

The Four-Component Instructional Design Model

An Overview of its Main Design Principles

*Jeroen J. G. van Merriënboer
Maastricht University
The Netherlands*



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Author

Jeroen J. G. van Merriënboer

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School of Health Professions Education
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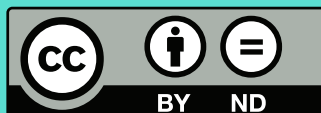


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The four-component instructional design model (4C/ID) receives a lot of attention because it nicely fits current trends in education: (a) a focus on the development of complex skills or professional competencies, (b) increasing transfer of what is learned in school to new situations including the workplace, and (c) the development of 21st century skills that are important for lifelong learning.



The 4C/ID model has been extensively described in scientific articles (e.g., van Merriënboer, Clark, & de Croock, 2002; Vandewaetere, Manhaeve, Aertgeerts, Clarebout, van Merriënboer, & Roex, 2015) and two books in the English language: *Training Complex Cognitive Skills* (van Merriënboer, 1997) and *Ten Steps to Complex Learning* (van Merriënboer & Kirschner, 2018).

The aim of this report is to give a concise description of the main characteristics of the 4C/ID model. First, a description will be given of the four components from which competence-based education is built. Second, it will be briefly explained how an integrated curriculum based on the four components helps to reach transfer of learning. Third, a description is given of the systematic 4C/ID design process, with a focus on the main instructional design principles that are prescribed by the model. The report ends with a short discussion positioning the 4C/ID model in the field of educational sciences.

The Four Components

The 4C/ID model aims to help instructional designers with the development of educational programs for teaching complex skills or professional competencies. It describes educational programs as being built from four components: (1) learning tasks, (2) supportive information, (3) procedural information, and (4) part-task practice (see Figure 1).

Component 1: Learning Tasks

Learning tasks are treated as the backbone of an educational program (see the large green circles in Figure 1). They can be cases, projects, professional tasks, problems or assignments that learners work on. They will perform these tasks in a simulated task environment and/or a real-life task environment (e.g., the workplace). A simulated task environment can have a very low fidelity, for example, when a case is presented on paper (“suppose you are a doctor and a patient is coming into our room....”) or when a role play is performed in the classroom, but it can also have a very high fidelity, like a high-fidelity simulator of an aircraft for training pilots or an emergency room for training trauma care teams.

Learning tasks are preferably based on whole tasks that make an appeal on knowledge, skills and attitudes that are needed for

performing tasks in the future profession or in daily life. In addition, they require both non-routine skills such as problem solving, reasoning and decision making, and routine skills which are always performed in the same way (van Merriënboer, 2013). Learning tasks drive a basic learning process that is known as inductive learning – students learn by doing and by being confronted with concrete experiences.

Variability. Effective inductive learning will only be possible when there is variability over learning tasks (indicated by the small triangles in the learning tasks in Figure 1). That is, learning tasks must be different from each other on all dimensions on which tasks in the later profession or in daily life are also different from each other. Only then, it will be possible for students to construct cognitive schemas that generalize or abstract away from the concrete experiences; such schemas are critical for reach-

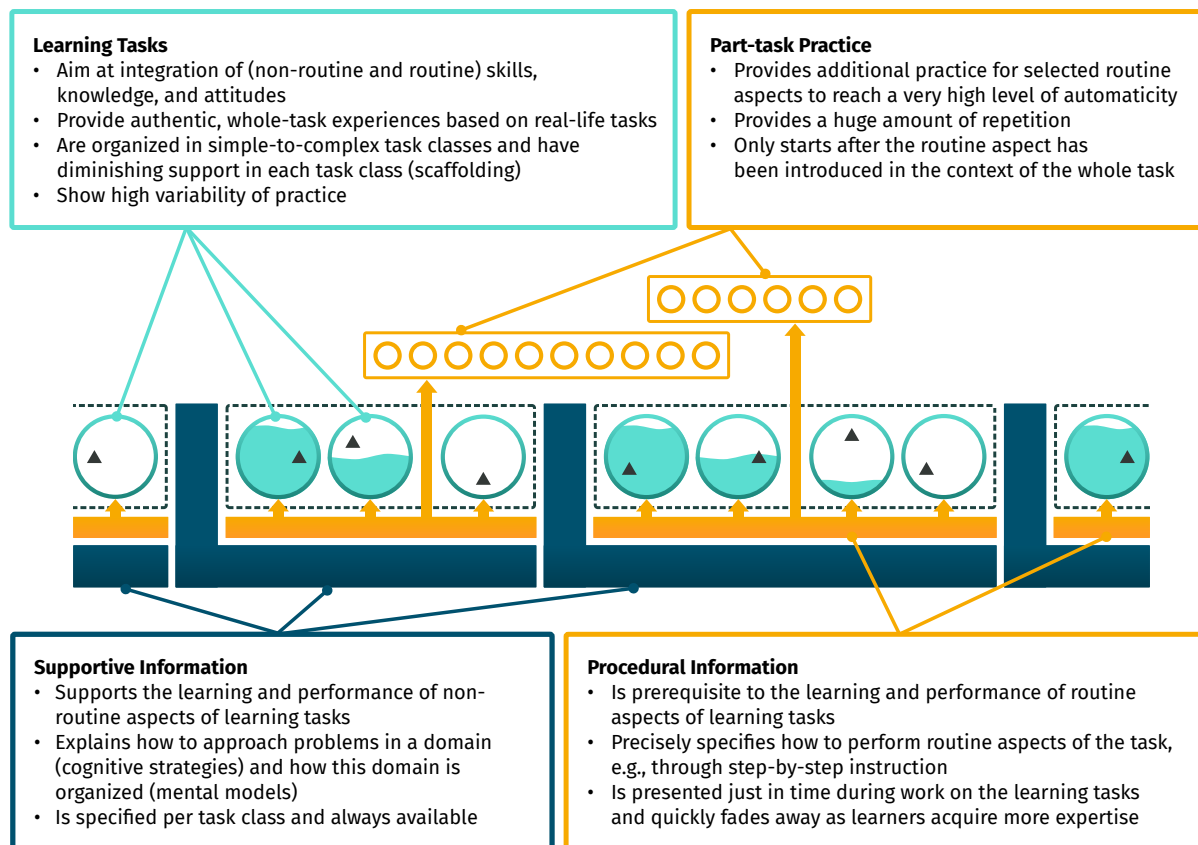


Figure 1: The four components.

ing transfer of learning (van Merriënboer, 2012). They represent which features of a learning task do not affect the way it should be performed (i.e., surface features) and which features do affect the way it should be performed (i.e., structural features).

Levels of Complexity. To prevent cognitive overload, students will typically begin to work on relatively simple learning tasks and, as their expertise increases, work on more and more complex tasks (van Merriënboer & Sweller, 2005, 2010). There are thus levels of complexity with equally difficult tasks (see the dotted dark green lines encompassing a set of equally complex learning tasks in Figure 1). But tasks at the same level of complexity must differ from each other on all dimensions on which real-life tasks also differ from each other. Consequently, there must be variability of practice on each level of complexity. At the first level of complexity, students will be confronted with learning tasks that are based on the easiest tasks a professional might encounter; at the highest level of complexity, students will be confronted with the most difficult tasks a beginning professional must be able to handle, and additional levels of complexity may be added in between in order to guarantee a gradual increase of complexity over levels.

Support and Guidance. Students will often receive support and guidance when they are working on the learning tasks (see the filling of the large circles in Figure 1). When students start to work on more complex tasks, thus, progress to a higher level of complexity, they will initially receive a lot of support and guidance. On one particular level of complexity, support and guidance will gradually decrease in a process known as ‘scaffolding’ – as an analogy of a scaffold that is broken down when the building is constructed (van Merriënboer, Kirschner, &

Kester, 2003). When students are able to perform the last learning tasks at a particular level of complexity independently, without any support or guidance (i.e., ‘empty’ learning tasks without any filling in Figure 1), they are ready to progress to a next level of complexity. Then, the process of scaffolding will start all over again, yielding a saw-tooth pattern of support and guidance throughout the whole educational program. Support can be given through different types of learning tasks, for example, on one particular level of complexity, students can first study worked-out examples or case studies, then complete increasingly larger parts of given incomplete solutions, and only at the end fully perform the tasks by themselves (Renkl & Atkinson, 2003). Guidance can be given by a teacher who guides the students through the process of performing the task, or by external aids such as process worksheets in which ‘leading questions’ are asked to guide the students through the process of performing the tasks (Nadolski, Kirschner, & van Merriënboer, 2006).

Component 2: Supportive Information

Learning tasks typically make an appeal on both non-routine and routine skills, which might be performed simultaneously. Supportive information (indicated by the blue L-shaped forms in Figure 1) helps students with performing the non-routine aspects of learning tasks, which require problem solving, reasoning and/or decision making. Teachers often call this information ‘the theory’ because it is typically presented in study books, lectures and online resources. It describes how the task domain is organized and how problems in the domain can be approached in a systematic fashion (i.e.,

how the actions of the task performer are organized in the domain).

The organization of the task domain is represented by the learner in cognitive schemas known as mental models. In the medical domain, for example, it pertains to knowledge of symptoms of particular diseases (conceptual models – what is this?), knowledge of the build of the human body (structural models – how is this built?), and knowledge of the working of the heart-lung system and other organ systems (causal models – how does this work?). The organization of own actions in the task domain is represented by the learner in cognitive schemas known as cognitive strategies. Such strategies identify the subsequent phases in a systematic problem-solving process (e.g., diagnostic phase – treatment phase – follow-up phase) as well as the rules-of-thumb or heuristics that can be helpful for successfully completing each phase.

Supportive information provides the link between what students already know (i.e., their prior knowledge) and what they need to know in order to perform the non-routine aspects of learning tasks. Instructional methods for the presentation of supportive information facilitate the construction of cognitive schemas in a process of elaboration. That is, the information is presented in such a way that it helps learners to establish meaningful relationships between newly presented information elements and the knowledge they already possess in memory (van Merriënboer, Kirschner, & Kester, 2003). This is a form of deep processing, yielding rich cognitive schemas (i.e., mental models and cognitive strategies) that enable the learner to understand new phenomena and to approach unfamiliar problems. The provision of cognitive feedback plays an important role in this

process. This feedback stimulates learners to critically compare their own mental models and cognitive strategies with those of others, including experts, teachers and peer learners.

The supportive information is identical for all learning tasks at the same level of complexity, because these tasks are equally difficult and thus make an appeal on the same knowledge base. Therefore, the supportive information in Figure 1 is not connected to individual learning tasks but to levels of complexity; it can be presented before learners start to work on the learning tasks (under the motto ‘first the theory and only then start to practice’) and/or it can be consulted by learners who are already working on the learning tasks (under the motto ‘only consult the theory when needed’). The supportive information for each next level of complexity is an extension or enrichment of the previously presented information – the additional information allows students to perform more complex tasks they were not able to complete before. The organization from simple to more and more complex tasks, coupled to increasingly more detailed knowledge of the domain, has also been called the ‘spiral curriculum’ (Bruner, 1960).

Component 3: Procedural Information

Procedural information (in Figure 1, the yellow beam with arrows pointing upwards to the learning tasks) helps students with performing the routine aspects of learning tasks, that is, aspects that are always performed in the same fashion. Procedural information is also called just-in-time information, because it is best provided during the performance of particular learn-

ing tasks. It typically has the form of 'how-to' or 'step-by-step' instructions that are given to the learner by a teacher or user guide, telling how to perform the routine aspects of the task while doing it. The advantage of a teacher over a user guide is that the teacher can act as an 'assistant looking over your shoulder' and give instructions and corrective feedback on precisely the moment it is needed by the learner for correctly performing the task. Procedural information for a particular routine aspect is preferably presented to the learner the first time he or she must perform this aspect as part of a learning task. For subsequent tasks, the presentation of procedural information is gradually faded because the need for it diminishes as the learner is slowly mastering the routine.

Procedural information is always specified at a basic level that can be understood by the lowest ability learners. Instructional methods for the presentation of procedural information aim at a learning process that is known as rule formation: Learners use how-to instructions to form cognitive rules that couple particular – cognitive – actions to particular conditions (e.g., IF you work on an electrical installation THEN first disconnect the fuses). After extensive practice, cognitive rules become automated schemas that enable learners to perform routine aspects fast, errorless and without conscious control (Anderson, 1987). Rule formation is facilitated when knowledge that is prerequisite to the correct use of how-to instructions is presented together with those instructions (e.g., prerequisite knowledge for the presented rule is: You can probably find the fuses in the meter board). Thus, when a learner is performing a learning task that contains routine aspects in the perceptual motor domain, a good teacher will tell the learner just-in-time what to look at and how to operate instruments and

objects, and also make sure that the learner has the knowledge that is prerequisite to correctly following the how-to instructions.

Component 4: Part-task Practice

Learning tasks make an appeal on both non-routine and routine aspects of a complex skill or professional competency; as a rule, they provide enough practice for learning the routine aspects. Part-task practice of routine aspects (the small yellow circles in Figure 1) is only needed when a very high level of automaticity of routine aspects is needed, and when the learning tasks do not provide the required amount of practice. Familiar examples of part-task practice are practicing the multiplication tables of 1 to 10 in primary school (in addition to whole arithmetic tasks such as paying in a shop or measuring the area of a floor), practicing the musical scales when playing an instrument (in addition to whole tasks such as playing musical pieces), or practicing physical examination skills in a medical program (in addition to whole tasks such as intake of patients).

Instructional methods for part-task practice aim at the strengthening of cognitive rules by extensive repetitive practice. Strengthening is a basic learning process that ultimately leads to fully automated cognitive schemas (Anderson, 1993). It is important to start part-task-practice in a fruitful cognitive context, that is, after learners have been confronted with the routine aspect in the context of a whole, meaningful learning task. Then, the learners will understand how practicing the routine aspects might help them improve their performance on the whole tasks. The procedural information specifying how to per-

form the routine aspect can be presented in the context of whole learning tasks, but in addition it can be presented again during part-task practice (in Figure 1, see the long upward pointing arrow from procedural information to part-task practice). Part-task practice is best mingled with the work on the learning tasks (intermix training; Schneider, 1985), yielding a highly integrated knowledge base.

The Integrated Curriculum and Transfer of Learning

The four components are aimed at four basic learning processes: (1) Learning tasks facilitate inductive learning, (2) supportive information facilitates elaboration, (3) procedural information facilitates rule formation, and (4) part-task practice facilitates strengthening of those rules. In an integrated curriculum, the relationships between the four components and associated learning processes take a central position. The supportive information is coupled to sets of equally complex learning tasks that show variability over surface and structural features and it is available to students before and/or during their work on the learning tasks; the procedural information is coupled to individual learning tasks and preferably presented to students just-in-time, precisely when they need it to correctly perform the routine aspects of tasks; part-task practice is only presented for routine aspects that need to become fully automated, it is introduced after the routine aspect has been introduced in the context of a meaningful learning task and is best mixed with the work on subsequent learning tasks. An integrated curriculum can best be seen as a skeleton: The learning tasks

serve as its backbone and the other three components are coupled to this backbone in such a way that they best support the development of the complex skills or professional competency taught. Suboptimal relationships between the four components will jeopardize the coherence of the educational program and thus hamper students' schema construction and schema automation.

According to the 4C/ID model, an integrated curriculum is a prerequisite for reaching transfer of learning, that is, to ensure that learners are able to apply the things they have learned to new situations inside and outside the educational program (in particular, the workplace). There are three reasons for this (van Merriënboer, Kester, & Paas, 2006). First, whole meaningful learning tasks that aim at the development of knowledge, skills and attitudes (i.e., 'integrative objectives', Gagne & Merrill, 1990) help learners construct a rich, integrated knowledge base, which increases the chance that useful knowledge can be found in memory when facing new situations. Second, the ordering of learning tasks from simple to complex, in combination with a gradual decrease of support and guidance on each level of complexity, helps students learn to coordinate the different aspects of performance; such coordination is also needed to strategically combine acquired skills, knowledge and attitudes in new problem situations. Third, the distinction between non-routine and routine aspects of complex skills enables learners to perform the selected routine aspects, after part-task practice, fast and effortlessly; as a result, they have more cognitive resources available to deal with the non-familiar aspects of new problem situations (reasoning, problem solving, decision making) and to reflect on the quality of found solutions (van Merriënboer, 2013).

Design Process and Principles

Five clusters of activities can be distinguished when designing educational programs from the four components. For each activity, 4C/ID prescribes a number of evidence-informed design principles. The activities are:

1. Design learning tasks (green elements in Figure 2). Learning tasks are typically designed on the basis of real-life tasks from the profession or daily life. Design principles relate to level of realism, fidelity, variability, support, and guidance. Different types of learning tasks can be distinguished, such as conventional tasks (where learners must find a solution), completion tasks (where learners must complete a partially given solution) or worked-out examples (where learners must study a given solution).

2. Set standards for acceptable performance (darker green elements). Students who work on learning tasks need feedback and their performance will be assessed. Performance objectives are based on a skills hierarchy, and describe for all different aspects of performance the standards (criteria, values, attitudes) that must be reached by the learners. Assessment instruments contain scoring rubrics for all those standards.

3. Sequence learning tasks (darkest green elements). Learning tasks are ordered from simple to increasingly more complex levels, using either a whole-task or part-task approach. If assessment information is available on student progress (step 2 above), this can be used to develop individualized learning trajectories or to give self-directed learners advice on the learning tasks they should best select.

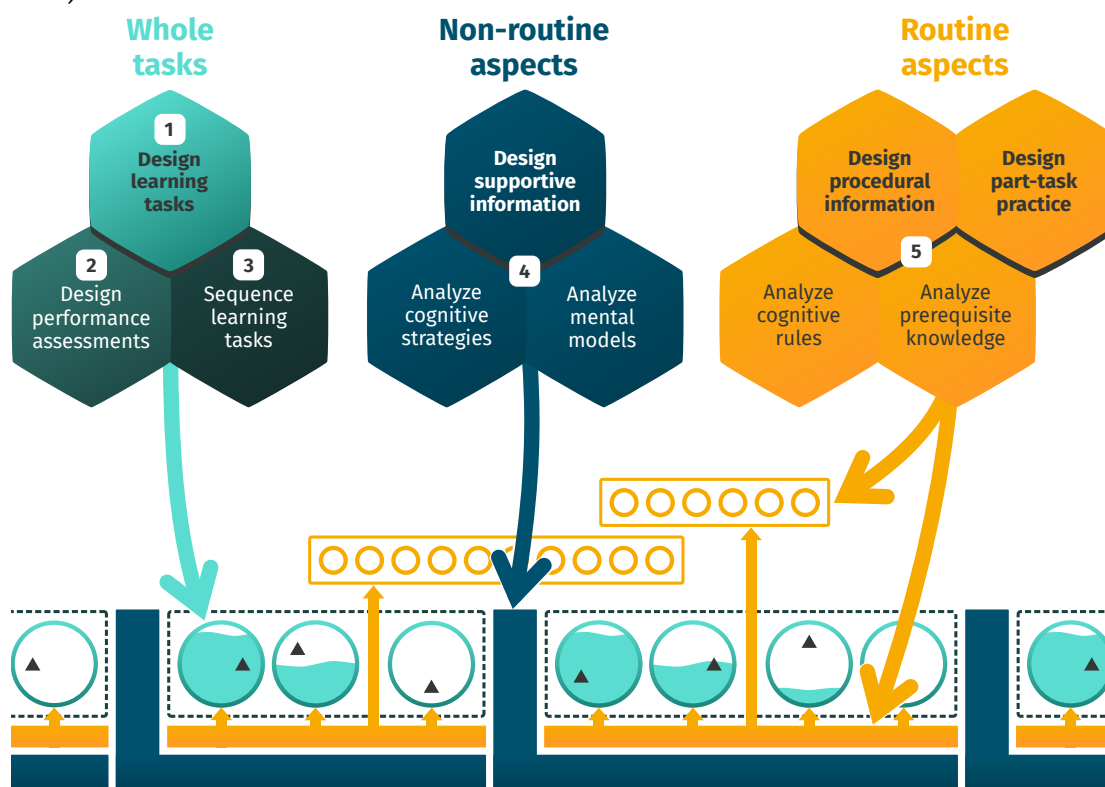


Figure 2: Five clusters of activities in the 4C/ID design process.

4. Design supportive information for non-routine aspects (blue elements). Supportive information helps learners to perform non-routine aspects of learning tasks and provides them with domain models (aimed at the development of mental models), systematic approaches to problem solving (aimed at the development of cognitive strategies), and cognitive feedback. Sometimes, an in-depth analysis of to-be-acquired mental models and cognitive strategies is necessary.

5. Design procedural information and part-task practice for routine aspects (yellow elements). Procedural information tells learners how to perform routine aspects of learning tasks and provides them with how-to instructions (aimed at the development of cognitive rules) and corrective feedback. Sometimes, an in-depth analysis of to-be-acquired cognitive rules and prerequisite knowledge is necessary. Part-task practice is designed when a very high level of automaticity of selected routine aspects is required.

Design Learning Tasks

Table 1 presents the main principles for the design of learning tasks. First, real-life tasks from the profession or from daily life should be taken as a starting point for the design of learning tasks. Such real-life tasks typically make an appeal on skills, knowledge as well as attitudes and thus help the learners develop complex skills or professional competencies. Second, learning tasks will typically be performed by the learners in either a simulated or the real task environment. In order to provide a safe environment for learning and to protect novice learners from processing too many irrelevant details, one might work from low-fidelity environments (e.g., paper based cases, role play), via higher fidelity environments (computer-based simulation, high-fidelity simulation) to real-life task performance at the workplace. Third, it is critical that learning tasks in the educational program differ from each other on all dimensions on which real-life tasks also differ from each other, thus, the learning tasks must be representative for all tasks a professional encounters in the real world.

Table 1: Design Principles for Learning Tasks.

LT1 Realism	Take meaningful whole tasks from the profession or from daily life as a starting point for the design of learning tasks; preferably, these tasks make an appeal on knowledge, skills and attitudes.
LT2 Fidelity	Throughout the educational program, there is a smooth transition from working in a safe simulated task environment, via task environments with increasingly higher fidelity, to real-life practice.
LT3 Variability	Learning tasks in an educational program must differ from each other on all dimensions on which real-life tasks also differ from each other, thus, the whole set of learning tasks must be representative for real-life task performance.
LT4 Support	Provide learners support by giving them learning tasks that do not require them to independently perform the total task, for example, have them study examples or demonstrations or let them complete partially given solutions.
LT5 Guidance	Provide learners guidance for performing the learning tasks by providing them with a systematic approach to problem solving, rules of thumb, or process worksheets.
LT6 Scaffolding	Gradually decrease the amount of given support and guidance as students acquire more expertise, until they are able to perform the learning tasks without any support and guidance.

This is true for both surface features, which do not affect the way the task is performed, and structural features, which do affect the way the task is performed. Fourth and fifth, learners who work on learning tasks should initially receive sizable support and/or guidance. Support is ‘built into’ the tasks and relates to the use of worked out examples or case studies, completion tasks, goal-free problems, reverse tasks, imitation tasks, and so forth. Guidance is ‘added’ to the task and relates to guidance provided by a teacher or a process worksheet with leading questions. It helps the learner to apply an effective cognitive strategy by following a systematic approach to problem solving. Finally, there should be a process of ‘scaffolding’ on each level of complexity, meaning that there is a gradual decrease of support and guidance as students acquire more expertise, until they are able to perform the learning tasks independently, without any support and guidance. But then, learners might continue to work on tasks at a higher level of complexity, and the process of scaffolding starts all over again – yielding a saw tooth pattern of support and guidance throughout the whole educational program.

Set Standards for Acceptable Performance

Table 2 presents the main principles for setting standards for acceptable performance. Such standards are necessary to assess learners’ performance on learning tasks and to provide them with feedback. First, a skills hierarchy or competence map is drawn up to identify all constituent skills that make up effective task performance; non-routine constituent skills will be at the top of the hierarchy and routine constituent skills might appear in the bottom of the hierarchy. This hierarchy or map provides an overview of all aspects on which student performance can be assessed. Second, performance objectives are formulated for all identified constituent skills: They contain an action verb to characterize the selected aspect of performance, the conditions under which this performance takes place, objects and tools that are used by the task performer, and standards for acceptable performance. Third, these performance objectives can be classified as non-routine, meaning that they relate to schema-based problem solving and reasoning and need the presentation of supportive information;

Table 2: Design Principles for Setting Standards for Acceptable Performance.

ST1 Skills hierarchy	Make a hierarchy or map of constituent skills enabling the complex skill or professional competency that is taught. This provides an overview of all relevant aspects of performance.
ST2 Performance objectives	Formulate performance objectives for all constituent skills in the skills hierarchy, containing an action verb, conditions, tools/objects used, and standards for acceptable performance.
ST3 Classify objectives	Classify objectives as non-routine (requiring supportive information), routines (requiring procedural information), or fully automated routines (also requiring part-task practice).
ST4 Specify standards	For each objective, specify the standards for acceptable performance in terms of criteria (e.g., allotted time, accuracy), values (e.g., according to particular conventions), and attitudes.
ST5 Performance assessment	Develop an assessment instrument with scoring rubrics for all standards, allowing you to measure student performance on (learning) tasks as well as progress over tasks.

routine, meaning that they relate to the application of rules or procedures and need the presentation of procedural information, or to-be-automated routine, meaning that they not only need the presentation of procedural information but also of part-task practice. Fourth, standards are further specified and may relate to hard criteria (time, errors), values (according to particular regulations or conventions) and desired attitudes. Finally, scoring rubrics can be developed for all identified standards and combined in an assessment instrument such as a development portfolio. A development portfolio makes it possible to assess the performance of a learner on all aspects that are relevant for a particular learning task, and to monitor learner progress over a series of learning tasks (van Merriënboer & van der Vleuten, 2012).

Sequence Learning Tasks

Table 3 describes the main principles for the sequencing of learning tasks from simple to complex. First, by default, a form of whole-task sequencing is used. Then, even the simplest learning tasks at the lowest level of complexity are based on the simplest tasks a professional might encounter in the real world. In the ‘simplifying conditions approach’, all conditions that simplify task

performance are identified and applied to tasks at the lowest level of complexity; for increasingly higher levels of complexity, the conditions are relaxed. Second, if it proves impossible to find whole tasks that are simple enough to start with in the educational program, part-task sequencing is used. According to 4C/ID, the preferred part-task sequencing approach is ‘backward chaining with snowballing’. Suppose that students learn computer programming which consists of three constituent skills: A = program design, B = coding, and C = debugging. At the lowest level of complexity, learners would then debug ready-made computer programs given their design and code (C_{AB}); at a medium level of complexity, they would code and debug computer programs given their design (BC_A), and only at the highest level of complexity, they would design, code and debug computer programs from scratch (ABC). Third, sequencing of learning tasks need not be identical for all learners. Given assessment results, it is possible to create individualized learning trajectories. Learners who quickly reach the standards will then receive more complex tasks with less support and guidance than learners who need more time to reach those standards, and they will thus also proceed more quickly through the series of learning tasks and reach the final attainment level after a shorter period of time/number of

Table 3: Design Principles for Sequencing Learning Tasks on Complexity Levels.

CL1 Whole-task sequencing	Identify conditions that simplify task performance, and use these conditions to sequence learning tasks from the simplest level to increasingly more complex levels.
CL2 Backward chaining	If necessary, use backward chaining with snowballing; if the whole task is ABC, learners first practice C given results of A and B, then practice BC given results of A, and finally practice ABC.
CL3 Individualization	Use student assessment results to set up individualized learning trajectories; learning tasks are selected on a level of difficulty and with a level of support /guidance fitting individual learning needs.
CL4 Self-directed learning	Give learners control over the selection of learning tasks; second-order scaffolding gradually shifts the responsibility over task selection from the teacher to the student.

learning tasks (Salden, Paas, & van Merriënboer, 2006). Fourth, assessment results may also be used to support a process of self-directed learning, which is a key 21st century skill. Then, learners are free to select their own learning tasks but receive advice on the selection process given their assessment results (van Merriënboer & Sluijsmans, 2009).

Design Supportive Information for Non-routine Aspects

Table 4 describes the main principles for designing supportive information, which helps learners to perform and learn non-routine aspects of learning tasks. First, a distinction is made between necessary domain models, systematic approaches to problem solving, and cognitive feedback. Second, with regard to domain models, a further distinction is made between conceptual models, which describe what things are important in the domain and how they are named (what is this?), structural models, which describe how things are organized or structured in the domain (how is this built?), and causal models, which describe how things work in the domain (how does this work?). Domain models are illus-

trated with concrete examples or cases. Often, descriptions of domain models and illustrations of them will be available in existing instructional materials. But if not, it may be necessary to analyze the mental models of experts in the task domain in a process of cognitive task analysis (CTA; see Clark, Feldon, van Merriënboer, Yates, & Early, 2008) in order to define the domain models that must be presented to learners. Third, with regard to systematic approaches to problem solving or SAPs, a description is given of the phases a task performer goes through when systematically performing the task. For each phase, rules-of-thumb or heuristics are provided that might help to successfully complete this phase. SAPs are illustrated with so-called modeling examples, that is, an expert showing how to systematically approach a problem and explaining why he is doing what he is doing; here, it is important to make hidden problem-solving processes explicit to the learners (van Gog, Paas, & van Merriënboer, 2006). Again, descriptions of SAPs and illustrative modeling examples might already be available in existing instructional materials, but if not, CTA will help to identify them. Fourth, cognitive feedback needs to be provided to the learners. It is seen as part of supportive in-

Table 4: Design Principles for Supportive Information.

SI1 Supportive information	Supportive information helps students perform non-routine aspects of learning tasks. It contains domain models, systematic approaches to problem solving (SAPs), and cognitive feedback.
SI2 Domain models and mental models	Domain models describe how the learning domain is organized and include conceptual models, structural models and causal models. The specification of domain models may require the analysis of mental models of experts in the task domain.
SI3 SAPs and cognitive strategies	SAPs describe successive phases in task performance and the rules-of-thumb that may help to successfully complete each phase. The specification of SAPs may require the analysis of cognitive strategies of experts in the task domain.
SI4 Cognitive feedback	Cognitive feedback stimulates learners to critically compare their own mental models and cognitive strategies with given domain models or SAPs, or with the mental models and cognitive strategies of other persons, including teachers, experts and peers.

formation because it aims at elaboration as the main learning process, which is connecting new information to what the learner already knows. Well-designed cognitive feedback stimulates learners to critically compare and contrast their own mental models with presented domain models or with the mental models of others (experts, teachers, peers), and it stimulates them to critically compare and contrast their own cognitive strategies with presented SAPs or with the cognitive strategies of others.

Design Procedural Information and Part-task Practice for Routine Aspects

Table 5 describes the main principles for designing procedural information, which helps learners perform and learn routine aspects of learning tasks, and part-task practice, which helps learners fully automate selected routine aspects. First, a distinction is made between necessary how-to instructions and corrective feedback. Second, with regard to how-to instructions, a further distinction can be made between the presentation of single rules, which specify what to do under particular conditions, and

the presentation of procedures, which specify how to perform a series of steps (often in the form of an algorithmic flow-chart, which should not be confused with a heuristic SAP). How-to instructions need to be given just-in-time, precisely when the learner needs them, by a teacher acting as an ‘assistant looking over your shoulder’, a manual, a quick reference guide or, nowadays, instructions on a smartphone. The instructions may need to include prerequisite knowledge, that is, things the learner needs to know in order to correctly perform the rule or procedure. For example, when the rule is ‘IF you start the procedure THEN push the power button’ it may be necessary to add: ‘the power button is red and can be found on the back of the machine’. How-to instructions are exemplified with concrete demonstrations. How-to instructions and demonstrations will often be available in existing instructional materials, but if not, CTA is used for their identification. Third, corrective feedback needs to be given to learners. If a rule or procedure is not correctly applied by them, immediate feedback is provided that signifies the error, explains its cause, and provides hints on how to recover from the error and continue with the task. Fourth, if full automaticity of particular routine aspects is required, part-task practice needs to be provided to the learn-

Table 5: Design Principles for Procedural Information and Part-Task Practice.

PP1 Procedural information	Procedural information helps students perform routine aspects of learning tasks. It contains how-to instructions and corrective feedback.
PP2 How-to instructions, cognitive rules, and prerequisite knowledge	How-to instructions tell just-in-time how to perform routine aspects of learning tasks. The specification of how-to instructions may require the analysis of cognitive rules used by experts in the task domain and the knowledge prerequisite to the correct use of those rules.
PP3 Corrective feedback	Corrective feedback immediately signifies an error, explains the cause of the error, and provides hints on how to recover from the error and continue with the task.
PP4 Part-task practice	Part-task practice helps to fully automate routine aspects of learning tasks. It first focuses on accuracy, then speed, and finally time-sharing with other tasks.

ers. In part-task practice, learners first practice until they can perform the routine without errors, then continue practicing under increasing time pressure, and finally continue practicing under time-sharing conditions (i.e., they perform the routine together with other tasks).

Discussion

This report provided a very short description of the main elements of the 4C/ID model. The model is rooted in the early 1990s (van Merriënboer, Jelsma, & Paas, 1992). By that time, traditional objectives-driven instructional design models were increasingly criticized because students often experienced their educational program as a disconnected set of topics and courses, with implicit relationships between them and unclear relevance to their future profession. This complaint prompted a new interest in instructional design for integrative goals (Gagné & Merrill, 1990), for example, when complex skills or professional competencies are taught. The traditional atomistic approach, where complex contents and tasks are reduced into simpler elements up to a level where the single elements can be transferred to learners through presentation and/or practice, was replaced by a holistic approach, where complex contents and tasks are taught from simple-to-complex wholes in such a way that relationships between elements are retained. The 4C/ID model shares this perspective with other whole-task instructional design models, such as Cognitive Apprenticeship Learning (Brown, Collins, & Duguid, 1989) and Merrill's First Principles of Instruction (Merrill, 2012; for an overview of whole-task models, see van Merriënboer & Kester, 2008).

Around the same time, in the 1990s, a social-constructivist approach to learning

became more and more popular, and it still is today. The 4C/ID model adopts a moderate constructivist approach. The basis for an educational program is whole-task practice, offering non-trivial, realistic and increasingly more complex tasks (problems, projects, cases) to learners, and often these tasks will be performed collaboratively. Schema construction by inductive learning and elaboration are the main learning processes. These processes are under strategic control of the learners: They actively construct meaning or new cognitive schemas that allow for deep understanding and complex task performance. Yet, the 4C/ID model also has some clear 'instructivist' features. These are readily visible in the how-to instructions and corrective feedback for routine aspects of learning tasks, and in part-task practice for routines that need to be developed to a very high level of automaticity. In my view, the learning sciences should acknowledge that social constructivist and traditional 'instructivist' approaches rest on a common psychological basis and should complement each other. The 4C/ID model aims to combine the best of both worlds.

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