting prior knowledge with new information: supportive information

Learners need information to learn profitably from the learning tasks (van Merrienboer and Kirschner, 2012). According to van Merriënboer (2020) supportive information help learners to deal with non-routine aspects of a learning task such as problem solving or decision making. Ideally supportive information connects the existing prior knowledge of the learners with the knowledge the learners should know in order to be able to perform such non-routine tasks. Therefore, information should be structured in a way that prior knowledge can easily be linked to the new information. Cognitive feedback is very important here (Hattie and Timperley, 2007; Kluger and DeNisi, 1996). Through feedback, learners are able to compare their cognitive schemata with others and correct them if necessary. Supportive information is often represented as theory from books, lectures, or online resources and should be identical for all learning tasks of a certain level of complexity. Such supporting information can be presented at the beginning of a new unit as well as during working process on the unit. For the next level of complexity, supportive information needs to be extended and supplemented (van Merriënboer, 2020).

2.3 Building up knowledge step by step: procedural information

In addition to the non-routine aspects, there are also the routine aspects connected to real-life tasks. For that, according to van Merriënboer (2020), procedural information should assist learners with such routine aspects. The aim of procedural information is to enable students to develop cognitive rules that become cognitive schemata through practice so that they can be used quickly, easily and error-free. As procedural information is therefore usually provided during the work on a learning task, they are also called just-in-time information. Typically, information is presented as a "How-to" or "Step-by-step" instruction—given either by the teacher themselves or in the form of a user guide. Learners should get procedural information at the beginning of a new task, while with the next comparable tasks the procedural information is gradually reduced. It is important to formulate information at a basic level so that every student, including lower-achieving ones, are able to understand them (van Merriënboer, 2020).

2.4 Automating routine aspects: part-task practice

Learning tasks consists of both routine and non-routine aspects. Typically, routine aspects are practiced within the context of learning tasks. However, if solving a learning task requires a high degree of automation of certain routine components—and these components are not sufficiently trained while solving the learning task itself, students should engage in part-task practice. According to van Merriënboer (2020) the purpose is to develop fully automated procedural schemata (Anderson, 1982), which is why in cases where working on the complete learning task does not provide enough repetition for automation, specific routine skills should be practiced separately in part-tasks. Ideally part-task practice is integrated into the work on whole learning tasks process and aligned with the complete task. To be effective, part-tasks should begin within an appropriate cognitive context. For instance, the routine elements should be made explicit within the full task before isolating them for practice.

2.5 Developing 4C/ID courses systematically: 10 steps of design activities

In addition to the four components that should enable competence-oriented learning, the model also lists 10 steps of design activities (van Merrienboer and Kirschner, 2012) to design courses fitting to the 4C/ID model. Within the 10 steps, the four components (steps 1, 4, 7 and 10) form a kind of super-category. The steps in between concretize the respective superordinate category. The first component "Learning tasks," for example, is further concretized with the help of steps two and three. We consider a detailed description of the 10 steps in a published article as an indicator of successful implementation of 4C/ID—and summarize which information regarding each of those steps could be expected in Table 1.

TABLE 1 Ten steps of design activities from the 4C/ID model (van Merrienboer and Kirschner, 2012) and a description of what information could be expected articles following those steps.

Ten steps	What should be done
1. Design learning tasks	The first step is to create complex and variable learning tasks based on real requirements.
2. Develop assessment instruments	This step involves identifying, formulating, and categorizing performance objectives and developing the associated assessment instruments. In other words, it is necessary to determine which objectives are to be achieved, under what conditions, and what constitutes acceptable performance.
3. Sequence learning tasks	The tasks are arranged here from simple to complex. For this purpose, the learning tasks are characterized and specified to fulfill task classes.
4. Design supportive information	The fourth step is to create supportive information. The aim of this step is to establish a link between what learners already know and what they should know.
5. Analyse cognitive strategies	In this step, the cognitive strategies for dealing with unknown challenges are analyzed.
6. Analyse mental models	This is followed by an analysis of the mental models, i.e., how a certain domain is organized.
7. Design procedural information	Rules and procedures for recurring aspects and knowledge requirements are described here. The aim is to build up cognitive schemata which, in the best case, can be fully automated.
8. Analyse cognitive rules	Here, if/then rules are used to specify all aspects that remain the same from task to task.
9. Analyse prerequisite knowledge	This step analyses the knowledge requirements in terms of concepts, plans and principles.
10. Design part-task practice	If a high degree of automation is required, these aspects must be automated in the form of part-tasks. These part-task exercises are to be created here.

3 Professional development: continuing professional development of already established competencies

Training courses should ideally follow a structure that prepares learners for professional behavior in a complex world (Leuders, 2020; van Merriënboer, 2020). The acquisition of competencies should encompass not only knowledge but also skills and attitudes, systematically integrating these aspects into learning opportunities. In in-service training, where participants already possess prior knowledge of the subject and have personal experience, this integration is particularly crucial. Professional action often requires the simultaneous application and coordination of multiple sub-competencies. Moreover, transferring learning from training contexts to real-world problem situations is essential. In such cases, rigidly separating different learning aspects can be counterproductive, as it obscures the interconnections between competencies and the authentic demands of professional practice. Therefore, learning should always reflect the full complexity of real-life tasks rather than being artificially simplified (Frerejean et al., 2021; Leuders, 2020).

3.1 Why 4C/ID for professional development?

In a globalized world, circumstances are constantly changing. Professional pre-service training programs therefore cannot prepare people for a career that lasts for decades but must be complemented by regular further training (International Labour Office, 2018). For example, teaching and school practice are in a constant state of flux, with new challenges emerging all the time. A study program cannot fully prepare students for the changing conditions of the next 40 years (Lipowsky and Rzejak, 2017), as training to become a good teacher is a complex task that ideally combines theory and practice. 4C/ID teaches skills in real-life situations and therefore seems ideal for further training in professional contexts—with each of the four components addressing specific needs for in-service training.

Professional development as in-service training is essential when professional actions are complex which 4C/ID a challenge that the 4C/ID model addresses by designing learning tasks that mirror authentic challenging situations. Tasks should be variable so that the tasks remain manageable. Complexity increases steadily over the task progress. Holistic tasks such as learning tasks, develop and use knowledge, skills and attitudes in equal measure. In addition, tasks are performed realistically and holistically, which prevents a separation of partial competences. This is an important skill that is highly relevant in a wide range of occupations.

The 4C/ID model is widely regarded as a valuable framework for curriculum design in vocational education and training. One essential difference of pre-service and in-service training is the learners prior experience with the specific competencies in practice. This knowledge facet cannot be ignored as it can be particularly useful or lead to overgeneralizations of personal experience—which is why in-service training should especially take learners prior experiences into account. Supportive information in the 4C/ID model helps to link the new-to-learn knowledge to existing prior knowledge—and prior experiences—and make it available in connection. It also prevents the learning of individual aspects in isolation. The link between knowledge and benefits facilitates the transfer of knowledge to practical situations.

Activities can be automated using procedural information and part-task practice. The rule-based automation of part-tasks can reduce the workload when completing the task. For learners with practical experience in particular, the aim is to reduce the workload of everyday tasks and to make it easier to work on complex tasks. This is why the application of the 4C/ID model can be particularly beneficial in training programs.

In summary, 4C/ID provides a structure for well-developed in-service professional development programs that is perfectly able to take into account the experiences of participants acquired during their execution of their jobs. 4C/ID teaches skills in authentic real-life situations and is therefore ideal for continuing professional development in professional contexts. Nevertheless, the question is whether the 4C/ID approach will also achieve the desired learning effects.

3.2 What makes training programs effective? The case of in-service teacher training

Lipowsky and Rzejak (2021) describe, as the result of a research synthesis, several principles for the methodological and didactic design of effective (in-service) training programs—with teacher training in mind. The similarities between the Principles of effective teaching and the 4C/ID model are presented below.

As a first principle, Lipowsky and Rzejak (2021) name the "linking of input, testing and reflection phases" ("Verknüpfung von Input-, Erprobungs- und Reflexionsphasen" S. 13). Knowledge acquisition, the actual action and reflection on the action carried out should not be realized separately, but as far as possible simultaneously in a joint task. A similar goal can be found in the 4C/ID model. Learning tasks should be as holistic as possible, in which knowledge, skills and attitudes are promoted in equal measure. These holistic tasks should be implemented in authentic everyday situations as far as possible, just as required by the principles for effective teacher training.

The next principle that emerged from the research synthesis was "the principle of feedback and coaching" ("Feedback und Coaching" S. 13). The aim is to support teachers' experiences and learning processes through feedback, examples and suggestions. In the 4C/ID model, this principle is implemented in the form of procedural information. Procedural information is often implemented in the form of just-in-time information—where teachers are provided with the information or examples they need during their work. Procedural information can also be implemented in the form of corrective feedback. In this case, the necessary instructions for the correct completion of the task should also be given during completion (Lipowsky and Rzejak, 2021).

As a final principle, Lipowsky and Rzejak (2021) name "meaningful content and activities" ("Bedeutsame Inhalte und Aktivitäten" S. 13). The benefits and relevance of the training content should be emphasized through practical relevance. This principle is implemented in the 4C/ID model primarily through supportive information. Supportive information provides the theoretical background to the learning tasks. By working on holistic, authentic tasks, the benefits of theory become omnipresent. Supportive information can be accessed at any time while working on the learning task. This creates a link between theoretical content and practice, in line with Lipowsky and Rzejak (2021).

4 Goals and research question

The goal of the present study was to generate an overview on the scope and quality of the utilization of the 4CID-approach in in-service training programs represented in present literature.

Costa et al. (2022) have already conducted a meta-analysis of the use and impact of 4C/ID in various academic fields and technical training programmes. The results showed that 4C/ID significantly improves performance in all fields, but seems particularly well-suited to higher education—whereas our study aims to examine the use and impact of 4C/ID in continuing education. The focus is on the qualitative evaluation of the implementation of 4C/ID. Therefore, the review refers specifically to the methodology section rather than the results, which distinguishes this study from the meta-analysis by Costa et al. (2022) and serves as a supplement to it. In particular, we conducted a systematic literature review to document the implementation of the four-component instructional design model in in service-training programs. Our first aim was to examine the extent to which 4C/ID is documented in publications that claim to use 4C/ID as the underlying theory for a training program—considering a detailed description of 4C/ID as an indicator of its successful implementation. Of particular interest was the extent to which the four components and the 10 steps were *documented* in the individual papers (Research Question 1): *How is 4C/ID documented in publications that cite 4C/ID as the theoretical framework for development of in-service training courses?*

Furthermore, we asked in which professions 4C/ID is already being implemented in in-service training programs. In the respective publications we analyse which learning goals were defined, which aspects were evaluated, and— on a quantitative level—how effective the interventions were (Research Question 2a): *In which professional groups is 4C/ID used and for which real-life tasks?*(Research Question 2b:) *What is the estimated mean pre-post effect for such in-service 4C/ID interventions?*

Of further interest was how the four components were *implemented* in the individual training programs and how the 10 steps were carried out and described in the individual papers (Research Question 3): *If 4C/ID is implemented, what methodological approaches and which methodological concretizations are used for components and steps?*

With our particular interest in the teaching profession, we asked to what extent 4C/ID is already being implemented in teacher training programs (Research Question 4):

5 Method

5.1 Literature search and selection of articles

By following the PRISMA guidelines (Page et al., 2021) we decided to use "4C/ID" OR "Four-Component Instructional Design" for our search syntax to search the Eric and Web of Science databases. In both databases, we searched in title and abstract. We assumed that the most relevant studies are those that explicitly refer to 4C/ID in the title or abstract, rather than just mentioning it somewhere in the article. In such studies, it is plausible to assume that essential parts of the theoretical background can be traced back to 4C/ID. This resulted in 38 hits in ERIC and 77 hits in Web of Science. In total, we found 115 texts. For these 115 texts we had strict inclusion and exclusion criteria. We excluded:

1) all texts that appeared twice or more in the search
2) texts to which we did not have access
3) texts that were not written in German or English
4) texts that were not published articles (e.g., books, dissertations, etc.) for quality assurance
5) texts that did not use 4C/ID as their theoretical basis
6) texts that did not describe a training program in the sense of our definition

Of the 115 texts, 17 papers had to be excluded because they appeared twice or more. Six papers were excluded because access to the texts was not possible. Forty-four papers were excluded because it was not a training program, 2 papers were excluded because 4C/ID was not the theoretical basis. We also excluded 2 papers because of various reasons: one paper because it was too short to get differentiated information and one paper because the training was held on 4C/ID but was not methodically applied.

This left us with 38 texts that were ultimately included because all inclusion criteria are fulfilled (Figure 1). These inclusion criteria were:

1) Only published articles
2) The text describes any kind of training program or development programme
3) The training program is based on the 4C/ID model.

The decision on whether studies were included was double coded, with coding performed by the first author of the paper and an additional trained researcher. The agreement between the two coders reached a fair agreement (Cohen's Kappa $\kappa = 0.36$)—but the relatively low value is why all studies for which at least one coder recommended inclusion were reviewed in a subsequent cycle and evaluated conclusively by the whole team. The relatively low level of agreement in the coding can probably be explained by the broad definition of professional development, which was the main criterion for the inclusion or exclusion of papers.

In a second step we performed a snowball backwards search. For each of these texts, we used the "Cited by" function in Google Scholar to identify texts that cited the 38 texts above We assumed that the 38 texts found could be prototypical regarding the use of 4C/ID. We therefore expected that other (possibly less prototypical) 4C/ID training studies would refer to the methodological design or other aspects of these 38 papers. It is therefore to be expected that these 38 studies will be cited by prototypically similar papers, among others. This is why we looked at the papers that cite them. These 38 texts were cited 971 times in total (on 21 November 2023).

Again, we excluded 202 texts because they appeared twice or more and 144 texts, we could not get access to (Figure 1). We also excluded 98 texts because they were not written in English or German. This left us with 528 texts where we have skimmed the abstract and texts. For these texts we had the same exclusion and inclusion criteria as for our first search. We excluded 350 texts because they do not describe a further training or the 4C/ID model. In addition, we excluded 156 texts because these were not articles but book contributions, books, dissertations, master's theses, PowerPoint presentations or Wikipedia entries. We also excluded 5 texts of other reasons (Figure 1). In the end we were left with 16 additional texts which we ultimately included. After all this we had in total 55 texts left which were coded in the following step.

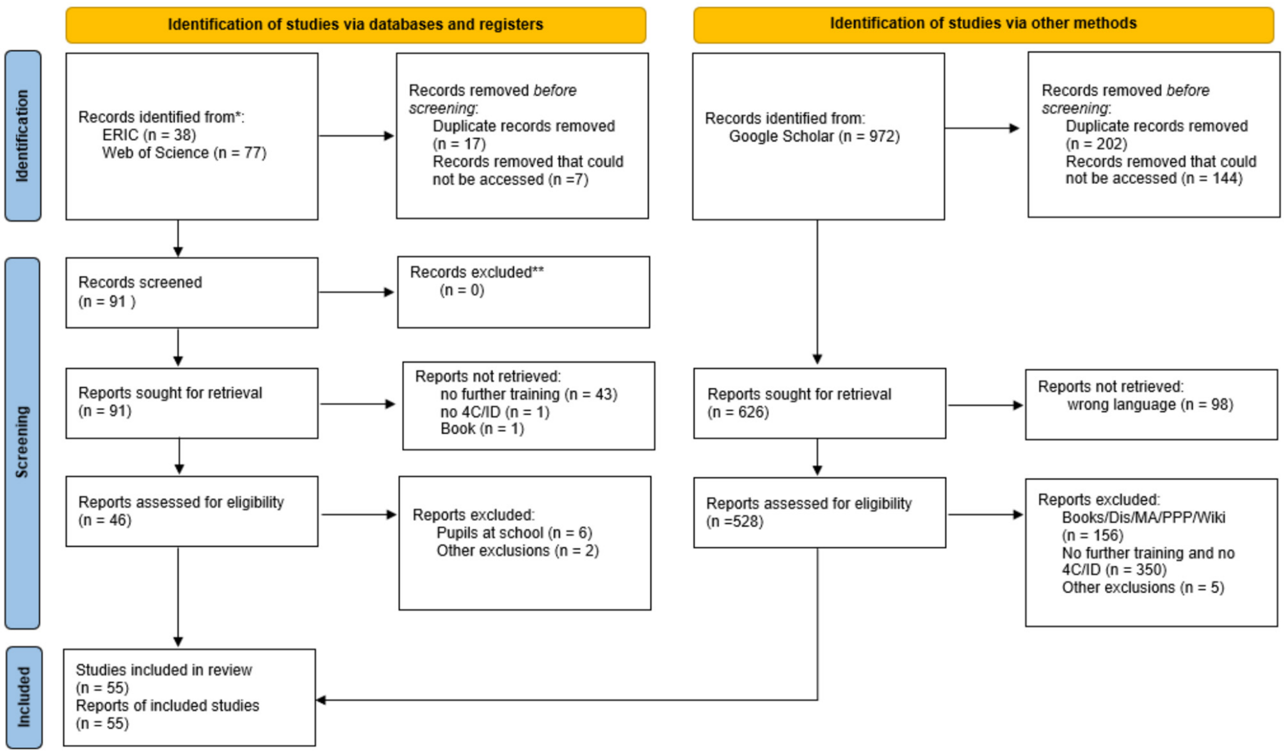

FIGURE 1
Identification of studies according to the PRISMA guidelines. *Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all database/registers). **If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

5.2 Coding of quantitative results

5.2.1 Four components

The first question was whether the four components were described by the respective paper or not. It was noticed that some papers did describe the four components, but not in relation to their own training, but only in general terms. In the following, we therefore categorized papers as "yes" if the four components were described with reference to our own training and "no" if the four components were only described in general terms or not at all. Papers that only described individual components were categorized as "no." The component "part-task practice" is an exception. According to the model, this is also optional, which is why papers that described the other three components but not part-task practice were still categorized as "yes."

5.2.2 Ten steps

The same observation was made for the 10 steps as for the four components. Here too, some of the 10 steps were only formulated in general terms and not in relation to the training program described in the paper. For this reason, the 10 steps were also categorized as "yes" if at least one of the 10 steps were described in relation to the further training mentioned in the paper. The papers that only described the 10 steps in general terms or not at all were then categorized as "no."

5.2.3 Data collection

In addition, it was categorized whether any type of data was collected on the results of the training. All papers that collected data on the results of the training or process data during the training were categorized as "yes," all others as "no."

5.2.4 Profession

An important part of the evaluation of the texts was the analysis of the professional area in which the training courses were carried out. For this purpose, individual professions were summarized into categories. Ultimately, this resulted in the categories education, medical care, skilled trades, emergency services, e-sports and an open category for the rest. The "education" category includes teachers, university students, and vocational students whose subject-related training takes place within vocational schools. An example of this is the paper on further training for painting cars (Mulders et al., 2022). Students from a vocational school are described, but they are doing the training in painting cars with VR, i.e., these students were being trained in an activity that they had already learnt. The medical care category included doctors, nurses, medical students, nursing students and pharmacists. Skilled trades included painters and jewelry makers. Emergency services and e-sports included the mentioned professional group, and the open category syntheses the still open professions—including a first aid program, driving simulation training and a course to brush up on programming skills.

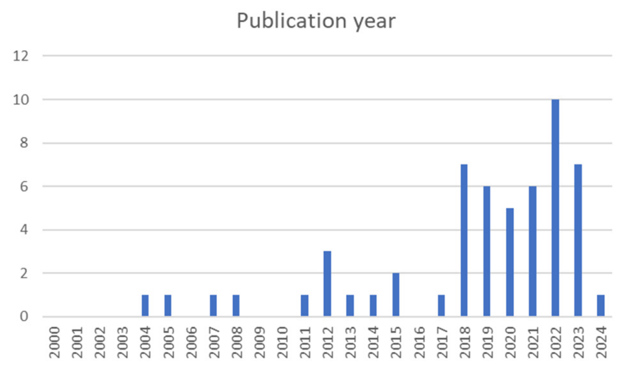

FIGURE 2
Publication years of the individual publications.

5.2.5 Real-life-task

Finally, the real-life tasks that were to be improved with further training were categorized as programming, teaching, expanding research skills, medical applications, expanding manual skills, expanding foreign language skills and other. In the Other category, an exercise for evacuation by emergency services, driving with an automatic system, and the appropriate use of skills from video games in the real world were categorized.

5.3 Coding of qualitative results

In addition, all papers were analyzed qualitatively with regard to the implementation of the four components, the profession, the subjects of matter and the real-life tasks. Therefore, we focused our qualitative description on the specific implementation of the four components.

6 Results and discussion

6.1 Descriptive analysis

The analysis of the papers shows that the texts we consider relevant were published in the last 20 years, between 2004 and 2024. Since 2018, the average number of publications has increased eightfold. Figure 2 illustrates this trend.

6.2 How is 4C/ID documented in publications that cite 4C/ID as a basis for intervention development?

Ideally, papers referencing the 4C/ID model as the foundation for their training should provide a more detailed account of its implementation. For clarity and comprehensibility, we recommend describing at least the model's four core components. However, a step-by-step outline of the training process, following the 10 steps of 4C/ID, would offer even greater insight and transparency.

TABLE 2 Categories for the professions and absolute and relative occurrences.

Profession	Absolute frequency	Relative frequency
Education	26	46%
Medial care	19	34%
Skilled trades	6	11%
Emergency services	1	2%
E-sports	1	2%
Open category	3	5%

This is currently not the case for the articles reviewed in the present synthesis:

Of the total of 55 texts, 30 texts (54%) were categorized as "yes" and thus described the four components with reference to the training, whereas 26 texts (46%) did not describe the four components or only described them in general terms. Because the quality of the implementation of 4C/ID can only be derived from at least one description of the four components, or even better from the description of the 10 steps, it is difficult for the other 46% of the papers to assess the extent to which 4C/ID has been implemented at all.

For the 10 steps, we also analyzed whether the 10 steps were described with reference to the training program. A general description of the use of the 10 steps was not sufficient here. Six of the 56 (11%) texts were rated "yes" and therefore described the 10 steps in detail, while 50 texts described the 10 steps only in general terms or not at all.

6.3 In which professional groups is 4C/ID used for which real-life tasks and which objects of 6.3 investigation?

6.3.1 Profession

The coding of the papers shows that 4C/ID is used in a wide range of professions (Table 2). Most of the papers were published in the educational field (46%) including teachers (Frerejean et al., 2021), trainee teachers (Lim et al., 2015), and vocational students (Fu and Guo, 2023). Thirty-four percent of the papers were published in the medical field. This includes professions such as doctors (Claramita et al., 2020; Kolcu et al., 2020), nurses (Musharyanti et al., 2021), pharmacists (Vandael et al., 2018), medical students (Braun et al., 2021; Domínguez et al., 2017b; Peahl et al., 2019), and nursing students (Andreasen et al., 2023). There were also individual papers on the professions of car painters (Mulders et al., 2022) or jewelry makers (Mahantakhun et al., 2020). There was also a category in which no specific occupation could be identified.

6.3.2 Real-life-tasks

Real-life tasks are comprehensive, holistic tasks that correspond to the requirements of real life and are ideally mastered at the end of a learning unit with 4C/ID. The real-life tasks trained for in the reviewed papers were categorized as programming, teaching, research skills, medical applications, manual skills, foreign language skills and other (Table 3). In the programming category, the tasks were to program loops (Güney, 2019), to create digital grade books with Excel (Lim et al., 2009), to design apps (Frerejean et al., 2019a), and to develop a computer program that was able, for example, registers members or resets passwords (Peng et al., 2022). In the teaching category, the tasks included designing differentiated lessons (Frerejean et al., 2021), creating research-based lessons (Yan et al., 2012), integrating technology into learning and teaching (Lim et al., 2015), using visual media to support teaching (Xu et al., 2020) and assessing learners' progress in lessons (Wolterinck et al., 2022). To improve research skills, real-life tasks such as conducting a literature review (Argelagós et al., 2022), formulating research questions (Argelagos et al., 2023), conducting qualitative research (Holtslander et al., 2012) and learning to conduct research competently were formulated (Maddens et al., 2020). Real-life tasks in the medical field include being able to provide first aid (Vanfleteren et al., 2022); learning about medication safety (Musharyanti et al., 2021); improving communication with patients (Claramita et al., 2020; Susilo et al., 2013), interpreting pulmonary function tests (Braun et al., 2021) or resuscitating trauma patients (Domínguez et al., 2017a). Manual skills include professionally painting of vehicles (Mulders, 2020, 2022), improving safety awareness in jewelry making (Mahantakhun et al., 2020) and acquiring technical knowledge such as identifying materials or calculating the height of a building (Sarfo and Elen, 2007). Another real-life task is the acquisition of foreign languages, which involves holding fluent conversations (Larmuseau et al., 2018a), finding information and creating a presentation to build vocabulary (Frerejean et al., 2019b). The category "others" included real-life tasks such as driving self-driving cars (Feinauer et al., 2023), an emergency service exercise on evacuation and firefighting (Hoang and Kato, 2023), working with Bayesian reasoning (Büchter et al., 2022) or using video game skills appropriately (Modreanu, 2022).

TABLE 3 Categories for the real-life tasks and absolute and relative occurrences.

Real-life-task	Absolute frequency	Relative frequency
Programming	7	13%
Teaching	7	13%
Expanding research skills	7	13%
Medical applications	18	32%
Expanding manual skills	7	13%
Expanding foreign language skills	5	9%
Open category	5	9%

6.3.3 Data collection and estimated mean effect of in-service 4C/ID interventions

In addition, we categorized whether any type of data on the training was collected. Of the 55 papers, 37 (66%) had collected data of some kind. Nineteen papers had not collected any data (34%). Therefore, only the 37 papers that collected data are considered below.

Sixteen of the 37 papers compared pre-test and post-test data. The focus here was primarily on the increase in knowledge (Braun et al., 2021; Peng et al., 2022; Vandael et al., 2018), whether the learning objectives were achieved (Sarfo and Elen, 2005, 2007), or the effectiveness of the learning environment (Argelagós et al., 2022).

In four papers, data collection was used to obtain feedback on either the learning environment or the training in general. Here, the immediate feedback, the teaching of theory in a variety of ways and the wide range of tasks were positively emphasized. On the other hand, the great difference in difficulty between the tasks and the large amount of reading material were criticized (Maddens et al., 2020). If more explicit questions were asked about what was envied about the learning environment, answers referred to the good coordination of the learning environment with practice and the fact that the content can be put into practice immediately (Meutstege et al., 2023).

Three of the papers compared the data of a control group with that of an experimental group receiving the 4C/ID training. The focus was on which group had a greater increase in knowledge (Musharyanti et al., 2021; Peahl et al., 2019), which group achieved better results in solving the tasks (Barnes et al., 2011), and course satisfaction (Peahl et al., 2019). The other papers investigated, for example, motivational aspects (Andreasen et al., 2023; Maddens et al., 2023), learner attitudes (Lim et al., 2009), mental models (Feinauer et al., 2023) and self-assessments (Claramita et al., 2020).

A multilevel meta-analysis was conducted to estimate the overall effect size (g) regarding pre-post differences of participants trained in the 4C/ID courses—considering the nested structure of the data (32 effect sizes nested within 12 studies). Only 12 of the 16 papers that claimed to compare pre- and post-test data could be included in the following meta-analysis. Four papers were excluded because no data were provided. The model was fitted using restricted maximum likelihood (REML). The overall effect size was significant [$g = 0.76$, $SE = 0.31$, $z = 2.45$, $p = 0.014$, 95% CI [0.15, 1.38]], indicating a moderate positive effect of 4C/ID courses regarding learning gains. Variance components revealed substantial heterogeneity across studies ($\sigma_{12} = 1.02$) and within studies across measures ($\sigma_{22} = 0.22$). The between-study variability accounted for a larger proportion of the total variance than the within-study variability, indicating that a significant proportion of heterogeneity exists at the study level. The test for residual heterogeneity was significant ($Q(31) = 1{,}230.78$, $p < 0.001$), suggesting that additional unexplained variability remains in the data. Model fit statistics indicated an acceptable fit (for further comparison: $AIC = 74.64$).

To explore potential sources of heterogeneity, moderator analyses were conducted (Table 4). We first checked our hypothesis whether studies which report the four components for their 4C/ID program (indicating overall quality of the program) show higher effects than studies that do not explicitly report how the four components were implemented. In line with our hypothesis, the category "4 components reported" showed a significant pre-post effect [$g = 1.33$, $SE = 0.46$, 95% CI [0.42, 2.24]]; the category "4 components not reported" showed no significant pre-post effect [g

= 0.39, $SE = 0.37$, 95% CI [−0.33, 1.12]]. However, the difference in effect size between "reported" and "not reported" was not statistically significant [$g = -0.93$, $SE = 0.59$, $z = -1.58$, $p = 0.115$, 95% CI [−2.10, 0.23]]. Compared to the overall model, the variance components in the first moderator model were slightly reduced: The between-study variance (σ_{12}) decreased from 1.02 to 0.86; the within-study variance (σ_{22}) stayed the same. The test for residual heterogeneity remained significant in the first moderator model [$Q(30) = 968.24$, $p < 0.001$], indicating that additional moderators or factors might explain the remaining variability. Model fit statistics for the first moderator model were $AIC = 71.91$ which suggest a better fit compared to the overall model.

It was then examined whether the studies differed according to the subject area in which the training was carried out. A distinction was made between the categories of education, crafts and medicine. The "education" category showed only a descriptive positive, yet not significant effect [$g = 0.41$, $SE = 0.28$, 95% CI [−0.14, 0.96]], while the category "Medicine" showed a descriptive zero-effect that was not significant [$g = -0.03$, $SE = 0.43$, 95% CI [−0.88, 0.82]]. In the "craft" category, participants increased significantly between pre and post-test [$g = 2.12$, $SE = 0.40$, 95% CI [1.31, 2.93]]. *Post-hoc* analysis showed that the difference in the effect size is statistically significant between "Education" and "Crafts" [$g = 1.71$, $SE = 0.50$, $z = 3.41$, $p = 0.001$, 95% CI [0.73, 2.69]]. Compared to the overall model, the variance components in this moderator model increased slightly: The between-study variance (σ_{21}) and the variance within the study (σ_{22}) remained nearly the same. The test for residual heterogeneity also remained significant in this moderator model [$Q(29) = 754.32$, $p < 0.001$]. The model fit statistic for the first moderator model was $AIC = 64.12$ which indicates a better fit compared to the overall model.

Finally, we tested whether certain methodological implementations of the learning environment produced better results. A distinction was made between the categories "online," "offline," "hands on," and "no specification." There were no significant effects in the individual categories (Table 4). The difference in the effect size was also not statistically significant. Compared to the overall model, the variance components in this moderator model remained nearly the same. The test for residual heterogeneity also remained significant in this moderator model [$Q(28) = 1{,}056.77$, $p < 0.001$]. The model fit statistic for the moderator model here was $AIC = 68.23$ which indicates a better fit compared to the overall model.

6.3.4 Discussion of estimated mean effect of in-service 4C/ID interventions

Moderator analysis showed that papers reporting in detail on the four components demonstrate a significant pre-post effect. This finding aligns with our expectations and reinforces our recommendation that, in the future, researchers should explicitly address the development and application of the four components and 10 steps when employing the 4C/ID model.

Surprisingly, however, the impact differed within the individual subject areas. No significant effect was observed in the field of education, and the effect was zero in medicine. In contrast, significant effects were observed in the crafts category. One possible explanation for the difference in impact between the crafts sector and the other two could be that the 4C/ID model is particularly well-suited to complex, practical training courses. Training courses in the fields of education and medicine do not achieve the same level of practical relevance and real-world implementation as those in the craft category. In the craft category, work is carried out directly on the object or with VR simulations. In contrast, training courses in the fields of education and medicine may be less realistic, involving more simulated scenarios such as vignettes.

However, this is contradicted by the fact that no difference in methodological implementation could be found, which was also surprising. In any case, it should be noted that only a few of the examined studies provided information on the before-and-after effects. Consequently, these studies offer insight rather than a representative overview.

6.4 Methodological concretizations

6.4.1 Implementation of the 4 components

For the 30 texts that described the four components with reference to their own training program, it was of particular interest to see how the four components were implemented methodically. We provide a systematic qualitative overview of the 30 studies in the following.

6.4.1.1 Implementation and types of learning tasks

Learning tasks are all-encompassing, authentic learning tasks that are linked to real challenges and form the basis of the 4C/ID model (van Merriënboer, 2020). The diverse use of the 4C/ID model in the various professions results in a diverse implementation of the learning tasks, which are explained in more detail below.

Six Texts implement the learning tasks in online learning environments. The interactive online learning environments are designed to teach the basics of first aid (Vanfleteren et al., 2022), improve foreign language skills (Larmuseau et al., 2018a) or learn medical applications such as dealing with diabetes patients (Vandewaetere et al., 2015) or using the "ABCDE method" (Faber et al., 2021). Some texts report on specific simulation training. For example, automated driving is practiced in a driving simulator (Feinauer et al., 2023), specific cases based on real medical records are simulated (McGraw et al., 2023) or car painting is practiced with VR glasses (Mulders et al., 2022). Of course, there are also four paper that implemented learning tasks in real situations, such as programming loops (Güney, 2019) or programming notebooks in Excel (Lim et al., 2009). Another example would be exercises by emergency services to clear a market or an apartment complex (Hoang and Kato, 2023).

6.4.1.2 Obtaining and presenting supportive information

Supportive information is classically the theory for a specific task and helps to master non-routine learning tasks (van Merriënboer, 2020). A distinction is made here between how the information is presented and how the learners obtain this information. The following section describes how the supportive information was presented in the various papers. Supportive information can traditionally be presented in form of a lecture or

TABLE 4 Moderator analyses and weighted mean effect sizes for all coded variables.

Moderators variables	N	k	Random-effects model					
			Effect size		95% CI		Q	P
			g	SE	Lower	Upper		
Four components							968.2411	0.0001
Reported	610	32	1.33	0.46	0.42	2.24		
Not reported	448	32	−0.93	0.59	−2.10	0.23		
Profession							754.3219	0.0001
Education	633	32	0.41	0.28	−1.19	2.01		
Craft	299	32	2.12	0.41	1.31	2.93		
Medicine	126	32	−0.03	0.43	−0.88	0.82		
Category							1056.7724	0.0001
Hands on	121	32	0.71	0.62	−0.51	1.93		
Offline	298	32	1.69	0.63	0.45	2.92		
Online	610	32	0.31	0.49	−0.66	1.27		
Not reported	29	32	0.44	1.03	−1.59	2.46		

a video. For example, Musharyanti et al. (2021) offer supportive information "in the form of interactive lecture and video playback." Kraft et al. (2019) "combines assigned readings, lectures and/or online videos."

Supportive information can also be implemented as graphical representations. Güney (2019) provides the supportive information in a flowchart, for example. This contains the components that must be included in a command for programming. Other graphical representations contain the 4C/ID components to facilitate lesson planning (Frerejean et al., 2021). Vanfleteren et al. (2022) visualizes the supportive information in the form of a decision tree.

Some supportive information is formulated as examples. For example, exemplary actions in similar situations can be described and discussed (Lim et al., 2009). Videos with examples can be shown (Vanfleteren et al., 2022), or role plays can be observed (Susilo et al., 2013) to provide information.

If the learning tasks have been implemented on an online platform, the supportive information can be obtained in the form of a help button. Such help buttons are self-regulating. In line with the 4C/ID concept, everyone can decide for themselves whether or not they need such help (Clarebout et al., 2010; Huet et al., 2011). Larmuseau et al. (2018a), for example, tries to promote students' foreign language skills. Here, the goal is to be able to hold a fluent conversation in a restaurant. The students learnt in an online environment in which help was provided with a help button. By clicking on the help button, the students received explanations of grammar so that they could use them in conversation. If the training does not take place online, supportive information such as graphical representations or literature can be handed out to the participants on paper. Or these can be made available on online platforms, as is usually done with videos.

6.4.1.3 Implementation of procedural information

Procedural information relates to the routine aspects of a learning task and provides direct support during the processing of the task. Here, too, we analyzed how the various papers implement procedural information in their training program (van Merriënboer, 2020).

Five papers use feedback to give procedural information. This feedback is usually implemented as feedback with hints to the correct solution if the students solution was wrong and can be given either digitally or directly by a person, usually the teacher (Frerejean et al., 2023). An example for a digital Feedback is a digital nurse; it provides corrective feedback to learners when they are working in an online environment (Faber et al., 2021).

Procedural information can also be provided in the form of step-by-step instructions. In the step-by-step instructions, for example, Excel applications are explained (Lim et al., 2009) or how to deal with diabetes patients (Vandewaetere et al., 2015).

In addition, some papers present procedural information in the form of help tables or help buttons. Akkaya and Akpinar (2022) use an online learning environment to investigate whether serious games can be used to improve object-orientated programming and computational thinking skills. Under the help button you will find, for example, information on how certain functions can be used in the online environment or examples of specific programming tasks. Other papers, for example Maddens et al. (2020), provide explanations or definitions that may be necessary when working on the current task.

6.4.1.4 Implementation of part-task-practice

In part-task practice, aspects of the learning task are, if necessary automated through repetitive practice (van Merriënboer, 2020). The implementation of part-task practice in the various papers is also of particular interest here. Part-task-practice are always very small, individually adapted, repeatable units, which is why a classic categorization was very difficult here. In addition, practicing with part-task practice is an optional component that is only necessary if the given subject matter is not yet sufficiently practiced during the learning tasks. Examples from the papers examined were the task of practicing vocabulary on the topic of eating or visiting a restaurant (Larmuseau et al., 2018a), the specific task of creating search strings with Boolean operators (Maggio et al., 2015), or, in the case of car paint sprayers, the specific task of practicing spraying paint at the correct distance (Mulders, 2022). The part-task practices are implemented either through specific tasks or through links or buttons that then lead to the specific exercises.

6.4.1.5 Summary of documented implementation of the four components

If the four components are described, then the first three components Learning tasks, Supportive information and Procedural information are often described methodically in their implementation. Part-task practice is sometimes missing, which is not surprising as it is considered optional. Part-task practice is only needed if the actions to be automatised are not already sufficiently practiced with the learning tasks. The 10 steps, if described, are described in detail and explain the exact design of the learning environment. Here too, individual steps are sometimes summarized and described together.

According to the 4C/ID model, learning tasks should be designed to be as realistic and authentic as possible. The degree of realism and authenticity can then be controlled by the help of the methodological design. These gradations are of course also related to the subject matter to be taught: While training courses on programming or teaching are suitable for concrete implementation, training courses on medication safety should first be practiced in a simulation.

Both supportive information and procedural information are largely provided in a self-regulating form. Learners always have access to this information if they need it. The implementation of the individual forms of support is varies widely. Only a few texts describe specific implementation of the part-task-practice, which is not surprising as not every training programme necessarily requires part-task-practice elements. They are only needed if aspects of the learning tasks to be automated are not already sufficiently practiced during the learning task.

6.4.2 Documentation of the ten steps

The following are two examples of texts that describe the use of the 10 steps in more detail. Both papers describe in detail how to organize a training course according to the 4C/ID model. Two completely different topics (learning to programme and differentiated teaching) from different disciplines are described and implemented in a variety of ways and are therefore positive examples of how 4C/ID should ideally be documented.

6.4.2.1 Learning programming with 4C/ID

Zafer (2019) uses the 4C/ID model and the 10 steps to describe how a training course on programming could look in concrete terms when programming loops. The aim of the training is to learn about different loops and their benefits and to be able to implement this knowledge in concrete programming. The 10 steps are described in detail in the paper.

The various learning tasks, such as the logic of loops or avoiding endless loops (Step 1), are sorted according to their difficulty and worked on in ascending order of difficulty (Step 2). Step 3 describes when learners move up to the next task category and which prerequisites must be fulfilled for this [e.g., "Understands the logic of the study of loop statements' or "Performs the desired algorithm using For, While, Do While, and Foreach" (Güney, 2019)]. A flow chart with the components that must be included in the command is provided as supportive information (step 4). The aim is to connect to the learner's memory and thinking (step 5) and support the development of new mental models (step 6). Methodical information for programming is provided as procedural information (step 7). Steps 8 and 9 relate primarily to the concrete design of the procedural information. Subsequently, in Step 10, part-task practice is provided to reinforce the cognitive rules.

6.4.2.2 Learning to design differentiated lessons with 4C/ID

In this paper, Frerejean et al. (2021) describe a training programme for teachers to design differentiated lessons. At the end of the training programme based on 4C/ID, teachers should be able to design differentiated lessons themselves. The training takes place in the school network, between the individual units what has been learnt can be put into practice in the classroom.

To this end, different learning tasks were formulated, such as: getting to know differentiated instruction with modeling examples; uncovering misconceptions or imitation tasks, in which the implementation of teaching activities is practiced together (step 1). A hierarchy was then established to determine which skills should be mastered with regard to the preparation, implementation and evaluation of the lesson (step 2). In step 3, the learning tasks were then organized according to their complexity. The training started with general information on differentiated instruction and progressed to the planning and implementing a lesson. In order to create appropriate supportive information, the cognitive strategies and mental models were first analyzed (step 5 & 6). This showed, for example, that teachers proceed linearly when preparing a lesson and that novice teachers often suffer from misconceptions, e.g., differentiated instruction is equated with personalized instruction. This then led to supportive information (step 4) such as modeling examples to build up appropriate cognitive strategies, or group discussions to avoid misconceptions. As differentiated teaching is largely a flexible and complex task, very few routine aspects needed to be taught. Therefore, steps 7–10 have been summarized by Frerejean et al. The identified routine aspects should already be mastered by the teachers and were not discussed further by the experts. Therefore, there was no need for part-task practice (Frerejean et al., 2021).

6.4.2.3 Summary of documented implementation of the 10 steps

When the 10 steps are described, they are described in detail. In addition to the two papers mentioned above, medical applications (basics of first aid and dealing with diabetes patients), manual skills (learning to paint cars using VR) and further training for teachers (integrated teaching in the areas of language, science and technology) were described in detail using the 10 steps.

6.5 4C/ID in in-service teacher training programs

Eleven of the 55 texts describe training programs for teachers. Seven papers describe at least the four components, two additionally describe the 10 steps in detail. Thematically, teachers in the training courses should learn how to design differentiated lessons (mentioned above) (Frerejean et al., 2021), integrate technology into learning and teaching (Lim et al., 2015), create research-based learning programs (Yan et al., 2012), create grade books with Excel (Lim et al., 2009), use visual media (Xu et al., 2020), implement assessment for learning in lessons (Wolterinck et al., 2022), improve foreign language skills (Larmuseau et al., 2018b; Wittmann and Olivier, 2021), provide differentiated instruction in lessons (Meutstege et al., 2023), conduct and publish research (Kukharuk et al., 2023) and conduct integrated lessons between languages and science (Rhodes et al., 2024).

The four components are implemented in a variety of ways in the training programs. Learning tasks range from concrete implementation at school (Frerejean et al., 2021) or in real-life situations (Lim et al., 2009) to implementation on online platforms such as Moodle (Lim et al., 2015). General information such as graphic representations of the 4C/ID principles (Frerejean et al., 2021), teaching/learning strategies (Yan et al., 2012) or structures to support lesson preparation (Rhodes et al., 2024) are provided as supportive information in the various training courses. Specific information such as concrete examples, checklists and handouts (Meutstege et al., 2023) are also provided. For procedural information, enquiries can be made to coaches (Frerejean et al., 2021) or step-by-step instructions are provided, e.g., for various Excel functions (Lim et al., 2009). None of the texts provided specific tasks for part-task practice.

In general, it was surprising to find only a few texts on in-service training with 4C/ID for teachers, especially because 4C/ID is just as suitable for teacher training as it is for medical or technical training and fulfills the criteria for effective training (Lipowsky and Rzejak, 2015). The real-life tasks of the individual training programs relate primarily to the technical and methodological skills of teachers. There are still gaps, particularly in subject-specific and didactic topics, although the implementation of these areas can also be interesting.

6.6 Summary of all results

We give a short summary of the raised research questions and the corresponding answers based on our systematic review.

How is 4C/ID documented in publications that cite 4C/ID as the theoretical framework for development of in-service training courses?

- 54% of the papers describe all four components of the 4C/ID model.
- Only 11% describe the 10 steps.

In which professional groups is 4C/ID used and for which real-life tasks?

- Most papers are published in the fields of education and medicine. Within these categories, there is a wide range of specific professions for which the training is designed.
- The real-life tasks mentioned most frequently are programming, teaching, and expanding research skills, as well as medical applications.

What is the estimated mean pre-post effect for such in-service 4C/ID interventions?

- The overall effect size was significant, indicating a moderate positive effect of 4C/ID courses regarding learning gains.
- In line with our hypothesis, the category “4 components reported” showed a significant pre-post effect, the category “4 components not reported” showed no significant pre-post effect. However, the difference in effect size between “reported” and “not reported” was not statistically significant.
- The “education” category showed only a descriptive positive, yet not significant effect, while the category “Medicine” showed a descriptive zero-effect that was not significant. In the “craft” category, participants increased significantly between pre and post-test. *Post-hoc* analysis showed that the difference in the effect size is statistically significant between “Education” and “Crafts.”
- There were no significant effects between the Categories “hands on,” “offline,” and “online.” The difference in the effect size was also not statistically significant.

If 4C/ID is implemented, what methodological approaches and which methodological concretizations are used for components and steps?

- If the four components are described, then the first three components learning tasks, Supportive information and Procedural information are often described methodically in their implementation.
- Part-task practice is sometimes missing, which is not surprising as it is considered optional.
- The 10 steps, if described, are described in detail and explain the exact design of the learning environment. Here too, individual steps are sometimes summarized and described together.

Has 4C/ID been implemented in teacher training programs to date? And if so, how and for what?

- Eleven of the 55 texts describe training programs for teachers. Seven papers describe at least the four components, two additionally describe the 10 steps in detail.
- In general, it was surprising to find only a few texts on in-service training with 4C/ID for teachers, especially because 4C/ID is just as suitable for teacher training as it is for medical or technical training and fulfills the criteria for effective training.

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7 Limitations and future research

A limitation of this systematic review is that only English-language publications were included in the analysis. As a result, relevant studies published in other languages may have been overlooked and therefore the results may not be complete.

In addition, the scope of the literature included was limited to articles in peer-reviewed journals, excluding other sources such as books, conference proceedings and dissertations. This decision was made to ensure a high methodological standard, which may also affect the completeness of the study.

Another challenge arises from the unconventional definition of further training used in this study. This may have influenced the double coding process, making it difficult to achieve the desired level of consistency; therefore, the categories used may not have been entirely clear or applied consistently, which could affect the reproducibility and comparability of the results.

Finally, another limitation is the limited number of studies that provide concrete, analyzable data. This limits the ability to perform a thorough quantitative analysis. As a result, the statistical power of the review results may be limited because only a small number of studies provide a solid data-driven basis for further interpretation.

The results show that training programmes designed in line with the 4C/ID model have not yet reported or described their specific design mechanisms in enough detail in the articles currently available. Both the four components and the 10 steps should be taken into account and specifically report in contrast of the reported studies. We strongly recommend describing the four components and 10 steps in relation to the research topic of interest.

8 Conclusion

4C/ID fulfills many of the criteria for good and effective training and our meta-analytical data underpins that 4C/ID—if implemented adequately—will lead to high quality training. In addition, our synthesis shows that 4C/ID is currently used in a variety of training programs. However, neither the four components or the 10 steps are adequately described in many papers, which makes both replication of the effects, a qualitative evaluation of the interventions, and the transformation of the courses into practice highly difficult.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

MN: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. TL: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing. FR: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing.

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