International Journal *of* Designs for Learning
2020 | Volume 11, Issue 3 | Pages 126-147

THE INSTRUCTIONAL DESIGN OF A 4C/ID-INSPIRED LEARNING ENVIRONMENT FOR UPPER SECONDARY SCHOOL STUDENTS' RESEARCH SKILLS

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In today's complex world, the acquisition of research skills is considered an important goal in education. Consequently, there is a growing body of literature that recognizes the value of well-designed learning environments for effectively supporting the development of this complex set of skills. However, a clear consensus on how these research skills can be facilitated is currently lacking, and the design processes underlying the learning environments aiming to foster students' research skills are not always clearly outlined. Furthermore, interventions aiming to foster these skills are often implemented in the domains of physics, biology, and chemistry, while other domains (such as behavioral and social sciences domains) remain understudied. In addition, current approaches to foster research skills often refer to only a few epistemic activities (Fischer et al., 2014) related to research skills. Inspired by a design-based research approach, this design effort case seeks to clearly explain the design considerations for, and the development of an online learning environment aiming to foster upper secondary school students' research skills in a behavioral sciences context. The online learning environment (RISSC or Research In Social SCiences) consists of a lesson series designed based on a systematic approach to four-component instructional design (van Merriënboer & Kirschner, 2018), and was piloted with two different cohorts in upper secondary education and in first year of university.

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https://doi.org/10.14434/ijdl.v11i3.29012

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INTRODUCTION

Evolutions in the 21st century[1] have increased the need for students' acquisition of complex skills, such as problem solving, (scientific) reasoning, decision making, creativity, innovation, and critical thinking (van Merriënboer & Kirschner, 2018). Hence, as reflected in several policy (OECD, 2018) and curriculum (Departement Onderwijs en Vorming, 2019) documents, fostering the development of complex skills has become an important challenge for education.

1 The challenges faced in the 21st century are often referred to as VUCA challenges: Volatility, Uncertainty, Complexity, and Ambiguity (OECD, 2018).

As a specific case for complex learning, this research project focuses on upper secondary school students' research skills. These research skills should enable students to address problems in research, professional practice, and daily life (Opitz et al., 2017). The literature poses a variety of conceptualizations (Kestens et al., 2016), such as scientific reasoning skills (Engelmann et al., 2016; Fischer et al., 2014; Opitz et al., 2017); scientific literacy (Norris et al., 2014) or research methods skills (Earley, 2014). However, the present research project uses the term research skills, as it adequately reflects the target concept as a broad set of skills (not merely referring to reasoning, literacy or research methods skills). In our work the definition suggested by Fischer[2] and colleagues (2014) was adopted, labelling research skills as a set of "skills and abilities to understand how scientific knowledge is generated in different scientific disciplines, to evaluate the validity of science-related claims, to assess the relevance of new scientific concepts, methods, and findings, and to generate new knowledge using these concepts and methods" (Fischer et al., 2014, p. 29). In short, research skills include the knowledge and skills involved in eight scientific activities, namely: (1) problem identification, (2) questioning, (3) hypothesis generation, (4) construction and redesign of artefacts, (5) evidence generation, (6) evidence evaluation, (7) drawing conclusions and (8) communicating and scrutinizing (Fischer et al., 2014). Fischer and colleagues (2014) argue that the relative weights and the nature of the eight activities involved in preparing, performing and evaluating research will differ across disciplines (see also Engelmann et al., 2018). For example, Fischer and colleagues (2014, p. 35) argue that "transferring criteria for evidence evaluation from one discipline to another appears problematic". Also, other recent literature highlights the importance of domain-specific knowledge when it comes to apply higher-order cognitive skills, such as research skills (Kirschner, 2017). As such, approaches to facilitation of research skills typically focus on one specific domain (Engelmann et al., 2018; Fischer et al., 2014), mostly situated in specific natural sciences disciplines (Engelmann et al., 2018; Gess et al., 2017; OECD, 2006; Opitz et al., 2017). Very little attention has been paid to behavioral sciences disciplines (Gess et al., 2017). As research has pointed to the (mainly) domain-specific character of research skills (Fischer et al., 2014; Kirschner, 2017), this research gap is problematic. Studies on the differences of research skills between disciplines (for example between natural and social sciences disciplines) have been rare (Fischer et al., 2014). Also, it appears clear that existing intervention research on fostering research skills focuses on some of the eight scientific activities (Fischer et al., 2014), but research aiming to foster the eight scientific activities in an integrated fashion seems scarce.

2 Fischer and colleagues (2014) refer to this definition using the term scientific reasoning skills as a 21st century skill.

Overall, a lot of intervention studies have been carried out with regard to fostering students' research skills (Engelmann et al., 2016). However, far too little attention has been paid to operational descriptions of these learning environments aiming to foster students' research skills. Adopting a design-based research approach while designing learning environments offers an effective solution for solving this research gap. As a theory-grounded approach, design-based research does not solely use theory to ground the design, but also the design process itself aims at contributing to a broader theoretical understanding (McKenney & Reeves, 2013). As such, design-based research requires the designer to document the entire design process (Wang & Hannafin, 2005).

In this paper, the development process of an online learning environment aiming to foster upper secondary school students' research skills is outlined. The development of RISSC is an illustration of a design process that is highly guided by a formal instructional design model (4C/ID model, van Merriënboer & Kirschner, 2018). For a detailed blueprint of this online learning environment, the concrete design decisions and the concrete learning tasks, we refer to Appendix A. We believe that this design case can be considered innovative because of its aim to foster a comprehensive set of eight scientific activities (rather than fostering isolated scientific activities) in an understudied behavioral sciences education domain. In addition, this paper investigates instructional design principles within a design-based research-inspired approach. The paper is structured as follows: The first section of this paper elaborates on problems identified in the literature regarding research skills. It will then go on by describing how we developed solutions informed by existing instructional design principles. The third section of this paper describes the testing and evaluation of the solutions in practice. Then, we continue by analyzing problems observed during the evaluation and reflection phases.

DESIGN-BASED RESEARCH

As described by Barab and Squire (2004), "design-based research is not so much an approach as it is a series of approaches, with the intent of producing new theories, artifacts, and practices that account for and potentially impact learning and teaching in naturalistic settings" (p. 2). Because the mainly domain-specific character of research skills has been stressed in recent research (e.g., Fischer et al., 2014; Neelen & Kirschner, 2016), we target one specific domain as a recurrent authentic classroom setting for our research. More specifically, we selected the domain of behavioral sciences (in the 11th and 12th grade of secondary education) as it is currently underrepresented in intervention-based research regarding research skills, which is currently mostly situated in natural sciences domains (e.g., de Jong & van Joolingen, 1998; Engelmann et al., 2016).

Design-based research is characterized by its use of iterative cycles of design, enactment, analysis, and redesign (Design-Based Research Collective, 2003; Wang & Hannafin, 2005). In this study, we draw on the model introduced by Reeves (2006), proposing four main phases of design research, namely: (1) problem analysis; (2) solution development; (3) iterative cycles of testing and refinement; and (4) reflection to produce design principles. In this study, the first phase (problem analysis) was performed by means of an exploration of Flemish curriculum documents and the literature with regard to research skills (education) in order to address problems. The second phase (solution development) was concerned with the development of a blueprint for an online learning environment, based on existing instructional design principles, and the implementation of this blueprint in Moodle (learning platform). In the third phase (testing and refinement), we piloted the online learning environment with students in upper secondary education and with students in first year of university. Students' qualitative feedback related to their experience with the main components of the RISSC environment was collected by means of open-ended questions. Students' comments were then processed by means of the knowledge management tool Citavi: all comments were categorized in common themes (such as: positive comments, negative comments, comments related to characteristics of the design…). Based on this feedback, we adapted the online learning environment and prepared it for a next testing cycle in upper secondary education. In the fourth phase (reflection), all observations are evaluated based on theoretical considerations. In what follows, these four phases will be outlined in detail. In describing the design processes, the design team is described as "we", which refers to a group of four educational sciences researchers. All four members of the design team have an educational background in educational sciences. In addition, all four members are active researchers in educational sciences. The main designer and first author of this manuscript is a PhD-student in educational sciences, and the three other members of the design team are professors in educational sciences (two members) and a post-doctoral researcher in educational sciences (one member). The influence of the background of the members of the design team on design decisions will be discussed throughout this design case.

PROBLEM ANALYSIS

As mentioned earlier, it is not a common practice of educational researchers to formulate operational descriptions of learning environments. However, we assume that, to interpret findings from intervention research describing effects on students' learning outcomes, a clear understanding of the design of the learning environments in which that learning occurred is desirable. As such, by adopting a design-based research approach, this paper aims to explicitly address all the steps followed in the design process of RISSC (Research In Social SCiences). A first design step concerns the problem analysis, in which we thoroughly explored (a) the literature on instructional design principles for complex learning (to find out what already is known), (b) the literature on research skills education (to define research gaps regarding research skills education); and (c) Flemish curriculum and policy documents (to understand the context in which our interventions would take place).

Instructional Design Principles for Complex Learning

As learners do not automatically engage in epistemic activities (Weinberger et al., 2005), there seems to be an agreement among researchers on the importance of well-designed learning environments effectively fostering the development of complex skills. It is argued that, if designed with caution (Seel, 2006), and if adequately used by the learners (Elen & Clarebout, 2006), processes of complex problem solving can be substantially fostered by means of multimedia programs (Elen & Clarebout, 2006; Engelmann et al., 2016; Seel, 2006). In order to construct learning environments with such caution, one can draw on instructional design principles for complex learning. According to the definition of Elen and Clarebout (2006, p. 1), "instructional design aims at contributing to the development of learning environments by describing the basic components of a learning environment, their interrelations and their interaction with learner characteristics". It is argued by van Merriënboer and Kirschner (2018) that educational instances often lack proven design approaches for complex learning, and that, in research, rich descriptions of the design of learning environments are often lacking. In some cases, the lack of such rich descriptions in intervention research might hamper the interpretation and comparability of findings in order to identify the conditions enhancing students' research skills (see for example in Engelmann, 2016).

A thorough design of a learning environment does not evolve without the designer drawing on an underlying instructional design theory. A model generally known because of its integration of elements from different models and theories (Merrill, 2002), focusing in the first place on training domain-specific complex skills, is the 4C/ID model (van Merriënboer & Kirschner, 2018). Roughly sketched, the 4C/ID model is built upon four crucial components: learning tasks, supportive information, part-task practice, and just-in-time information. Central assumptions related to these four components are that (a) high variability in authentic learning tasks is needed in order to deal with the complexity of the task; (b) supportive information is provided to the students in order to help them build mental models and strategies for solving the task under study (Cook & McDonald, 2008); (c) just-in-time (procedural) information (related to steps, procedures, facts, concepts and principles) is provided for recurrent skills, and (d) part-task practice is provided for recurrent skills that need to be automated. For these kind of part-task practice tasks, immediate corrective feedback is provided.

Overall, the 4C/ID model is considered highly suitable for designing learning environments aiming to foster complex skills because, with its holistic design approach, it helps "to deal with complexity without losing sight of the interrelationships between the elements taught" (van Merriënboer & Kirschner, 2018, p. 5).

Research Skills (Education)

Previous research has identified several deficits related to students' research skills. Although providing an extensive overview on these deficits is beyond the scope of this paper, we briefly illustrate some findings, because they helped guiding the subsequent design decisions. Learners seem to lack basic methodological knowledge to formulate and to evaluate evidence-based arguments, and they tend to make claims without justifications (Cavagnetto, 2010; Fischer et al., 2014; Sadler, 2004). Learners also experience problems in formulating hypotheses and finding the right variables, and they tend to look for information confirming (rather than disconfirming) a hypothesis (de Jong & van Joolingen, 1998). Another problem is that learners seem to design inconclusive experiments, to misencode experimental data, and to draw wrong conclusions (de Jong & van Joolingen, 1998). Finally, the interpretation of graphs causes problems (de Jong & van Joolingen, 1998). Overall, problems can be identified for all of the eight scientific activities mentioned by Fischer et al. (2014).

This leads to the question how to foster students in their acquisition of research skills. This question has been subject to a large body of intervention-based research (Fischer et al., 2014). In a meta-analytic study, Engelmann and colleagues (2016) provide an overview on the current state of research on fostering scientific reasoning. More concretely, they list and compare 30 intervention studies based on their effect sizes in relation to the domain, age group, the aspects of scientific reasoning included in the intervention, and the learning activities intended by the researchers. However, apart from this information, the authors did not focus on the detailed design of the learning environments. In addition, although the authors aim to provide an overview on what characteristics are particularly beneficial in educational interventions related to research skills, the comparability of the findings of individual studies addressed in the meta-analysis is limited due to a shortage of detailed information in some of these studies (Engelmann et al., 2016). Overall, the authors argue that interventions successfully facilitate scientific reasoning in all age groups, thereby indicating that there is considerable room for improving students' scientific reasoning. The authors classify interventions as either (a) fostering skills in scientific discovery, such as research on the instruction of meta-strategic knowledge (Ben-David & Zohar, 2009), probing (Chen & Klahr, 1999), and task structuring (Lazonder & Egberink, 2014); (b) fostering scientific argumentation, such as an intervention on online synchronous scientific argumentation (Chen & She, 2012); or (c) fostering the understanding of the nature of science, such as research on explicit teaching (Peters, 2012) and on embedded meta-cognitive prompts (Peters & Kitsantas, 2010). However, the variability of the effect sizes across studies could not be explained based on differences in the aspects of scientific reasoning included in the interventions. As an important finding of their meta-analysis, Engelmann and colleagues (2016) argue that teaching scientific reasoning seems to require the presence of at least some constructive activities requiring learners to create something that goes beyond the information given in the learning environment, as all studies analyzed in the meta-analytic study contained at least some constructive or interactive learning activities, and yielded positive effects.

In a theoretical study, Fischer and colleagues (2014) examine how research skills can be successfully fostered. The authors stress that scientific reasoning can be enhanced by making it an explicit topic of instruction (see also Osborne, 2010). In addition, the study shows that research has consistently stressed the importance of students' engagement in authentic research practices (Cavagnetto, 2010; Engelmann et al., 2016; Fischer et al., 2014). Overall, the importance of structural support such as scaffolding (see also de Jong & van Joolingen, 1998; Fischer et al., 2014; van Merriënboer & Kirschner, 2018), hints, and prompts (see also de Jong & van Joolingen, 1998), sentence starters (see also Fischer et al., 2014), guiding questions (see also Fischer et al., 2014; van Merriënboer & Kirschner, 2018), collaboration scripts (see also de Wever et al., 2015; Fischer et al., 2014), peer assessment (Fischer et al., 2014) and support for critical reflection (Fischer et al., 2014) have been subject to a vast literature (Fischer et al., 2014). For example, de Jong and van Joolingen (1998, 2006) argue that several instructional interventions, such as providing direct access to domain information at the appropriate moment (a principle that can be compared with the 4C/ID's procedural knowledge component, van Merriënboer & Kirschner, 2018), providing learners with assignments, and including model progression in the program (if complex enough), can positively influence learning outcomes.

Flemish Curriculum and Policy Documents

The current design case takes place in upper secondary education in Flanders (Belgium). In the Flemish educational guidelines for the general track[3] in secondary education, three specific objectives related to research are formulated for students in the 11th and 12th grade (Cornelissen et al., 2014). Although these curriculum standards vary in a very

3 In Flanders, four different types of education are offered from the second stage of secondary education onwards (general secondary education, technical secondary education, secondary education in the arts and vocational secondary education).

minimal way[4] between specific track disciplines, overall, these curriculum standards state that students have to be able (1) to orientate themselves towards a research problem (in a specific discipline) by collecting, organizing and editing information in a well-considered way; (2) to prepare, carry out and evaluate research (in a specific discipline), and (3) to report the research results and conclusions and confront them with other points of view (Departement Onderwijs en Vorming, 2019). The existence of these three objectives does not necessarily imply that the implementation of these objectives is evident for, and consistent between schools (Cornelissen et al., 2014; Sermeus et al., 2017). In an exploratory observation of inspection documents of Flemish school, we noticed that the inspection states for several schools that a (school specific) vision, policy or strategy with regard to the realization of the three objectives is lacking (Vlaams Ministerie van Onderwijs en Vorming, 2019).

Current Design Case

The goal of the learning environment, further on referred to as RISSC (Research In Social SCiences), is to support upper secondary school students' research skills, relying on theoretical instructional design principles. In RISSC, learning tasks are available related to each of the eight epistemic activities (Fischer et al., 2014). These learning tasks are designed for students in a specific behavioral sciences context because (a) the reliance of research skills on domain-specific knowledge has been emphasized several times in research (Fischer et al., 2014; Engelmann et al., 2016; Kirschner, 2017; Opitz et al., 2017), and (b) a majority of (intervention) studies on the support of research skills limits the focus to scientific disciplines almost exclusively situated in the field of natural sciences. As a result, research into supporting research skills in a behavioral sciences context is particularly scarce. As a sub-track in general secondary education, the behavioral sciences track aims to introduce students to the world of behavioral, social, and cultural sciences and aims to prepare students for higher education (Ministerie van Onderwijs en Vorming, 2019). In the literature on Flemish research skills education in the behavioral sciences track, we identified several problems with regard to students' ability to prepare, conduct, and to evaluate research (Sermeus et al., 2017). In general, these studies point out that students score below expectations on research skills tests developed specifically for a behavioral sciences context (Sermeus et al., 2017; Maddens et al., 2019). For example, in 2019, Maddens and colleagues found that, although students in the first year of university reach a mean score of 69% on a research skills test, students in upper secondary education reach a mean score of 57%. Moreover, it was noticed that students show difficulties across all eight subskills. Although the authors (Maddens et al., 2019) recommend to look at overall scores, and not to rely on scores on the subscales, descriptive statistics inform us that students show the most difficulties with regard to identifying dependent and independent variables, evaluating evidence, drawing conclusions, and communicating research. Although research comparing these issues to other research skills domains is lacking, these domain-specific insights are important in order to enhance our solution development (see next section).

SOLUTION DEVELOPMENT

Instructional Design Considerations

As mentioned in the previous section, the literature on fostering students' research skills has suggested several instructional guidelines (Engelmann et al., 2016; Fischer et al., 2014). Overall, all authors mentioned in the previous section seem to agree on the fact that learning can benefit from support. Next to these research skills-related guidelines, we draw on instructional design principles for complex learning in general. Overall, as an integrative model, focusing in the first place on training domain-specific complex skills, the 4C/ID-model (van Merriënboer & Kirschner, 2018) provides an excellent base for the design of the RISSC environment. If not all, several of the support principles mentioned above, such as the importance of structural activities, the importance of authentic research practices and the role of scaffolding, are implemented in the 4C/ID model (Merrill, 2002; van Merriënboer & Kirschner 2018). In other words, although some principles are emphasized more than others, the 4C/ID model clearly draws on existing strands of research on instructional methods for basic learning processes involved in complex learning (van Merriënboer, Clark & de Croock, 2002).

In short, this design case draws on the (a) instructional design principles for complex learning in general; and (b) instructional design principles formulated for research skills, as a specific complex skill. In what follows, some important theoretical principles underpinning the design decisions are described, and are illustrated by means of the operationalizations in the RISSC environment. The RISSC environment is an online learning environment. As stated by Merrill, "principles of instruction can be implemented in any delivery system or using any instructional architecture" (Merrill, 2002, p. 44). In addition, according to Clark (1983, p. 445), "there are no learning benefits to be gained from employing any specific medium to deliver instruction". As such, citing Cook and McDonald (2008, p. 7), we assume "the argument of superiority, inferiority, or equivalence is moot. It is a far better investment of resources to investigate "what works?" in e-learning, rather than trying to justify its existence". Following this rationale, the technology versus non-technology question does not seem to be the most

4 For each discipline, a discipline-related context is added to the curriculum standard. For example, in humanities, the standard prescribes students to orientate themselves towards a research problem in social/behavioral sciences.

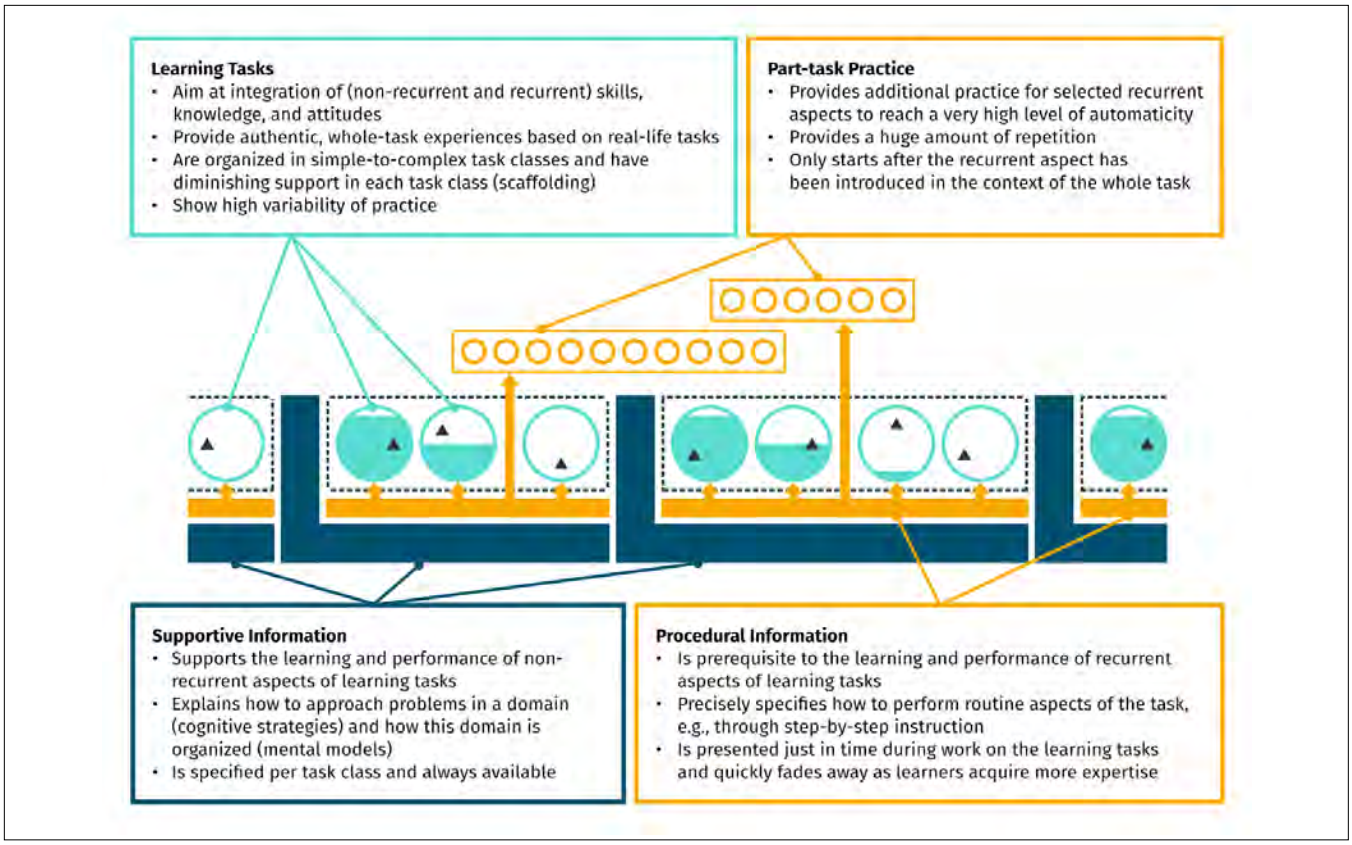


FIGURE 1. 4C/ID model (reprinted from http://www.4cid.org/).

important one to be raised. However, we do argue that the use of digital technology in RISSC can be beneficial from both an educational and methodological point of view. From an educational point of view, the use of technology might facilitate the incorporation of real-world cases (for example, by means of video data of researchers); and the scaffolding of students' learning. From a methodological point of view, the use of technology might facilitate the analysis of learning processes as it can provide information on time-stamped events. In turn, this information might help the researcher in finding patterns in this logdata (a process which is referred to as learning analytics) (Gašević, Dawson, Rogers, & Gasevic, 2016).

4C/ID model as an integrative instructional design model

As mentioned, for the design process of RISSC, we draw on the principles of the 4C/ID model (van Merriënboer & Kirschner, 2018). The "Ten steps"[5]- related to the 4C/ID model described by van Merriënboer and Kirschner (2018)- were used as a prescriptive guideline in designing the first version of the online learning environment. The following sections discuss how we operationalized the four main steps (the design of learning tasks, the design of supportive information, the design of procedural information, and the design of part-task practice) in RISSC.

4C/ID-Based Instructional Design Process

Design learning tasks

Content of the learning tasks. In a first step, we decided on the learning tasks for the online learning environment. One possible approach to construct a design blueprint for fostering research skills is to use existing performance objectives (such as those stated in the Flemish curriculum standards, see "Problem analysis") as the main input for design decisions. However, according to the Ten Steps, "instruction cannot be linked to one specific objective but must always be linked to interrelated sets of objectives" (van Merriënboer & Kirschner, 2018, p. 90): key to the 4C/ID model is its whole-task approach, where the design of (a variety of) simple-to-complex[6] real-life based whole tasks, aiming at integrating

5 The Ten Steps can be seen as a simplified version of the 4C/ID model itself (van Merriënboer & Kirschner, 2018).

6 The complexity of tasks increases between task classes, because the learner has to integrate more skills in every task class. For example, while the first task class focuses on questioning and hypothesis generation, the second task is inclusive and focuses on questioning, hypothesis generation, and problem identification. Within a task class, the difficulty does not increase, but the amount of support decreases within this task class.

knowledge, skills and attitudes is the core design activity of the training blueprint (van Merriënboer & Kirschner, 2018). In line with van Merriënboer and Kirschner (2018), we define real-life and authentic tasks as tasks having more than one 'good' answer, confronting the learner with unknown elements, and with multiple acceptable solutions. Thus, these tasks are ill-structured rather than well-structured. In addition, as is frequently the case in real life, these tasks require learners to make judgments. In order to define such tasks, we followed the recommendation of van Merriënboer and Kirschner (2018, p. 55) to use examples from professionals working in the task domain, as "preparatory activities typically include studying documentation, and function descriptions, as well as existing educational programs and open educational resources so as to avoid duplicate work". As such, in RISSC, all cases are studies performed by real researchers, working in real contexts, and reporting in real journals, and can thus be considered authentic. As we aim to enhance students' research skills, we are very lucky with the 'public' character of existing research and with the way researchers report their research process. These papers provided "on-the-job documentation". As such, we were able to translate authentic material (identified in papers, journals, newspapers…) into real-life learning tasks. For example, we provided students with a video in the RISSC environment in which a researcher explains her PhD-research in a short video. After having watched this video, students are asked (among other things) to evaluate the research questions used in the research, and to think about the manners of data collection suited for this kind of research question (see Appendix A).

As mentioned, the identification of these real-life tasks for the domain under study (research skills in behavioral sciences) appeared crucial in designing the RISSC blueprint. Preparatory activities, such as studying existing learning material regarding research skills; studying online documentation for case studies; and evaluating the research process in several disciplines provided sufficient background information to select real-life tasks. We stopped the search for cases when we succeeded in formulating cases for every learning task. In RISSC, cases, (modelling) examples and tasks were selected from research in the domains of psychology, educational sciences and sociology, in which we aimed at a representative selection. In doing so, we noticed that we needed to be careful in order to avoid an 'educational sciences bias', as all four designers are educational scientists. Therefore, we needed to pay explicit attention to a balanced implementation of cases from several domains in behavioral sciences. Using these cases facilitates transfer by means of an inductive learning process, in which "learners construct general cognitive schemas of how to approach problems in the domain and of how the domain is organized based on their concrete experiences offered by the tasks" (van Merriënboer & Kirschner, 2018, p. 64). The domains of psychology, educational sciences and sociology were selected based on their communalities concerning the performance of research and their common interest in human behavior (be it learning behavior, social behavior or behavior in general). One of these communalities concerning performing research in behavioral sciences is that, unlike research in the domains of the natural sciences, strict rules are rather rare in social sciences domains (Stark et al., 2009), which might have consequences for evidence evaluation, but also for other steps in a research cycle.

Performance objectives related to the learning tasks. In RISSC, every learning task is linked to one or several of the eight epistemic activities defined by Fischer and colleagues (2014). In order to get there, we first clearly operationalized each epistemic activity in terms of observable objectives. These operationalizations were then discussed with an expert team (see Maddens et al., 2019), consisting of the four main designers of the online learning environment, and one additional member (a professor with expertise in educational effectiveness and evaluation).

In line with the Ten Steps (van Merriënboer & Kirschner, 2018) we then continued by specifying performance objectives for each skill to describe the different aspects of effective task performance. According to van Merriënboer and Kirschner (2018, p. 90), a good performance objective contains "an action verb that clearly reflects the desired performance after the training, the conditions under which the skill is performed, the tools and objects required (…) and the standards for acceptable performance". In RISSC, performance objectives are specified for each subskill. For example, in the first task class, the following performance objective is formulated for the subskill "questioning": "After having completed this task class, the learner is able to evaluate and to formulate a good research question based on the HEROES-criteria".

Module 1 (one hour): Task class on questioning and hypothesis generation
Module 2 (one hour): Task class on problem identification
Module 3 (one hour): Task class on evidence generation, evidence evaluation and construction and redesign of artefacts
Module 4 (one hour): Task class on drawing conclusions and communicating and scrutinizing
Module 5 (one hour): Task class on problem identification, questioning, hypothesis generation, construction and redesign of artefacts, evidence generation, evidence evaluation, drawing conclusions and communicating and scrutinizing
Module 6 (two hours): Integrated task: writing a two-pager research proposal

TABLE 1. Overall structure of the RISSC-environment.

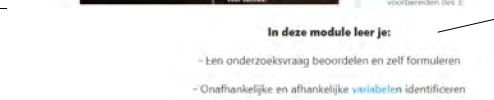
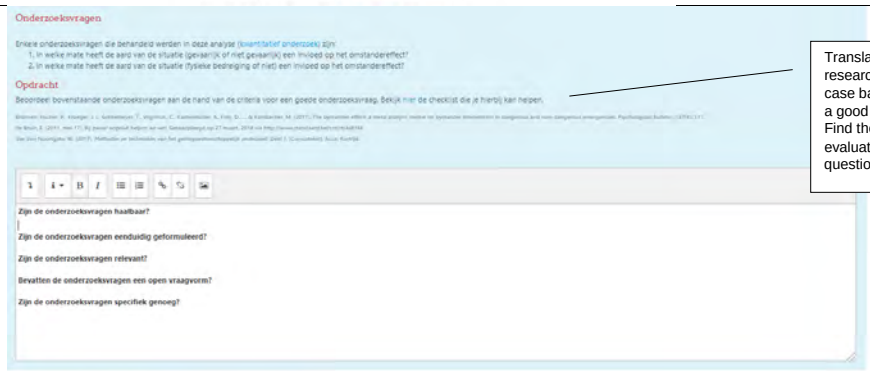
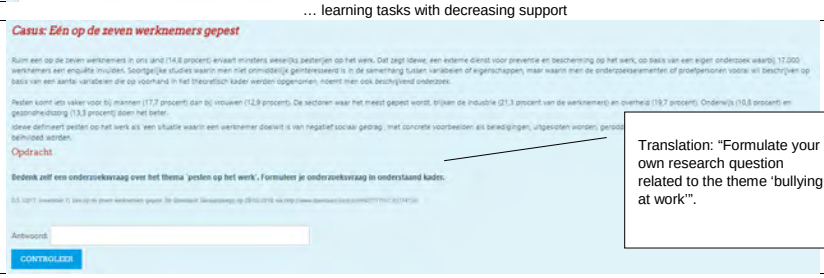
Opening page with welcoming message and overview of the modules.	 Translation of Module 1: "Module 1: I can formulate a research question (Lesson 1: +/- 45 minutes)"
Each task class opens with a description of the learning goals	 Translation: "In this module you learn how to… - evaluate and formulate a research question - identify dependent and independent variables"
Learning task 1a: *Case study/worked out example (evaluate) = given + goal + solution* Learners receive a casus on the "bystander effect". They are asked to evaluate the quality of the research questions given. In addition, learners are asked to identify a dependent and an independent variable in the research questions.	 Translation: "Evaluate the research questions of this case based on the criteria for a good research question. Find the **checklist** for evaluating a good research question here."
Learning task 1b: *Case study (evaluate) = given + goal + solution* Learners are asked to evaluate 5 research questions.	 Translation: "Formulate one suggestion for improvement for each of these 5 research questions formulated by your peers".
	… learning tasks with decreasing support
Learning task 3: *Conventional (find) = given + goal + find solution* Learners are asked to formulate a research question related to the theme "bullying at work".	 Translation: "Formulate your own research question related to the theme 'bullying at work'".

TABLE 2. Simplified blueprint example illustrating completion strategy.

Sequencing the learning tasks. As mentioned earlier, complex learning requires learners to coordinate qualitatively different constituent skills (van Merriënboer & Kirschner, 2018) in real-life task settings. By means of scaffolding, the support and guidance for these ill-structured problems are faded within each task class (Merrill, 2002; van Merriënboer & Kirschner, 2018). This is implemented in the RISSC environment by means of a completion strategy (van Merriënboer & Kirschner, 2018), in which the support is faded. For example, the first task in a task class consists of a case study in which students are asked to evaluate a given case with a given solution, and in which the criteria for acceptable performance (or goals) are clearly defined. This is followed by a completion task, in which students are asked to complete a task; and ends with a conventional task in which students need to perform a whole task without a given solution (see for example Table 2). The support decreases within each task class by means of fading, but the complexity increases between task classes (van Merriënboer & Kirschner, 2018). In RISSC, this increasing complexity is dealt with by means of an emphasis manipulation technique as a whole-task sequencing approach (van Merriënboer & Kirschner, 2018), in which different sets of constituent skills are stressed in different task classes, and in which every task class requires the learners to integrate new skills from the current task class with the skills learned in previous task classes. In this emphasis manipulation technique, the whole-task approach is always kept in mind. The first task class, for example, focusses on problem identification, questioning and hypothesis generation, but the tasks are integrated in several cases involving real (whole) research projects (see Table 3).

The design of learning tasks did not occur without difficulties. A first difficulty concerns the fidelity of the learning tasks. Although the aim of the RISSC-environment is to provide tasks representative for tasks occurring in the real world, we needed to construct these tasks within the boundaries of our research context. As the learning environment was completed within a controlled classroom setting, it should be mentioned, overall, the fidelity ("the degree of correspondence of a given quality of the simulated environment with that quality of the real world" (van Merriënboer & Kirschner, 2018, p. 58)) is rather low. In RISSC, the "authentic tasks" are provided to the learner by means of cases, videos and examples. As such, the learners are confronted with "the world of research" in a rather reflective way. Although a "perfect" authentic task would invite learners to perform a real study from beginning to end, students had to formulate their *plans* for a study (see Appendix A, last task class). As such, due to practical constraints, the fidelity of the tasks was lower than one would wish for. A second difficulty concerns the sequencing of the learning tasks. As mentioned, we decided to decrease support within a task class. However, the difficulty level of a task remained equal within the task class. As such, the tasks within a task class were quite similar in order to train the specific skill. However, it was not easy to find a balance between formulating a sufficient number of tasks in order to train a skill, and not to overrule or to bore the student with similar tasks in a short time frame. In the next section, we will discuss students' opinions on these aspects and will formulate possible opportunities for improvement.

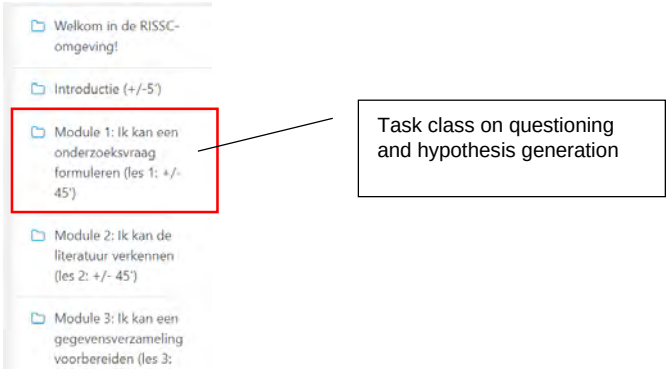
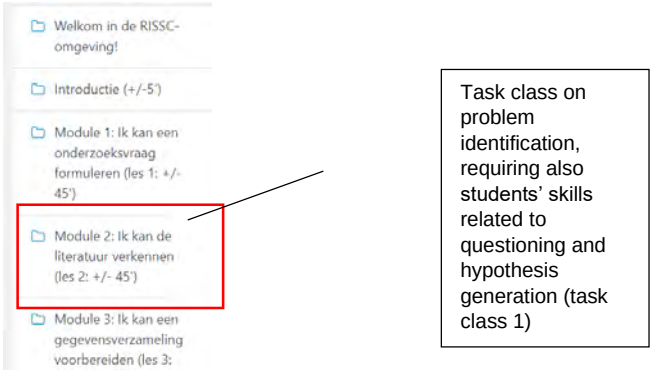
Elaboration: Emphasis manipulation by topical sequencing (inductive strategy) based on the "Ten steps' (van Merriënboer & Kirschner, 2018)
Elaboration aspect 1 
Elaboration aspect 2 
Task classes on other subskills

TABLE 3. Simplified blueprint example illustrating emphasis manipulation technique.

Design supportive information

Skills can be classified as non-recurrent (involving schema-based problem solving, reasoning and decision making for constituent skills) or recurrent (involving specific cognitive rules for particular aspects of skills situated lower in the skill hierarchy) (van Merriënboer & Kirschner, 2018). Supportive information helps learners to carry out the nonrecurrent aspects of the learning tasks related to research skills and refers to "'(a) information on the organization of the task domain and how to solve problems within that domain, (b) examples illustrating this domain-specific information, and (c) cognitive feedback on the quality of the task performance" (van Merriënboer & Kirschner, 2018, p. 142). In a second step in the 4C/ID-based design process, we designed this supportive information. Concerning research skills, the supportive information can differ for different epistemic activities (de Jong & van Joolingen, 1998; Fischer et al., 2014). For the epistemic activity 'evidence generation', for example, experimentation hints (or systematic approaches to problem solving or SAPs (van Merriënboer & Kirschner, 2018)) and reflection prompts can be provided, while in the epistemic activity 'drawing conclusions', visualizing tools and knowledge integration environments (or conceptual domain models (van Merriënboer & Kirschner, 2018)) might be helpful (de Jong & van Joolingen, 1998). In RISCC, the suitability of these support tools was always evaluated in relation to the domain under study (behavioral sciences). More specifically, we evaluated under which conditions the support tools appeared helpful, and whether these conditions were also apparent in behavioral sciences. For example, experimentation tools defined in the literature (de Jong, 2006), designed for geography, biology, or physics were not always useful for a behavioral sciences context as these contexts can be defined as less 'predictable' than natural sciences domains.

As the literature specific to fostering research skills in behavioral sciences is particularly scarce, this evaluation process was not always straightforward, and sometimes, assumptions had to be made.

Supportive information is provided in RISSC for complex tasks such as formulating a research question, where students can consult general information on characteristics of a good research question in behavioral sciences, can consult examples or demonstrations of this general information (for example a typical research question in behavioral sciences) and can receive cognitive feedback on their own research questions (Merrill, 2002; van Merriënboer & Kirschner, 2018). In doing so, learners are, for example, asked to critically compare and contrast their own research question with an example. As will be discussed in the following section of this paper, this evaluation process appeared more difficult for the learners than we expected. Two types of supportive information can be distinguished in the literature and are provided in the RISSC-environment. The first type concerns "the cognitive strategies that allow one to perform tasks and solve problems in a systematic fashion" (van Merriënboer & Kirschner, p. 143). In RISSC, after every task class, we provide learners with a systematic approach to problem solving chart (SAP-chart) as a kind of process worksheet, specifying the phases that an expert performs in conducting research. In order to do so, we first needed to describe those phases necessary in a research process. An example of such SAP-chart can be found in Figure 2, visualizing the process worksheet for the first task class of the RISSC environment. A second type of supportive information concerns mental models facilitating reasoning in the task domain. More specifically, three types of such domain models[7] can be identified: conceptual models (helping learners to answer the question "what is this"), structural models (helping learners to answer the question "what happens when"), and causal models (helping learners to answer the question "how does this work") (van Merriënboer & Kirschner, 2018). In RISSC, all three types of domain models are implemented: a conceptual mental model is for example provided for explaining different types of databases; a structural mental model is provided to indicate how an abstract is typically organized; and a causal mental model is provided to explain the principle of how Boolean operators are used in a search query.

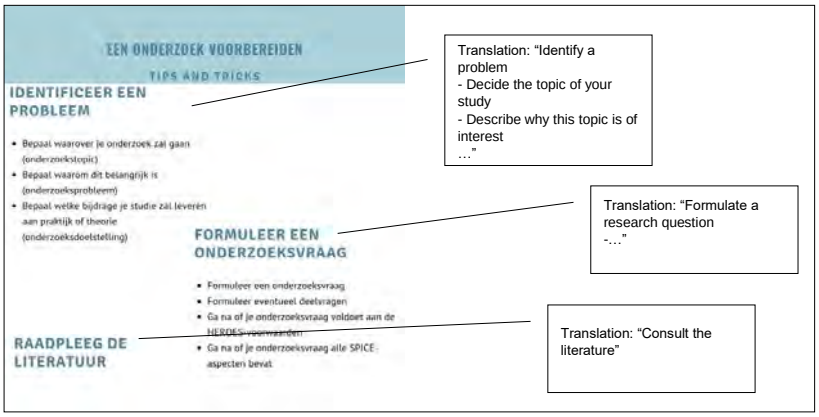


FIGURE 2. Example of a (part of a) SAP-chart in RISSC.

FIGURE 3. Example of supportive information for the nonrecurrent skill "formulating a research question" in RISSC. When students click on the link 'criteria for a good research question', they are guided towards an instructional video (conceptual model).

In RISSC, the supportive information is provided to the learners by means of multimedia such as texts and information videos, and is directly accessible during the whole learning task (de Jong & van Joolingen, 1998, van Merriënboer & Kirschner, 2018). The decisions regarding this multimedia were based on Mayer's (2014) principles for instructional design with multimedia. For example, with regard to the multimedia principle (as one of the main principles introduced by Mayer), supportive information was provided in a combination of texts and videos in order to make use of both the visual and auditory channel of working memory (van Merriënboer & Kirschner, 2018). In addition, videos could be paused, which is in line with the self-pacing principle (Mayer, 2014), stating that "giving learners control over the pace of the presentation may facilitate elaboration" (van Merriënboer & Kirschner, 2018, p. 161). Most videos were constructed by the design team itself, or by colleagues working in the same faculty (Mistiaen et al., 2015). Using an inductive presentation strategy (van Merriënboer & Kirschner, 2018), the supported information is always illustrated by means of modelling examples and case studies. An example of supportive information can be found in Figure 3.

Design procedural information

In a third step in the 4C/ID-based design process, the procedural information was designed. Procedural information is

7 For a more detailed description on what constitutes these domain models, we refer to van Merriënboer and Kirschner, 2018 (p. 141-169).

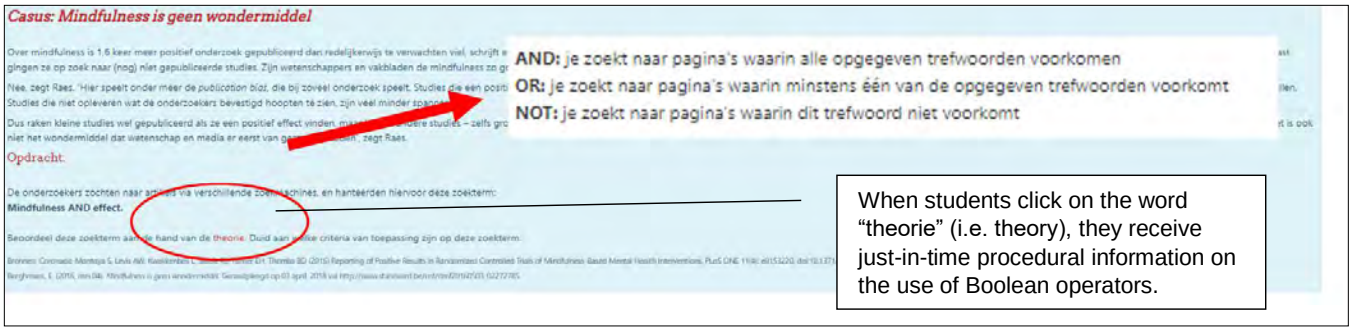


FIGURE 4. Example of procedural information for the Boolean operators (rules).

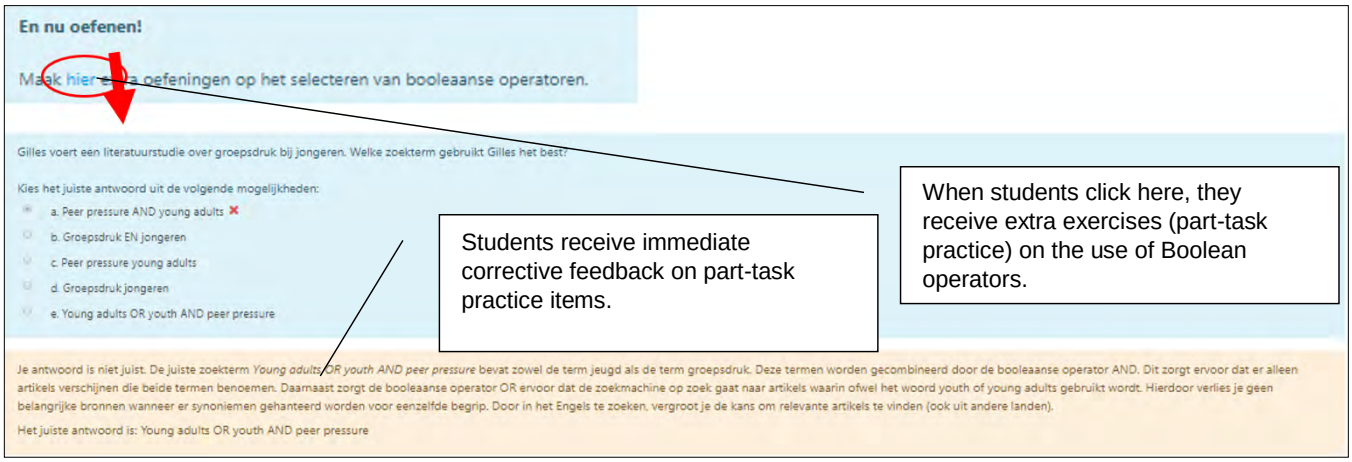


FIGURE 5. Example of part-task practice for the recurrent aspect "formulating a search query."

necessary for carrying out recurrent aspects of learning tasks (involving specific cognitive domain-specific rules or step-by-step procedures for particular aspects of skills situated lower in the skill hierarchy) (van Merriënboer & Kirschner, 2018). With procedural information, van Merriënboer and Kirschner (2018) understand (a) just-in-time information displays describing rules or procedures related to recurrent aspects of complex skills and the information necessary for correctly applying these rules and procedures (prerequisite knowledge), (b) demonstrations of the application of these rules and procedures; and (c) corrective feedback on errors. As mentioned, strict rules are rather rare in social sciences domains (Stark et al., 2009). However, we did define several recurrent skills for which procedural information was requested and implemented in RISSC. In RISSC, examples of this procedural information are: information on how to recognize a dependent and an independent variable (by means of on-demand presentation of cognitive rules), information on how to use Boolean operators, information on how to read a graph… This information is presented just-in-time, which means students can consult information displays on a specific rule, procedure, fact, concept or principle (for example on the effect of the word 'AND' in a search query), as it is introduced. An example of procedural information (with procedural directions for formulating a search query) in RISSC can be found in Figure 4. Here, a small self-contained unit of information (the use of Boolean operators) is provided explaining one specific rule in simple language. This information is integrated with the task environment itself to prevent split attention (the continuous switching between carrying out the task and processing the just-in-time information) (van Merriënboer & Kirschner, 2018). In this procedural information display, the specific rule consists a condition part (or IF-side specifying conditions or states), and an action part (or THEN-side specifying actions to be taken when the rule applies) (van Merriënboer & Kirschner, 2018): IF you want to search for literature consisting the word "youth" and the word "stress", THEN make use of the Boolean operator "AND".

Design part-task practice

The design of part-task practice is the fourth step in the 4C/ID-based design process. Part-task practice involves practice items promoting rule automation for recurrent aspects of the whole complex skill (van Merriënboer & Kirschner, 2018). Because an overreliance on part-task practice is not helpful for complex learning (van Merriënboer & Kirschner, 2018), in RISSC, additional part-task practice is available for some, but not all of these recurrent routine aspects of skills, for example for the formulation of a search query or the identification of dependent and independent variables. For example, part-task practice items are made available to the learners for using Boolean operators, in which learners repeatedly

apply the same rules in different short exercises. In addition, students receive corrective feedback, pointing the students to an error, and giving a hint for applying the correct rule (van Merriënboer & Kirschner, 2018). An example of part-task practice and related corrective feedback in RISSC (for the recurrent aspect 'formulating a search query') can be found in Figure 5.

Procedure

In order to work in the online learning environment, students login to a Moodle environment with their personal login and code. They are automatically enrolled in the course (RISSC) and can start the course immediately once they are logged in. In the first lesson (± 50 minutes), students complete an introduction module (including a welcome video and instructions on how to navigate through the course content), and the first module. Next, students complete module by module. Each module takes more or less 50 minutes. In every module, students encounter problems and cases to which they are asked to formulate an answer. Sometimes these answers take the form of multiple-choice options (for example when selecting a correct Boolean operator for a specific search query), and sometimes an open answer is needed (for example when formulating a research question). While solving the exercises, students can consult theory pages and make extra exercises (part-task practice) if necessary. In addition, students can click on difficult words to see their descriptions. When finished with a module, students can move on to the next module.

TESTING AND ITERATIVE REFINEMENT

Once having designed the theoretical blueprint (see Appendix A) for the online learning environment based on existing instructional design principles, and having implemented the design decisions in a Moodle environment (see Solution Development), the Moodle was prepared for testing in authentic settings. In what follows, we will describe the first testing cycle in which the online learning environment was tested in two well-chosen different settings. The first setting (upper secondary education) was selected as the online learning environment is designed for this target group. The second setting (first year of university) was chosen because of two reasons. The first reason is that these students recently graduated from upper secondary education. Therefore, they are well able to evaluate the material. A second reason for the suitability of this group is that these students are enrolled in an educational sciences academic bachelor in university, and thus are expected to show interest in social sciences. As such, this seemed a great opportunity to receive feedback from educational scientists under training. As such, we expected to receive valuable feedback from both target groups before starting a new iteration in an ecologically valid setting in upper secondary education. In upper secondary behavioral sciences education, 50 students were asked to complete the RISSC environment. One of the designers of the RISSC environment introduced and illustrated the learning environment in class. In the following weeks, students were asked to complete the learning environment at home (individually). In class, the teachers asked about students' progress and tried to motivate students to work in the online learning environment. In addition, the designer stayed in touch with the teachers in order to inform them regarding the class' activity in RISSC. Still, there was a large variation in the students' activity in the online learning environment due to two reasons. First, as students completed the RISSC environment at home, they could choose how much time they spent on completing the tasks. Although the students received a suggestion for planning their completion of the learning environment (for example, students were advised to work 1 hour on each module), the time students spent in the learning environment differed largely between students. Second, students were aware of the fact that teachers had no insight in the students' (individual) activity. As such, this could have impacted their (controlled) motivation (Deci & Ryan, 2000) for completing the entire learning environment, as students who are motivated in a controlled way, are hypothesized to be less likely to complete the modules if they know that their teachers do not have access to their activity in the online learning environment. However, we still received some important feedback based on open ended questions implemented in the Moodle. By means of the following six open ended questions, we wanted to gain insight into students' experience with the main components of the RISSC environment: (a) How do you evaluate the exercises?; (b) How do you evaluate the theory?; (c) How do you evaluate the possibility to ask questions in a forum?; (d) How do you evaluate the possibility to chat with your peers?; (e) What did you like about the online learning environment?; (f) What did you dislike about the online learning environment? Overall, students indicated that they experienced the learning environment as fun, instructive and interesting and that they felt like they had learned a lot. In addition, students appreciated the fact that there was a large variety in exercises, and that they always had the possibility to consult the theory pages. Also, students indicated that what they had learned might be useful in the future. However, also some pitfalls were noticed by the students. Several students indicated that completing the online learning environment was time consuming, and that they had to read a lot when completing the online learning environment. In addition, some students were frustrated because the overview of their progress in the Moodle was not always accurate. Moreover, some students did not find it very clear whether their answer was correct or incorrect. In the logdata, we noticed that students did not use the chat or the forum, and that there was a large variety in the activity of the students: some students completed the whole course, while for others, the activity was extremely limited.

We made some small adjustments to the online learning environment before testing the online learning environment in the university setting. For example, several large parts of text were replaced by instruction videos or brief visual overviews, or were embedded in the exercise page itself by means of a pop-up screen. In addition, the accuracy of the progress overview was checked, as was the feedback on open ended questions. Also, the chat and the forum parts of the online learning environment were given a more prominent place in the Moodle: for example, the title of the chat plugin was changed from "chat" to "talk live to your peers here". At this point, only very small adaptations were made because we wanted to receive feedback from the two different target groups before moving on to a next iteration, in which significant adaptations will be made based on the integrated feedback received from two different settings.

In the second setting 143 students in the first year of university (in educational sciences) were asked to complete the online learning environment. Similar to the setting in upper secondary education, one of the designers of the RISSC environment introduced and illustrated the learning environment in class. In the following weeks, students were asked to complete the learning environment at home (individually). As these students are being educated to become future educational scientists, their feedback was extremely valuable. Again, the students could perform the activities at home, but their participation was related to a course and was graded as a pass/fail. Although, again, there was still a large variation in students' activity (hours spent in the online learning environment), every student completed the entire online learning environment. In this Moodle, the same open-ended questions as in the first setting were posed. Overall, students indicated that they valued several important design decisions: students appreciated the variability in exercises and cases, the usefulness of what they had learned for their future assignments, the close relationship between theory and practice, the use of example answers, and the fact that they could always consult the supportive information. Furthermore, students valued the fact that the theory was provided in several ways, that they received immediate feedback on part-task practice items, that they had a clear overview of their progress, and the fact that the difficulty increased across modules and that everything was

RISSC POSITIVE ASPECTS	RISSC NEGATIVE ASPECTS
• I think this Moodle prepared me well for future research assignments. • I think it is good that you can always check whether you understood the theory by means of the exercises. • I liked the example answers. This way, you receive immediate feedback. • I liked the fact that the theory was provided in several ways (videos, articles...) • Good that you can click on a word if you need more information. • I liked the fact that I received immediate feedback. • I liked the fact that there was a large variety of different kinds of assignments. • I think it was good that you could always consult the information related to previous exercises. • I appreciated the theory provided throughout the exercises, this helped me to solve the questions and to remember the theory. It gives a clear overview on what "performing research" actually is. • I appreciated the fact that I could clearly see my own progress in the Moodle. • I appreciated the fact that the modules were related and that there was a last, integrated module. • I liked the short overviews of the theory that needed to be applied to the exercises. • I liked the fact that everything was illustrated with an example. • I liked the fact that the difficulty/complexity increased across modules. • When something was wrong, I received feedback on the reason why it was incorrect.	• I had to read a lot. Therefore, sometimes, I lost my attention. The Moodle took a lot of time. • Sometimes, I had to open a lot of pages and lost the overview. Sometimes, the scoring procedure was not totally clear. • I would be more concentrated if I would have to do this in a classcontext, instead of at home (more pressure, less distraction). Sometimes, I did not totally understand the questions. • There was a large difference in the difficulty level of the exercises. • It would be good if we received a test beforehand, in order to be able to skip parts that were too easy. • Some questions were not formulated specifically enough. Therefore, I found it hard to compare my own answer to the example answers. • Some example answers were too difficult. When I looked at these answers I realized that I would not have succeeded to formulate it in that way. • I do not see any advantages in the chat. Maybe this is because it is the first time I've worked in an online learning environment, that I find this a bit unusual. I think some assignments were really not suited to be solved in an online learning environment. • For me, this was not very interesting. Therefore, I lost motivation and did not always answer in a correct way.

TABLE 4. Students' quotes.

illustrated with an example. However, students also reported some issues concerning the online learning environment. For example, students indicated that some exercises needed more concrete instructions, that they had to read a lot in order to complete the online learning environment, and that they lost track of their progress because of an overload of information. In addition, some students felt like the scoring procedures were not always clear, disliked the fact that they had to complete the learning environment at home, experienced the example answers as too difficult, and did not see any advantages in the chat function. In Table 4, the most important comments of the students are depicted.

Based on this pilot phase in two different contexts, it was noticed that overall, some main 4C/ID-based decisions (van Merriënboer & Kirschner, 2018) were highly valued by the students: students seem to appreciate the online learning environment because of its use of different cases and kinds of assignments (variability in practice), its usefulness for later studies or jobs and the interplay between theory and practice (real-life tasks), the fact that they could consult the theory at any time (supportive information), and the use of example answers (cognitive feedback). Furthermore, students valued the fact that the theory was provided in several ways (multimedia principle), that they received immediate feedback (corrective feedback) and an explanation on why an answer was incorrect (cognitive feedback). In addition, students noticed and liked the increasing difficulty of the task classes and the fact that the modules were interrelated (elaboration theory).

However, while testing the design decisions in these two authentic contexts, we also observed some limitations of the RISSC environment. In what follows, these limitations will be outlined in relation to instructional design theory. In addition, we will outline how we tackled (and how we plan to tackle) these problems by making several improvements in the online learning environment and planning to test them in an ecologically valid setting in upper secondary education (in class). A first comment relates to the opportunities for communication and/or collaboration in the RISSC environment. At this point, the opportunities for interaction in RISSC are limited to a forum and a chat function. It is noticed that these options were not used by the learners. Although it is noticed that, except for one student, students in first year of university did not mention anything about a lack of interaction, we know that for online courses, social networks are important (van Merriënboer & Kirschner, 2018). As students in first year of university often clustered their activity in the online learning environment in one or two days, this problem might have been less apparent. In the next iteration in upper secondary education, students' activity will be spread over several weeks. In addition, students in first year of university indicated that they used other means, such as social media, in order to communicate with their peers. It is expected that the lack of interaction might cause more problems related to students' motivation in future implementations in upper secondary education. Second, in RISSC, students indicate that the difficulty level of the exercises differed widely, that the scoring procedure and/or explanation of the tasks was not always clear, and that example answers were too difficult. Also, students think they would be more motivated if they would have had a better view on the progress they are booking. Third, during the testing phases, it appeared clear that there is a large variety in the perception of students regarding the usefulness and the personal relevance of the online learning environment.

The abovementioned comments all relate to the fact that we did not succeed in stimulating students' motivation. The founders of the 4C/ID-model (van Merriënboer & Kirschner, 2018) recently stressed one crucial shortcoming in current research on educational programs based on the 4C/ID model. A remaining question, the authors argue (van Merriënboer & Kirschner, 2018, p. 322) "is how to maintain learners' motivation and deal with negative emotions in educational programs based on the Ten Steps". Van Merriënboer and Kirschner (2018) continue by arguing that systematic research on motivation and the 4C/ID model is largely missing, and suggest self-determination theory (SDT; Ryan & Deci, 2000) as a good theoretical framework for conducting such research. SDT maintains that for one to understand human motivation and regulation, one should also consider three innate psychological needs, namely the need for competence, the need for autonomy, and the need for relatedness (Deci & Ryan, 2000). The satisfaction of these needs is hypothesized to be related to the most effective functioning (Deci & Ryan, 2000). In short, the need for relatedness roughly refers to the need to have close relationships with others, including teachers and peer learners, and relates to the first comment mentioned above. Second, the need for competence or effectiveness refers to the need to be effective in dealing with the environment (related to the second comment above). Third, the need for autonomy refers to volition, and to activities as being concordant with one's integrated sense of self (related to the third comment above). (Deci & Ryan, 2000; van Merriënboer & Kirschner, 2018). As these three innate psychological needs require fundamental support, the role of instructional design comes into play. As such, this led us to the next iteration.

In order to systematically and gradually tackle these problems mentioned above, and to be able to observe pure results of certain instructional decisions, we first aimed at building in *autonomy support* (related to students' need for autonomy as described earlier) in the RISSC environment in a new iteration. In doing so, we aim to tackle students' comments with regard to a lack of positive perceptions regarding the usefulness of the learning environment. As several studies established that circumstances enhancing students' perception of autonomy facilitate intrinsic motivation and promote internalization (Deci et al., 1994), this was

expected to be a promising first step in improving the RISSC environment. As the need for autonomy might play a central role in educational courses that are mainly organized online (Martin et al., 2018), and in which student drop-out or a lack of student engagement constitutes a real risk, providing meaningful rationales, such as explaining students why task engagement could be beneficial to them (as one form of autonomy support) might be promising in enhancing (online) learners' motivation. As such, in adapting the online learning environment, we focused on providing meaningful rationales.

In total, five main adaptations were made to the online learning environment: (a) while in the baseline online learning environment, a professor explained the objectives of the online learning environment (see Appendix A), we expanded this information with an explanation of the value/usefulness of these objectives in daily life, professional life, and future studies; (b) in the beginning of each task class, we added an information page to the learners explaining the learning objectives specific to that task class. In addition, while the baseline online learning environment contained the following statement: "At the end of this module, you will be asked what you will remember of this module", we adapted this information and added the following statement: "At the end of this module, you will be asked to formulate three situations in your daily life, professional life or future studies in which you can use what you've learned in this module", as such again stressing the personal relevance to the learners, and challenging them to think about the personal value of the learning environment; (c) in the supportive information pages of the adapted online learning environment, avatars were added explaining the value/usefulness of the information for students' personal goals. On every page, an avatar was added of a student (e.g. "I can use this when writing my bachelor's thesis), a professional (e.g. "I can use this to identify questions related to my students' wellbeing") and a peer in daily life (e.g. "I can use this to identify the quality of research questions provided in the media") (see Figure 6); (d) after every task class, students are asked to formulate three concrete situations in which what they had learned might be useful in the future; (e) in the last task of the online learning environment, we stressed that students could choose the context of their research proposal according to their own interests. Thus, overall, in line with operationalizations in existing research (Deci et al., 1994), we presented participants reasons why engaging in the online learning environment was worthwhile the effort, in the hope to enhance their feelings of autonomy.

This new version of the RISSC-environment, with autonomy support, is tested with 70 students in upper secondary behavioral sciences education. Unlike the first testing phase, students complete the online learning environment in class, one hour each week, under supervision of their teacher. We expect that the fact that students complete the online learning environment in class, will lead to less variation in students' activity. However, by integrating the learning environment in students' curriculum, we make sure that students complete the entire learning environment, which is also crucial in drawing reliable conclusions regarding their learning progress. In line with the previous testing phase, students complete the online learning environment individually.

In order to gain more insights into students' learning behavior (and the relation of this learning behavior with several design considerations, and with students' learner characteristics), we plan to administer and analyze students' logdata in this iteration. The conditions in this iteration will differ from the conditions in the pilot phase: most importantly, the students in this iteration will complete the learning environment in class, under supervision of their teacher, whereas the students in the pilot were asked to complete the learning

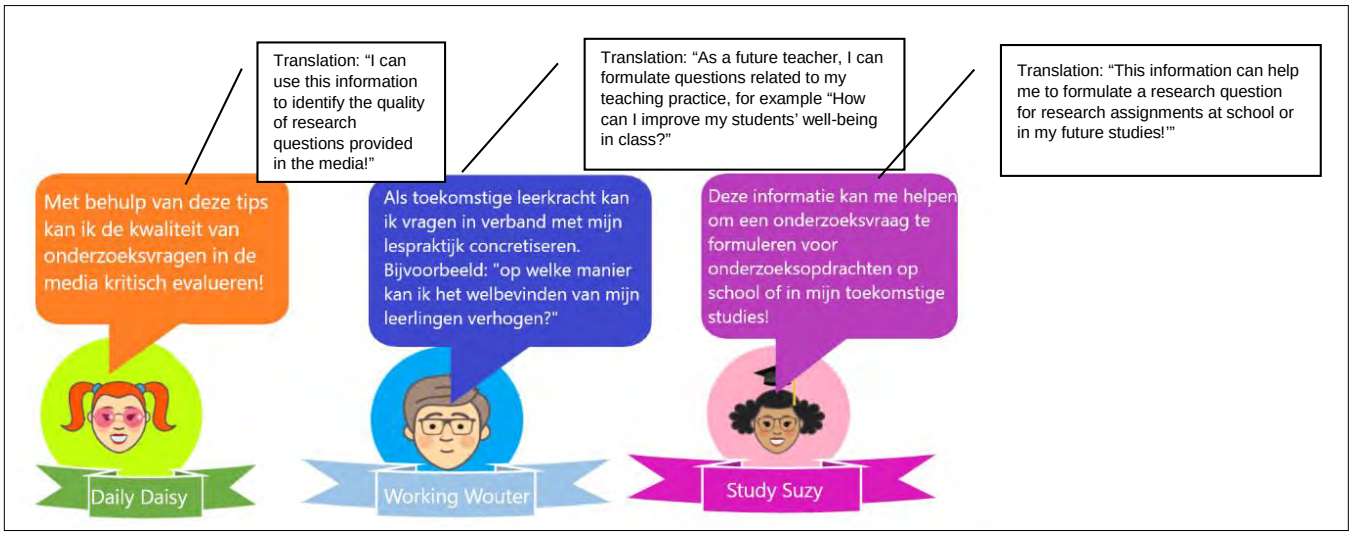


FIGURE 6. Avatars.

environment at home. The latter circumstances led to a large variety in students' participation in the online learning environment. Because of this large difference in circumstances (which makes generalization of these findings to the next iteration problematic), we considered that this kind of logdata was not very informative in the pilot, but we expect this logdata to be highly informative in this (and coming) iteration(s). More concretely, we will look into students' behavior in relation to the four components of the 4C/ID-model (van Merriënboer & Kirschner, 2019). For example, we will look at the number of times a student consults supportive information and/or procedural information. In addition, we will look at the time spent on performing the learning tasks and the part-task practice items. In doing so, we hope to gain insight in possible interactions between students' learner characteristics (motivation and prior knowledge), several design characteristics (such as providing autonomy support), and students' learning behavior. Thus, this information is expected to be useful for future implementations of the online learning environment.

REFLECTION TO PRODUCE DESIGN PRINCIPLES

As mentioned in the previous section, the new version of the RISSC-environment is tested with 70 students in upper secondary behavioral sciences education. In order to be able to purely observe the outcomes of providing autonomy support, we chose to investigate the need for autonomy in an isolated fashion in the first iteration. However, as was already mentioned, all three innate psychological needs (need for autonomy, need for relatedness, and need for competence) require fundamental support (Ryan & Deci, 2000). As such, while addressing issues regarding the need for autonomy, we still expect to observe problems with regard to students' need for competence and relatedness, also explaining lower motivation. As such, providing support for all three needs will be crucial to the next and final planned iteration in upper secondary education. The design decisions regarding this support will be based on (a) observations of the pilot phase in two different contexts, (b) on the observations and on the feedback received in the iteration focusing on autonomy support, (c) on theoretical and (d) practical considerations.

Looking back at the design process (and looking forward to the next steps in the design process), it should be mentioned that not every decision was/will be aligned with the 4C/ID model and its prescriptive guidelines. Because we had to work within the boundaries of our specific context with its specific peculiarities, some design decisions had to be made that did not align with the 10 steps to complex learning (van Merriënboer & Kirschner, 2018). One specific example of such decision relates to the format of the online learning environment itself. We could argue that the fidelity of the learning tasks can suffer from the fact that they are purely implemented in an online learning environment. It must be mentioned that, overall, the fidelity ("the degree of correspondence of a given quality of the simulated environment with that quality of the real world" (van Merriënboer & Kirschner, 2018, p. 58)) is rather low. In RISSC, the "authentic tasks" are provided to the learner by means of cases, videos and examples. As such, the learners are confronted with "the world of research" in a rather reflective way. A learning environment with high fidelity would allow learners to interact with researchers, to go out in the "field" to perform research and to communicate about their research with peers and professionals. For example, in research, real-life tasks are often performed by a team rather than a sole individual. However, due to practical constraints (such as time), we could not reach this high level of fidelity. We do believe that there are possibilities to include some kind of interaction with researchers, teachers or with "peer-researchers" in the online learning environment. These opportunities will be explored in the next iteration (investigating need for relatedness and need for competence support).

CONCLUSION

In this paper, we tried to clearly illustrate the design process of the RISSC environment as part of a design-based research approach. In doing so, we hope to contribute to instructional design theory by providing a concrete instructional design case for complex learning. In addition, as RISSC will be used in future intervention studies, this operational description provides crucial information in order to interpret the findings in relation to RISSC's specific design characteristics. The development of RISSC is an illustration of a design process that is highly guided by a formal instructional design model (4C/ID model, van Merriënboer & Kirschner, 2018). Although this design model and its prescriptive 10 steps facilitated RISSC's development process, this process took place within the boundaries of its theoretical and practical context (as was already mentioned in the previous sections). The RISSC environment can be considered unique because of its domain-specific focus on research in behavioral sciences; its attention to eight distinct epistemic activities (Fischer et al., 2014); and its integration of instructional design theory with a design-based research (inspired) approach. Although this design process resulted in a baseline learning environment, and an iteration focusing on autonomy support, during the implementation and reflection phase several opportunities for enhancement were noticed. Therefore, a new cycle of iterative refinement of the RISSC environment is planned.

ACKNOWLEDGMENTS

This study was carried out within imec's Smart Education research program, with support from the Flemish government.

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APPENDIX A

Blueprint of Baseline Online Learning Environment

Baseline RISSC		
Wide-angle view		
Epitome	*Procedural epitome* (explaining objectives of the learning environment); making different steps clear for the students. *Concrete: video of a researcher explaining the objectives of the online learning environment.*	
Question: "Explain the goal of the online learning environment in your own words."		
Elaboration: Emphasis manipulation by topical sequencing. (inductive strategy) Increasing fidelity within and between task classes		
Elaboration aspect 1 (task class 1)	Task class on questioning and hypothesis generation designed based on the "Ten steps" (van Merriënboer & Kirschner, 2018) Three different authentic task experiences based on real life tasks and situations with diminishing support within the task class. (scaffolding: completion strategy: evaluate cases -> completion tasks -> find: conventional tasks) (van Merriënboer & Kirschner, 2018)	
Description task class 1: Learners are confronted with research situations where the design and the purposes of the studies are clearly defined. Learners need to evaluate, complete and formulate research questions. *Learning objectives:* - Evaluate, complete and find a research question. - Identify dependent and independent variables.		
Information page with learning objectives + **"At the end of this module, you will be asked what you will remember of this module".**		
Supportive information *Presentation of cognitive strategy (inductive strategy, available during each learning task)* SAP (systematic approach to problem solving) for evaluating the quality of a research question (HEROES) (haalbaar, eenduidig, realistisch, open vraagvorm, specifiek). *Conceptual domain model on concepts related to research questions (video on research questions)* *Content: "De klimaatbrosser is 17 en volgt school in het aso" (De Standaard, 21/02/2019).*		
Learning task 1a: *Case study/worked out example (evaluate) = given + goal + solution* Learners receive a casus on the "bystander effect". They are asked to evaluate the quality of the research questions given. In addition, learners are asked to identify a dependent and an independent variable in the research questions. Feedback: example solution ("acceptable solution" (van Merriënboer & Kirschner, 2018, p. 67). *Content: article "bij zwaar ongeluk helpen we wel", De Standaard, mei 2011 (omstandereffect)*	**Procedural information:** How to recognize a dependent and independent variable? (on-demand presentation of cognitive rules) Just-in-time information on prerequisite knowledge for performing the learning tasks (facts, concepts, principles…) (for example: "meta-analysis"), in small, distinct units.	**Part-task practice:** Recognizing dependent and independent variables + corrective feedback
Learning task 1b: *Case study (evaluate) = given + goal + solution* Learners are asked to evaluate 5 research questions. Feedback: example solution		
Learning task 2: *Completion (complete) = given + goal + complete solution* Learners receive information on a study on "ethics in journalism" (problem formulation and outcomes of the study). They must formulate a research question related to this casus. → Feedback: example solution *Content: article "Journalisten crashen op werkethiek", De Standaard, mei 2010*		
Learning task 3: *Conventional (find) = given + goal + find solution* Learners are asked to formulate a research question related to the theme "bullying at work". *Content: article "Eén op de zeven werknemers gepest", De Standaard, november 2017*		
Supportive information: *Cognitive feedback (instructional agent)* Learners receive feedback on their research question formulated in learning task 3.		
Wide-angle view	Elaborating the SAP-chart with sub procedures and rules-of-thumb Short statement on objectives learned: "Now you know how to formulate a good research question".	
	Short question: which information will you remember of this module?	
Task value item		
Elaboration aspect 2 (task class 2)	Task class on problem identification designed based on the "Ten steps" (van Merriënboer & Kirschner, 2018)	
Task class 2: Learners are confronted with research situations in which the research questions and the research scopes are clearly defined. Learners need to evaluate, formulate, extend or formulate the literature study. *Learning objectives* - Formulating and evaluating a search query - Evaluating references		

- Identifying ideas in a text document

Information page with learning objectives +
"At the end of this module, you will be asked what you will remember of this module".

Supportive information: *Presentation of cognitive strategy (inductive strategy, consultable during each learning task)*
SAP for formulating a search query.
SAP for evaluating a source (TABASCO: totaliteit, actueel, betrouwbaar, accuraat, status, coherentie).
Conceptual model of literature-search concepts, databases and types of sources.

Learning task 1: *Case study (evaluate)*

Learners are confronted with a clearly defined casus of a meta-analysis on mindfulness. The learners are asked to evaluate the quality of search query and of the references.
→ Feedback: example solution
Content: "Mindfulness is geen wondermiddel", De Standaard, mei 2016

Learning task 2: *Completion (complete)*

Learners are confronted with a research question and the output of a search query. The learners complete the real-life task by indicating which search query they would use to receive this outcome.
→ Feedback: Example solution
Content: "Harde werkers zijn vaker drinkers", De Standaard, januari 2015

Procedural information:
How to use Boolean operators?
(Just-in-time information)

Part-task practice:
Boolean operators + corrective feedback

Learning task 3: *Conventional (find)*

Learners formulate a search query, and they choose one reference. The research question and the casus are given to the students. The learners give arguments on why they chose this reference.

Content: "Online daten biedt weinig kans op ware liefde", De Standaard, februari 2012

Supportive information: *Cognitive feedback (instructional agent)*

Learners receive feedback on the third learning task.

Learning task 4: *Conventional (find)*
Learners read an article on "Tinder" (given and goal given). Learners distinguish two arguments pro, and two arguments contra the use of Tinder from the article.
→ Feedback: Example solution
Content: "Swipen is geen taboe meer", De Standaard, april 2018

Wide-angle view*	Elaborating the SAP-chart with sub procedures and rules-of-thumb
	Short question: which information will you remember of this module?
	Task value item
Elaboration aspect 3 (task class 3)	Task class on evidence generation, evidence evaluation and construction and redesign of artefacts designed based on the "Ten steps" (van Merriënboer & Kirschner, 2018)

Task class 3:
Learners are confronted with research situations in which the research questions, the research scopes and the theoretical framework are clearly defined. Learners need to evaluate, formulate or extend the evidence generation part of the research process.

Learning objectives
- Linking a strategy for evidence generation to a specific casus
- Decision-making regarding evidence generation (sample, instrument…)
- Evaluating the validity and reliability of evidence generation

Information page with learning objectives +
"At the end of this module, you will be asked what you will remember of this module".

Supportive information: *Conceptual mental model*
Overview of different kinds of research designs for evidence generation (with specific examples in a video)

Supportive information: *Conceptual mental model*
Overview pros and cons types of data collection.

Supportive information: *Presentation of cognitive strategy*
Checklist for quality of evidence generation (strategy for data collection, sample…)

Learning task 1: *Case study (Complete)*

Learners are confronted with a case study in which the research question and the design of the study is clearly defined. The learners are asked to complete the casus by indicating which strategy for data collection was used, and to indicate if they are possible pitfalls in this study. Second, learners are asked to evaluate what other manners of data collection would have been possible for the specific case under study.
-> Feedback: Cognitive feedback

Content: "Universiteit onderzoekt hoe we gelukkiger worden", De Standaard, januari 2014

Learning task 2: *Case study (evaluate)*

Learners are confronted with an introduction of a survey. Learners are asked to evaluate the reliability of the study.

→ Feedback: example solution.

Content: "Moslimonderzoek Humo en VTM hangt met

Procedural information:

Just-in-time information on how to evaluate the validity and the reliability of a study (for example: IF answer to question "if I would perform this research a second time in the same circumstances, would this yield the same results" is YES, THEN the study can be considered reliable).

haken en ogen aan elkaar", De Standaard, oktober 2016	Just-in-time information on prerequisite knowledge for performing the learning tasks (facts, concepts, principles…) (for example: "sample"), in small, distinct units (closure principle).
Learning task 3: *Conventional (find)* Learners are confronted with the outcome of a study on gifted achievers. The methodology is missing. Learners have to indicate how they would plan the research to come to the given results. → Feedback: example solution *Content: "Faciliterende en belemmerende factoren voor schools presteren bij hoogbegaafde leerlingen van de eerste graad secundair onderwijs", masterproef KU Leuven 2017*	
Wide-angle view*	Elaborating the SAP-chart with sub procedures and rules-of-thumb
	Short question: which information will you remember of this module?
Task value item	
Elaboration aspect 4 (task class 4)	Task class on drawing conclusions and communicating and scrutinizing designed based on the "Ten steps" (van Merriënboer & Kirschner, 2018)
Task class 4: Learners are confronted with research situations in which the research questions, the research scopes the theoretical framework and the design are clearly defined. Learners need to evaluate, formulate or extend the conclusions based on the given information. *Learning objectives* - Calculating means - Drawing conclusions from scatterplot, graph, table… - Formulating an abstract in academic language - Structuring an abstract	
Information page with learning objectives + **"At the end of this module, you will be asked what you will remember of this module".**	
Supportive information: *Structural mental model* How is an abstract organized?	
Supportive information: *Presentation of cognitive strategy* Evaluating academic language (ethical guidelines)	
Learning task 1: *Case study (evaluate)* The learners are confronted with a casus on a study on "Youth for climate", in which the global outlines of an abstract are given. The learners need to evaluate the content by structuring the abstract, and by drawing conclusions based on a table and figure. -> Feedback: Example solution *Content: klimaatspijbelaars ontcijferd: Universiteit Antwerpen en VUB (De Standaard)*	**Procedural information:** Procedural information on how to interpret relative numbers, how to calculate a mean…
Learning task 2: *Completion (complete)* The learners are confronted with extra information on the casus defined above. They are asked to formulate possible pitfalls with the sample and the ethical guidelines. -> Feedback: Example solution *Content: klimaatspijbelaars ontcijferd: Universiteit Antwerpen en VUB (De Standaard)*	**Procedural information** Procedural information on how to read graphs
L 3: *Conventional (find)* The learners are asked to write an abstract based on a figure (given). The learners can choose between two cases: 1) "youth for climate"; 2) wellbeing in their own city/town. → Feedback: example solution *Content: statistiekvlaanderen.be: jouw gemeente in cijfers (voldoende activiteiten voor ouderen): baseren op artikel https://nieuws.vtm.be/binnenland/dit-de-gelukkigste-gemeente-van-vlaanderen, resultaten vergelijken met resultaten van eigen gemeente/stad* *Content: klimaatspijbelaars ontcijferd: Universiteit Antwerpen en VUB (De Standaard)*	
Wide-angle view	Elaborating the SAP-chart with sub procedures and rules-of-thumb
	Short question: which information will you remember of this module?
Task value item	
Elaboration aspect 5 (task class 5)	Task class on problem identification, questioning, hypotheses generation, construction and redesign of artefacts, evidence generation, evidence evaluation, drawing conclusions and communicating and scrutinizing designed based on the "Ten steps" (van Merriënboer & Kirschner, 2018)
Task class 5: Learners are confronted with research situations in which in each learning task, parts of the research process are described. Learners need to evaluate, formulate or extend the research questions, the search queries, the analyses and the conclusions based on the given information. *Learning objectives*	

- Evaluate, complete and find a research question. - Identify dependent and independent variables - Formulating and evaluating a search query - Evaluating references - Identifying ideas in a text document - Linking a strategy for evidence generation to a specific casus - Decision-making regarding evidence generation (sample, instrument…) - Evaluating the validity and reliability of evidence generation - Calculating means - Drawing conclusions from scatterplot, graph, table… - Formulating an abstract in academic language - Structuring an abstract	
Information page with learning objectives + **"At the end of this module, you will be asked what you will remember of this module".**	
Supportive information: Links to supportive information of previous task classes	
Learning task 1: *Case study (Reverse learning task)* The learners are confronted with a casus on a study on grade retention. A researcher explains the goal of her research and parts of her research design. Learners are asked to predict the research question, the dependent and the independent variables, the design of the study, and the manners of data collection -> Feedback: Cognitive feedback *Content: Machteld Vandecandelaere: zittenblijven (KU Leuven)*	**Procedural information:** Links to procedural information of previous task classes
Learning task 2: *Worked-out example (Evaluate)* The learners are confronted with an article on grade retention. They are asked to formulate two pros and two cons of grade retention formulated in the article. -> Feedback: Example solution *Content: Doorkleuteren of overgaan? Soms is eerste optie beter. De Standaard*	**Procedural information** Links to procedural information of previous task classes
Learning task 3: *Reverse learning task (evaluate)* The learners are asked to evaluate possible references and search queries for a literature search on grade retention. → Feedback: cognitive feedback	**Procedural information:** Links to procedural information of previous task classes
Learning task 4: Conventional task (find) Learners are asked to structure an abstract → Feedback: cognitive feedback *Content: Goos, M., Juchtmans, G., & Vandecandelaere, M. (2014). Zittenblijven gebuisd?!? Samen op zoek naar alternatieven en een veranderaanpak op school. Caleidoscoop, 26(4), 21-27.*	**Procedural information:** Links to procedural information of previous task classes
Wide-angle view	Elaborating the SAP-chart with sub procedures and rules-of-thumb
	Short question: which information will you remember of this module?
Task value item	
Whole task: two-pager: Students are asked to write a two-page long research proposal.	Write two-pager, send it to a professor.