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Designing Instruction for Complex Learning

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Editor's Note

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Continuing technological and societal innovations create high demands on the field of education. In order to deal with increasing globalisation, multidisciplinarity, mobility and the complexity of current and future jobs, a strong emphasis is placed on quality and efficiency at all levels of education and training (European Union, 2009, 2018). To prepare learners for a job market that is continually evolving, it is imperative that educational programmes provide them with an extensive knowledge and skills base that they can apply flexibly when encountering unfamiliar tasks in daily practice. This requires different instructional design approaches, including a shift away from objectives-based design approaches towards more task-centred approaches in an attempt to better address the learning of complex cognitive skills and professional competencies.

The objectives-based approach breaks down tasks into their constituent parts and describes desired outcomes for each of these part-tasks in learning objectives which are often classified according to a taxonomy such as Bloom's revised taxonomy (Anderson & Krathwohl, 2001) or Marzano and Kendall's taxonomy (2007). Bloom's revised taxonomy, for example, classifies objectives in the cognitive domain in six categories based on remembering, understanding, applying, analysing, evaluating and creating. These taxonomies result from the idea that different instructional methods are needed to reach objectives in different categories. Teaching concepts and principles (e.g., understanding what a scientific paper is and how it is structured) requires different instructional methods from teaching the application of procedures (e.g., carrying out a literature search for a paper). This objectives-based approach is suitable for tasks where there are few relations between the objectives. However, it is less effective for those that require an integration of knowledge, skills and attitudes and the coordination of sometimes many different constituent skills (van Merriënboer & Dolmans, 2015). First, the *compartmentalisation* of learning into separate categories of objectives and using separate methods for declarative, procedural and affective learning is ineffective because carrying out a complex professional task requires more than just the stacking of these constituent elements. Instead, carrying out complex tasks generally requires an *integration* of knowledge, skills and attitudes in so-called competencies. Instruction should therefore focus on developing an interconnected knowledge base that allows one to activate different kinds of knowledge when confronted with new and unfamiliar tasks (Janssen-Noordman, van Merriënboer, van der Vleuten, & Scherpbier, 2006).

Second, the objectives-based approach of teaching complex skills leads to *fragmentation*. Because it breaks up the complex tasks into separate isolated parts, students only learn a limited number of skills at the same time. Instruction is focused on parts of the task and provides little opportunity to learn how to *coordinate* the performance of these separate parts into a coherent whole when confronted with a professional task (Lim, Reiser, & Olina, 2009). In an attempt to address these problems of fragmentation and compartmentalisation, task-centred approaches centre learning on whole real-world (i.e., authentic) problems or professional tasks as a way to better connect the learning setting to the workplace setting and foster the necessary skills. This holistic approach advocates creating educational programmes that contain sequences of learning tasks that are based on authentic professional tasks. Examples of task-centred models are cognitive apprenticeship (Brown, Collins, & Duguid, 1989), elaboration theory (Reigeluth, 1999), first principles of instruction (Merrill, 2002) and the four-component instructional design model (4C/ID model) (van Merriënboer, 1997).

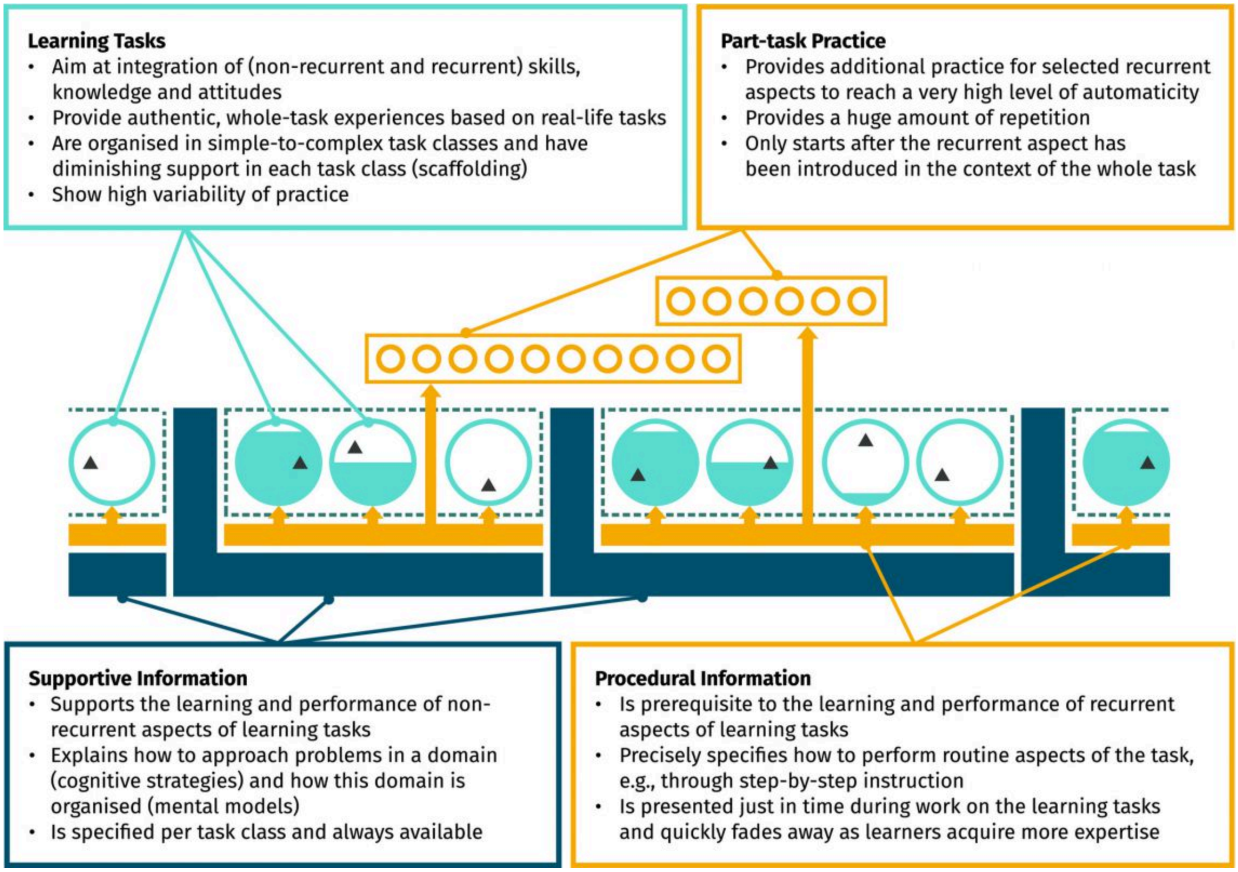
This chapter provides a brief summary of the 4C/ID model and illustrates its application in higher education by describing an educational programme that was designed using the model. The chapter concludes with a short reflection on the educational programme that was developed, a list of important considerations for implementing task-centred curricula and a look at future developments in task-centred learning.

Four-Component Instructional Design (4C/ID)

The basic assumption of the 4C/ID model is that educational programmes for complex learning or the teaching of professional competencies (i.e., the integration of knowledge, skills, and attitudes and coordination of skills and their constituents) can be described in four components, namely learning tasks, supportive information, procedural information and part-task practice (see Figure 1).

Figure 1

Overview of 4C/ID model, Based on Van Merriënboer and Kirschner (2018)



Learning tasks form the backbone of the instructional blueprint and are based on authentic real-life situations that are encountered in practice because this helps the learner to acquire the knowledge, skills and attitudes in an integrated fashion. Learning tasks can be projects, tasks, cases, problems, or other types of assignments. Importantly, they show a variation that is representative of the variation in tasks in professional or daily life because this "variability of practice" will help in the transfer of learning. Learning tasks of equal complexity are grouped together, creating task classes that are sequenced from simple to complex. Learners start with the simplest tasks that a professional could encounter and end with tasks at the level of complexity that a recently-graduated student should be able to handle (van Merriënboer, Kirschner, & Kester, 2003). While working on these tasks, the teacher and the instructional materials provide the necessary support and guidance to help learners to carry out the tasks to completion. In a process of scaffolding, this support and guidance are gradually withdrawn until the learners are able to independently carry out tasks of a certain level of complexity before engaging in more complex tasks (i.e., the next task class). The three other components are logically connected to this backbone of learning tasks.

While Figure 1 may suggest a linear path through these learning tasks, the model allows for extensive flexibilisation and personalisation of learning. Learners may be given the opportunity to select different paths through the designed learning tasks, based on their interest or demonstrated proficiency. One way to support this dynamic selection is by using electronic development portfolios that help students and teachers to monitor progress and make informed decisions on future learning tasks that fit the learner's level and needs (Beckers, Dolmans, & van Merriënboer, 2019; Kicken, Brand-Gruwel, van Merriënboer, & Slot, 2009).

The second component, supportive information, is often referred to as "the theory" and includes information to develop mental models and cognitive strategies that are necessary to complete the learning tasks. Supportive information aims at non-recurrent aspects of the task that deal with problem-solving, reasoning and decision making. It can be presented in the form of lectures, workshops, or study materials and is available for students to study before or while they carry out the learning tasks. These first two components help students to acquire highly-structured knowledge, or cognitive schemas. Learning tasks stimulate the construction of such schemas through *inductive learning*: a process whereby students learn from mindful abstraction from concrete experiences and examples. Supportive information helps schema construction by *elaboration*: acquiring new knowledge and linking it to the existing knowledge base.

The remaining two components stimulate the *automation* of schemas and the development of automatic, task-specific procedures that can be applied without much demand on cognitive resources. Procedural information aims at recurrent and procedural aspects and provides step-by-step instructions when the learner performs those aspects. Part-task practice, the fourth component, can be included to provide repeated practice to train routine skills until they can be performed automatically. (For a more extensive description of the model, see van Merriënboer, 1997; van Merriënboer et al., 2003; or van Merriënboer & Kirschner, 2018).

A 4C/ID Approach to a Blended Course in Android App Development

Developing mobile applications is a typical complex skill, as it requires extensive knowledge of programming languages, databases, development environments, etc. It also requires multiple skills, such as operating the development software, writing clean and correct codes, and/or designing a user interface. A professional, critical and creative attitude is necessary to translate clients' wishes into a working application. Therefore the development of mobile applications lends itself well to teaching with a task-centred approach. The Amsterdam University of Applied Sciences in the Netherlands designed a course on Android app development using the 4C/ID model (www.android-development.app).

Traditionally, the design of such courses starts from the "theory". Teachers begin with a clear picture of the information their students should know and design a series of lectures to "transmit" this theory to the students. In addition, they design homework assignments to practise with single, small aspects of the whole task. For example, these assignments could focus on how to use loops in the programming language or creating, reading, updating, and deleting information in a database. Teachers then mix lectures with small practice items until all topics have been covered. This follows the approach of traditional design models: starting with the presentation of theoretical knowledge and coupling it to specific practice items. The 4C/ID model topples this approach: it starts by specifying professional tasks, translates these into learning tasks and only then investigates which "theory" should help students to complete these learning tasks.

In their description of the design of the course, Marcellis, Barendsen, and van Merriënboer (2018) elaborate on the use of 4C/ID and the Ten Steps to achieve a blended design consisting of the four components. The learning tasks form the backbone of the curriculum. These are not small practice items focused on a particular aspect of the task (i.e., using loops or updating a database). Instead, learning tasks are whole tasks, based on professional practice, grouped in task classes that grow in complexity. The first task class starts with the least complex (i.e., simplest) whole tasks. For example, the very first task asks the student to develop a single-screen app that simulates a dice roll and asks the user to guess whether the next roll will be higher or lower. Subsequent task classes include learning tasks of increasing complexity, imposing more demands on the user interface, interaction modes and handling of data. At the end of the course, students are asked to create multi-screen applications that retrieve information (e.g., movie information, recipes) from remote locations and allow the user to view, swipe, and manipulate these data.

Students receive strong support and guidance when starting learning tasks in a new and more complex task class. The design achieves this by employing modelling examples and imitation tasks at the start of each task class. The teacher demonstrates the development of an application while thinking aloud and asks students to build an identical application on their computers. In subsequent tasks, students receive partially-completed applications they must finish (i.e., completion tasks), while the final tasks in a task class are conventional tasks without any support and guidance. Hence, support gradually decreases as the student progresses through the task class.

Supportive information helps students with the non-recurrent aspects of the task by providing domain knowledge (e.g., how databases work) and systematic approaches to developing apps (e.g., demonstrations by the teacher). Procedural information helps with the recurrent aspects (e.g., using the development environment or automatic highlighting of incorrect programming syntax). For the designers, providing supportive and procedural information constituted a serious challenge, as both are subject to frequent and unpredictable changes. For example, development software is frequently updated with changed functionality and programming languages continually evolve, requiring programmers to learn new syntax and unlearn old methods. To make sure that the supportive and procedural information reflect the most recent conventions and rules in the domain, the course designers depended less on pre-prepared lectures or recorded videos and instead referred students to a list of external sources, including manuals and Android developer documentation. Not only is it easier to keep a list of links up to date, it also creates a more authentic situation where students learn to study official documentation, as they would do in practice.

As the course is intended for students from all over the world who are studying full-time or part-time, the designers chose a blended design where learning tasks, supportive information and procedural information resided in an online learning environment. Classroom activities can be followed by students on-site and include modelling examples, imitation tasks in small groups and feedback sessions led by the teacher. Other learning tasks are presented in the online learning environment and are performed individually by students. Student evaluations show that students perceive the learning tasks as very helpful for learning how to develop an Android app. The modelling examples specifically contribute to understanding how to approach a certain challenge in Android app development, especially when they not only show the actual coding, but also make explicit the reasoning behind each step. In addition, students perceive the classroom sessions in which they discuss theory using guided questions as beneficial. This Android app development course illustrates a well-executed application of fundamental 4C/ID principles leading to a course design that is strongly informed by educational research.

Conclusion

Designing educational programmes using the 4C/ID model is different from designing using objectives-based approaches. It requires task-centred thinking which may be challenging for designers, teachers and faculty who are schooled and experienced in objectives-based instructional design. The 4C/ID model is well-aligned with the concept of competency-based education, but it stresses that competencies should always be clearly related to the professional tasks the student is expected to carry out after completing the programme. An educational programme taking a competency framework as a backbone for its development and assessment may still hamper the transfer of learning to the workplace if the learning activities in that programme are not strongly based on professional tasks. Designing task-centred learning environments therefore requires assigning equal weight to tasks on the one hand and to the competencies required to carry out these tasks on the other. The Ten Steps approach starts the design by specifying professional tasks to serve as a basis for designing learning tasks. The professional and learning tasks are then explicitly linked to the competencies that are necessary to carry out those tasks up to standards, for example by generating a matrix with tasks at one end and competencies or standards at the other. As seen in the example provided in this chapter, this shifts the balance from the atomistic, compartmentalised and fragmented teaching of isolated objectives towards integrative acquisition of knowledge, skills and attitudes.

Concerning the design and implementation of task-centred curricula, Dolmans, Wolfhagen, and van Merriënboer (2013) identify 12 common pitfalls and tips that may help to make such (re)designs work. The four most significant deal with building infrastructure, multidisciplinary teaching teams, continuous progress monitoring and involving students. First, in task-centred designs, a series of whole-tasks forms the backbone of the programme. Therefore, the main educational activities consist of small group meetings in which students collaboratively work on these learning tasks. To facilitate this, there should be sufficient small group rooms available that are equipped with all the necessities such as whiteboards, projectors, and high-speed wireless Internet. Other facilities could be necessary, such as lecture halls, simulation labs, or individual reading and studying rooms, but they are present in most schools. It is more often the lack of sufficient small group rooms that impedes the implementation of task-centred learning.

Secondly, task-centred curricula require the design of a series of learning tasks for an integrative acquisition of knowledge, skills and attitudes. Content that was previously taught separately by different teachers must now be taught in an integrated fashion and teachers should therefore work together in multidisciplinary teams that preferably also include outside domain experts working in the field. These experts can help to align the educational programme with practice and ensure the relevance of the tasks, tools and required knowledge. Teaching staff should also be prepared to adopt different roles, as teachers in task-centred curricula generally have a tutoring or coaching role in order to facilitate small group learning or skills training. They may also be involved in whole-task design and continuous assessment. If teachers are unfamiliar with these new roles, faculty development programmes may be needed to prepare staff members for this change.

Thirdly, in the Ten Steps approach, the assessment programme is developed simultaneously with the design of learning tasks because assessment drives learning. In a task-centred curriculum, assessment should not be used solely for making pass/fail decisions for separate courses. Instead, it should allow for the monitoring of individual student progress at the level of the whole curriculum. This can be done by using electronic development portfolios that combine multiple assessment results and provide a dashboard that informs both students and teachers of the students' progress and improvement. This approach no longer relies on traditional assessment arrangements, such as fixed-length semesters with pre-planned exam weeks.

Lastly, students themselves should play an important role in the design of the whole curriculum and of individual learning tasks. Involving students in the design process provides valuable insights into the curriculum's strengths and weaknesses, as they are the only ones to experience the curriculum. As it is crucial that students experience the learning tasks as meaningful and useful, their perceptions are very informative for designers. Thoroughly informing students of the ideas behind the task-centred curriculum may also benefit implementation, as those students can become advocates of the reform. Furthermore, just as teachers have different roles in a task-centred curriculum, students also need to be prepared for their new roles. They need to function in small group meetings and learn how to actively contribute to group discussions, how to act as group leaders or scribes and how to provide effective feedback to peers. As is the case with faculty development, such student training preferably extends over a prolonged period.

To conclude, dealing with current and future developments in the job market requires that educational programmes produce lifelong learners who are equipped with the knowledge, skills and attitudes to deal with familiar and unfamiliar complex tasks in their domain. The way these programmes are designed must therefore match this goal of creating learners who are able to transfer their knowledge from the learning to the professional setting. Task-centred instructional design models such as the 4C/ID model stimulate this process by prescribing learning methods that lead to a rich knowledge base allowing for creative applications of knowledge in new and innovative settings. Additionally, they create a strong alignment between education and practice by blending learning in the educational setting with learning in the workplace. This encourages cross-institutional and international collaboration when designing educational programmes, which is especially important in those settings where tasks require international and interdisciplinary work, such as the banking, aviation, or tech sector. A clear implication for educational policy is that collaboration between employers and higher education must be strengthened: A two-way interaction is needed where educational institutions not only prepare students for the job market, but where employers also bring state-of-the art knowledge, future job requirements and tasks to the educational institutions.

Future Developments

In the book *Ten Steps to Complex Learning*, van Merriënboer and Kirschner (2018) present an extensive systematic approach to design task-centred educational programmes with the 4C/ID model, based on evidence from research on education and learning going back to the late 1980s. They also identify several important directions for advancing the model. Future developments will focus on the integration of new educational technologies (e.g., blended programmes, gamification), dealing with large learner groups (e.g., learning analytics, customisation), teaching domain-generalisable skills (e.g., intertwining domain-general and domain-specific programmes) and promoting motivation and preventing negative emotions. With research on these topics now maturing, designers can look forward to an expanded set of guidelines to design effective, efficient, and enjoyable programmes for complex learning.

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