

## BLUEPRINTS OF AN ONLINE LEARNING ENVIRONMENT FOR TEACHING COMPLEX PSYCHOMOTOR SKILLS IN FIRST AID

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As most of the life-threatening events, such as heart failure and trauma, occur out-of-hospital, first aid is considered crucial for a victim's survival chances. Unfortunately, a substantial part of these psychomotor or consciously brain-controlled motor skills are executed poorly or incorrectly due to the inexperience of first aid attendants or low retention after training. Together with an enlarged demand over the past years for first aid skills within the business sector and, corresponding, the tremendous load in teaching hours, this high need for training sessions in first aid led to the development of an online learning environment for psychomotor skills within the domain of Health Sciences. Although online learning environments already exist for teaching cognitive skills, developing one for psychomotor skills is considered challenging as it has not been proven effective yet. What is considered important, however, is to avoid cognitive overload and to maintain learners' motivation throughout the entire online learning environment. As such, to avoid cognitive overload, the designers used a cognitive instructional model, namely the 4C/ID model and used it as a framework for their online learning environment. On top, choice options were added to the online learning environment to maintain motivation throughout the process of learning psychomotor skills. The ultimate goal lies in enabling the learner to perform the psychomotor skill fluently in practice. The design process of the online learning environment, the corresponding design challenges, failures, and how they were dealt with are described in detail.

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### INTRODUCTION

Heart failure and trauma due to (traffic) accidents are leading causes of death worldwide (Kornblith et al., 2019; Kuriachan et al., 2015; Metra & Teerlink, 2017; Porzer et al., 2017). Despite improvements in prevention, heart failure and trauma incidence remains unchanged as most of these life-threatening events occur out-of-hospital with numerous individuals not surviving the event (Jazayeri & Emert, 2019; Wong et al., 2019). First aid can enhance the chances of surviving heart failure or trauma as a first-aid attendant prevents further illness or injury of an individual and stabilizes its condition before professional help arrives (Zideman et al., 2021). Therefore, mastering first aid skills is considered invaluable for both professional caretakers and inexperienced individuals to improve patient outcomes.

Although their lifesaving significance, first aid techniques are often performed poorly or wrongly, causing less effective salvation of victims. For instance, superficial or rushed chest compressions during resuscitation do not affect restoring circulation (Veronese et al., 2018). Similarly, misplacement of a victim's arm in the recovery position can provoke vascular and neurological damage (Handley, 1997; Turner et al., 1998). One possible explanation for these poor executions of first

aid is that without regular exposure, these skills deteriorate within 3 to 6 months after training (Binkhorst et al., 2018; Kaye et al., 1991; Madden, 2006; Niles et al., 2009). In order to maintain competency acquired during an initial first aid training, also called retention, repeated practice is absolutely necessary (Au et al., 2019; Semeraro et al., 2021).

The demand for both initial training and refresher training of first aid skills within the business sector has evolved because in Belgium, a legally required yearly accreditation in first aid is mandatory for companies. However, organizing in-company training is often challenging. Whereas theoretical courses can be taught in large groups, the training of psychomotor skills, or consciously brain-controlled motor skills such as first aid, ideally takes place individually or in a small group. In fact, during such small-group practical sessions, learners are guided to gain knowledge through experience, also called hands-on education (Arnholz, 2019). Due to the low number of participants, a first-aid instructor often repeats the same practice session several times a day, causing a very time-consuming and high load in teaching hours. Other challenges in organizing in-company training are the diverse working schedules of employees, especially in the case of part-time work, and the need for permanent staffing. Moreover, current evolutions, such as the pandemic situation with the COVID-19 virus, oblige employees to work from home (Vergroesen, 2020). Considering the enlarged need and demand for training sessions in first aid on the one hand and the high load in teaching hours on the other, the interest in an online form of training psychomotor skills has increased (Greif et al., 2021).

Therefore, this paper describes an attempt in developing a high-quality e-learning environment for psychomotor skills in the domain of Health Sciences. However, the way these skills should be instructed in an e-learning environment has not been studied yet. Because two designers in this paper have been teaching refresher courses in first aid to employees of the KU Leuven for years and the third developer has expertise in instruction psychology, together they represent the perfect team for designing such an online learning environment. In order to create an e-learning environment for psychomotor skills, the designers explored in a first problem analysis what kind of psychomotor skills they were dealing with and how these skills can be instructed online. Additional design challenges and possible solutions to the rising problems when learning a new psychomotor skill are discussed in detail. Next, the blueprints and implementations of our e-learning environment for psychomotor skills particularly in first aid, and how the developers in this case, dealt with the design challenges and failures are yielded.

## PROBLEM ANALYSIS

### Psychomotor skills

Psychomotor skills can be subdivided according to their function into fine, coarse, complex, visual and auditory psychomotor skills (Magno, 2015). This paper focuses on teaching complex psychomotor skills, integration of specific consciously brain-controlled skills into one larger skill, such as basic life support and the recovery position within the domain of first aid. Regardless of the subject of interest, each complex psychomotor skill entails specific knowledge, skills, and attitudes that set it apart and transform a person mastering the skill from student to suitable professional (Fernandez, 2014).

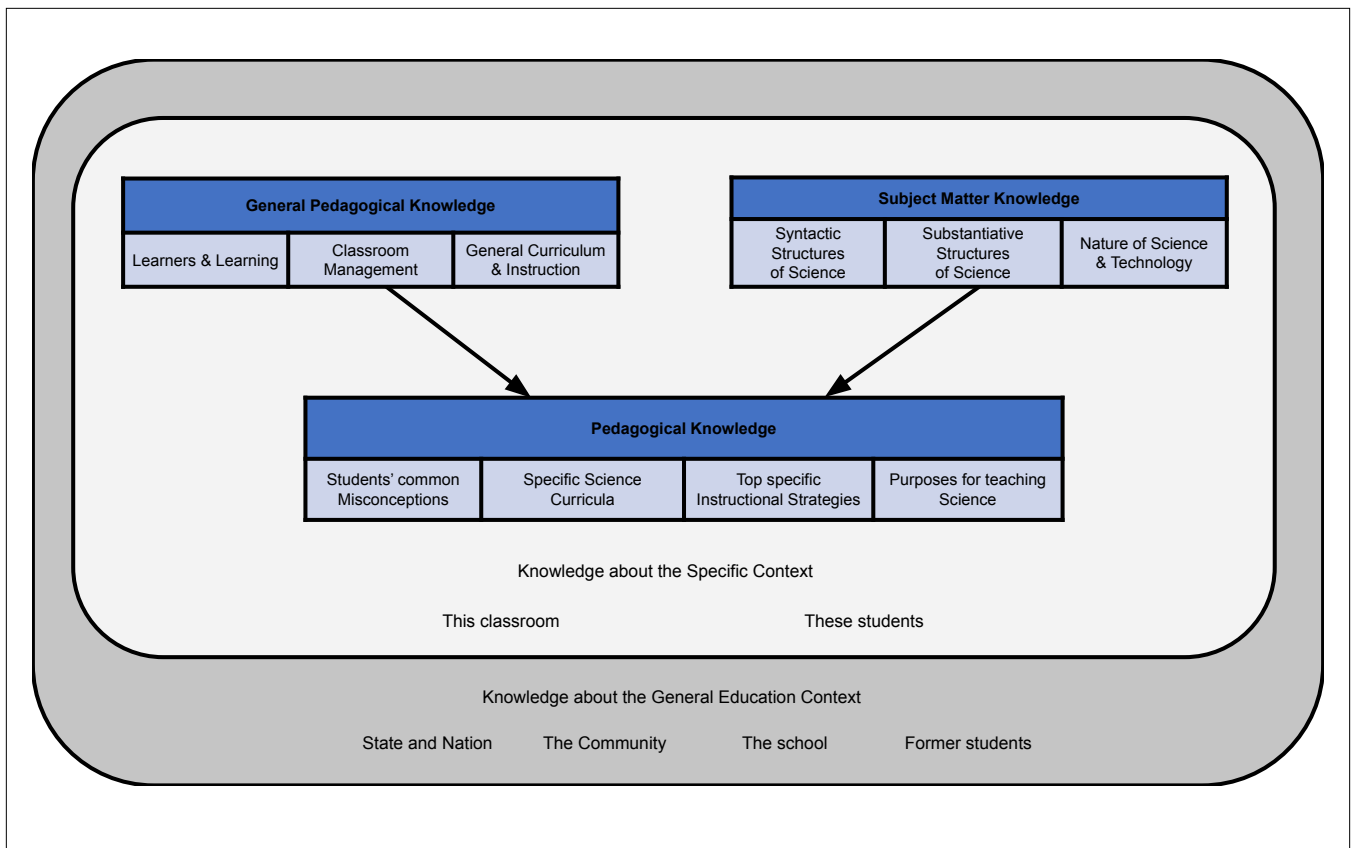
When teaching such a complex psychomotor skill, it is a prerequisite that the knowledge of the teacher reaches far beyond knowledge of the specific context of the skill alone. As Bucat stated, there is: “[...] a vast difference between knowing about a topic, and knowing about the particular teaching and learning demands of that particular topic.” (Bucat, p 3, 2005). Pedagogical Content Knowledge, or PCK, is a concept widely used in literature to represent both (Fernandez, 2014). To establish fruitful PCK, Carlsen (Figure 1) suggested a model where a teacher should seize both Subject Matter Knowledge, the “what” to teach, and General Pedagogical Knowledge, the “how” to teach, to gain the knowledge that makes one a good teacher (Carlsen, 1999). Following Carlsen’s model, the developers first gained full knowledge about the complex psychomotor skill, in this case within the domain of first aid, to master it thoroughly and broaden their knowledge about online learning and instructional design models.

Subsequently, PCK can be acquired by, amongst other things, understanding the common misconceptions of students regarding the skill. In this case, misconceptions were collected from different sources: extensive first aid teaching expertise of the developers’ knowledge from initial and continuous training and information retrieved from scientific medical and pedagogical literature. Where the first can be seen as more practical knowledge, the latter two refer to formal knowledge intended to serve as a prescription to guide teachers (Fernandez, 2014). While searching for knowledge about the pedagogical aspect of learning a complex psychomotor skill, the developers came across some issues that potentially made the design of an online learning environment challenging.

### Design Challenges

#### *Using a cognitive instructional model for learning psychomotor skills*

When acquiring a new complex skill, the limited capacity of the working memory is to be considered (van Merriënboer



**FIGURE 1.** Carlsen's model of Pedagogical Content Knowledge (Carlsen, p 136, 1999; used by permission).

& Sweller, 2010). Presenting excessive new and unstructured information simultaneously is detrimental to the learner. It can trigger cognitive overload, where the brain can no longer process all the learning material (van Merriënboer & Sweller, 2010). Therefore, choosing an appropriate online instructional design that focuses on acquiring competence in a well-structured manner can offer the first solution to this problem.







A study by Merrill in 2002 reviewed a number of these instructional models, such as the Star Legacy (Vanderbilt Learning Technology Center) and the Constructivist Learning Environments (Jonassen). He described the four-component instructional model or henceforth called the 4C/ID-model of van Merriënboer (Bennett et al., 2011; Vandewaetere et al., 2015; van Merriënboer 2002, 2007) as "the most comprehensive recent model of instructional design that is problem-centered and involves all of the phases of instruction." (Merrill, p 56, 2002). Accordingly, the designers in this paper decided to use this model as a framework for their online learning environment. Noticeable, this might be a major challenge as the 4C/ID model has already been proven effective as a cognitive model but has less been explored for learning psychomotor skills.

Although the high-quality instructional structure of the 4C/ID model attempts to avoid cognitive overload, this problem

might be induced by the digital and multimedia learning materials too. Therefore, using evidence-based multimedia principles can contribute to create a powerful online learning environment (Mayer, 2005). Table 1 describes six of Mayer's multimedia principles in online learning used in this paper (Mayer, 2017).

#### *Adding (not too much) learner control to the design*

Figure 2 yields the practical problems faced during the design of our online learning environment. To avoid cognitive overload when acquiring competence in a new psychomotor skill, e.g., the recovery position, the 4C/ID model of van Merriënboer (2002) and Mayer's principles offer a possible solution. To maintain motivation throughout the learning process, learner control, a situation where each individual can personalize the online learning environment to their needs (Van Laer & Elen, 2017), was added to the online environment. Both the 4C/ID model and learner control have not yet been proven effective for psychomotor skills. Even though learner control positively impacts learners' motivation in cognitive tasks, it can urge overload if too much is present as making choices takes cognitive space. Therefore, it will be challenging to find the perfect equilibrium between the working memory capacity on the one hand and learner control on the other.

	<i>Coherence Principle.</i> Exclude interesting but irrelevant material as it reduces cognitive capacity to process essential material in a lesson.
	<i>Redundancy Principle.</i> Graphics with narration alone is more effective than also including on-screen text. Adding one or two keywords as on-screen text has benefit.
	<i>Segmenting Principle.</i> Add self-pacing options to enable learners to process information before continuing.
	<i>Modality Principle.</i> Present information about a graphic verbally rather than as text so that learners can listen and refer to graphics, especially for system paced dynamic graphics.
	<i>Voice Principle.</i> Narration should use a human voice rather than a computer voice, and this should match any on screen character.
	<i>Embodiment Principle.</i> Drawing graphics as you explain is more beneficial than explaining a presented drawing as it reflects a real-life social interaction.

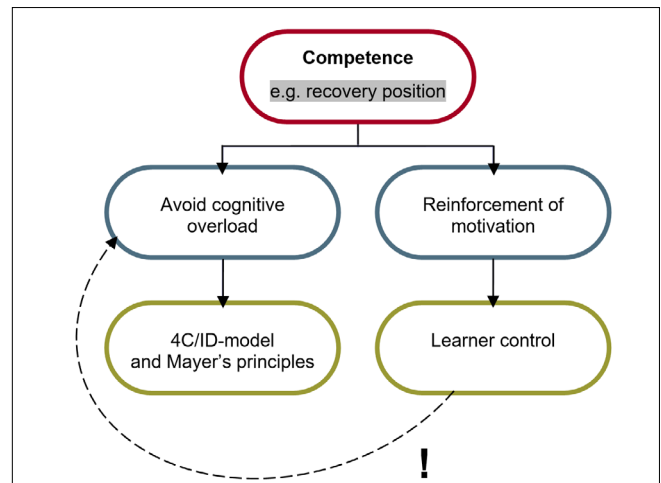
**TABLE 1.** Mayer's principles: Using multimedia for e-learning (Mayer R., 2017).

Previous research shows the motivation of a student to be crucial when acquiring psychomotor competence, monitoring, and maintaining (Liang-Yi & Chin-Chung, 2017). Although online education already offers many advantages contributing to motivation such as wider accessibility (Clarke, 2007), learner control is considered a highly suitable solution to this motivational issue in education too (Kinzie & Sullivan, 1989). Learner control can take many forms. The learner can be given a choice in modifying the pace, the sequence and content of the learning material, feedback on certain learning tasks or media such as volume or images (Kraiger & Jerden, 2007; Randolph & Orvis, 2013).

Previous research on learner control mainly focused on cognitive skills and resulted in both positive (Buchem et al., 2014; Corbolan, Kester, & van Merriënboer, 2009; Fischer et al., 2017; Mayer, 2005; Schnackenberg & Sullivan, 2000; Zhang et al., 2006). and negative (Iyengar & Lepper, 2001; Merrill, 2002; Schwartz, 2004) impacts on learning. Shared control, a type of control in which the learner is only given choice in part of the learning environment and the remainder is program-controlled, poses a worthy alternative (Corbolan et al., 2006-2008).

## BLUEPRINTS 4C/ID-BASED LEARNING ENVIRONMENT

The designers developed an online learning environment based on the 4C/ID-model of van Merriënboer (van Merriënboer, 2002) to master complex psychomotor skills online. The backbone of the 4C/ID model consists of 4 important subparts yielded in Figure 3: (1) supportive information, (2) learning tasks, (3) procedural information,



**FIGURE 2.** Challenges of this design.

and (4) part-task practice (Bennett et al., 2011; Vandewaetere et al., 2015; van Merriënboer et al., 2002; 2007).

A group of learning tasks, subsequently defined as a task class, consists of a collection of authentic learning tasks dealing with the same subject and equal degree of difficulty. In total, three task classes were designed within the domain of first aid, each with incrementing difficulty and including learner control to reinforce the learner's motivation. In this paper, only the design of the first task class, "the four steps in first aid," will be discussed. The remaining task classes were designed similarly. First, a general overview of the task class can be found. Next, the development process and design failures will be explained.

Figure 3 outlines the first task class. At the beginning of the task class, some general information, such as clearly outlined

objectives and the functioning of the task class, is provided. In the next screens, the learners' prior knowledge is briefly tested to make sure they are acquainted with the learning standards to be met.

After the test, the supportive information, displayed by the L-form in Figure 3, is provided. Mostly supportive information includes some cognitive strategies (e.g., a manual or decision tree) and assists in learning and performing non-recurrent aspects of the learning tasks in one particular task class (Cook & McDonald, 2008). Supportive information may also include an elaborated sample case and is always available during the learning process (van Merriënboer et al., 2002). In general, it offers a systematic approach to solving problems. In this case, the learner is first shown a fully worked case to serve as a solution example for the tasks following in the learning environment. Next, useful background information in the form of a decision tree and information sheets is pointed out. The supportive information can always be consulted by clicking on an icon in the upper right corner of the screen.

After that, the learner can start solving four authentic learning tasks, shown by the big circles in Figure 3, incorporating the principles of multimedia introduced by Mayer (Mayer, 2017). The 4C/ID model aims to integrate (non-recurrent and recurrent) skills, knowledge, and attitudes; therefore, learning tasks are always practiced in their entirety and not in a sequence of sub-tasks which later on need to be integrated independently by the learner. These whole-task experiences are authentic and based on real-life tasks (e.g., case studies, projects, problems, role play, ...) and thus emphasize reality (Clarebout & Elen, 2011). Therefore, the search for appropriate and qualitative tasks is also a challenge. Due to their high practice variability, transfer to other similar learning tasks is triggered (van Merriënboer & Kirschner, 2007). In this paper, the learner tasks embrace medical cases where the learner

is asked to provide correct assistance to the victim. The first case involves a general case about an unconscious victim, the next covers a bike accident, the third case an amputation of a thumb, and the last one handles an electrocution case. Before commencing the first learning task, the learner is shown an option screen where he can choose one of the proposed learning tasks, introducing learner control for the first time. In order to still comply with the basic principles of the 4C/ID model, i.e., learning tasks are provided in a manner of diminishing support (Vandewaetere et al., 2015) but include added learner control, the amount of support given in each learning task is provided by means of an icon. This enables the learner to make a well-reasoned decision over choosing a suitable learning task. After finishing one learning task, the learning environment automatically retraces to this options menu for the learner to start with the next one.

Learner control is not only provided by sequence, i.e. choosing the most suitable learning task from the option menu as described earlier, but is also available within each learner task. More specific, learners can choose whether or not they need extra feedback, also called procedural information, during a specific part of a learning task. Procedural information is shown in Figure 3 through arrows underneath each learning task and is, in the online learning environment, clickable by an icon in the upper right corner of the screen. Procedural information is provided to the learners at the required moment in order to help them solving recurrent aspects of the task and diminishes over time, a process called scaffolding (Vandewaetere et al., 2015). Examples are step-by-step instructions, checklists or feedback on a learning task (van Merriënboer & Kirschner, 2007). However, as opposed to the supportive information, this feedback icon only appears when relevant.

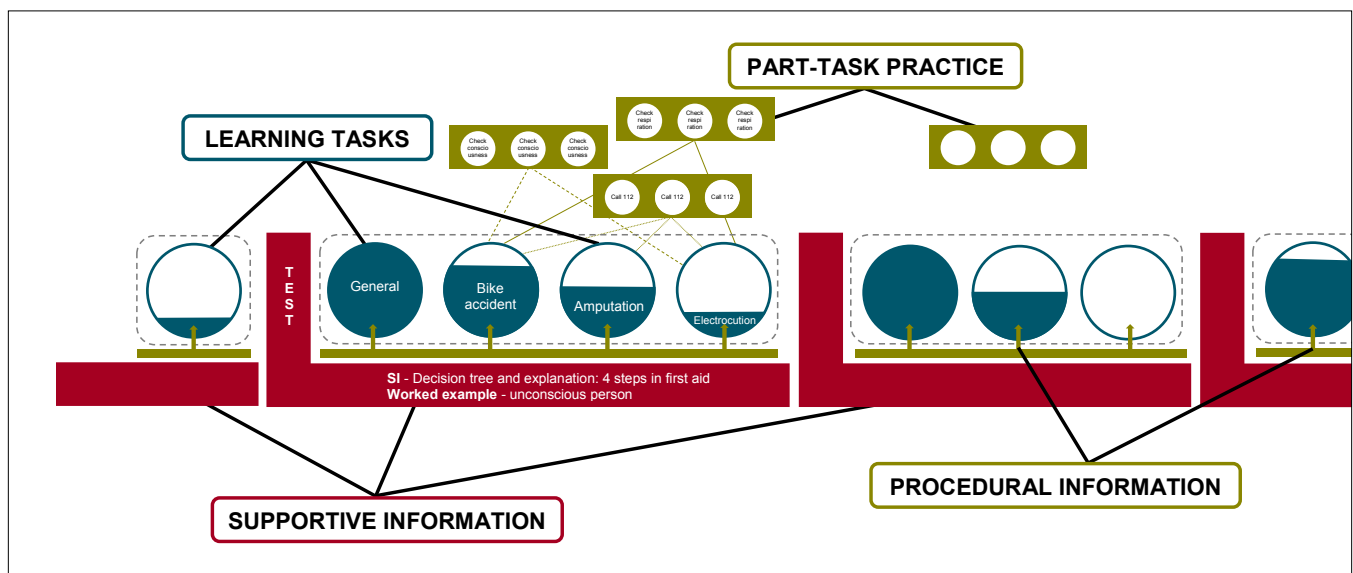


FIGURE 3. Blueprints of the 4C/ID-based learning environment: 'the four steps in first aid.'

Some parts of learning tasks require a high form of automation and therefore include part-task practices, yielded by the small circles above the learning tasks in Figure 3. These can be practiced by clicking the provided icon on the screen. However, since designers deem these part-task practices essential, it is mandatory to fulfill them before continuing the learning task. Therefore, no learner control was comprised in this part.

This paper's blueprints of the online learning environment were designed based on the "Ten steps to complex learning" propounding ten subsequential steps for production (van Merriënboer & Kirschner, 2007). These steps were used as guidelines throughout this phase of solution development and are further discussed next.

## Ten Steps for Design

### Step 1: Design learning tasks

It is important to consider which set of typical learning tasks will represent the whole psychomotor skill and what the training program aims to achieve (Vandewaetere et al., 2015). In order to do so, a distinct definition of the new psychomotor skills and clear corresponding objectives need to be determined. The psychomotor skill in this online learning environment was based on the to be obtained learning goals stated in the Royal Decree of December 15, 2010, regarding first aid provided to employees who become victims of an accident or who become ill (BS 28.12.2010). The designers

choose the recovery position as it incorporates a complex psychomotor skill within this education framework. It refers to a position used to prevent choking in unconscious patients, in which the body is placed facing downwards and slightly to the side, supported by the bent limbs (Figure 4).

Although the recovery position or any medical technique can be seen as a psychomotor skill, the technical skill, i.e., 'how' to perform the technique, is not sufficient to possess the competence of the whole psychomotor skill. Knowing 'when' to use the skill is considered important too. Therefore, the need for authentic learning tasks is immense. For example, if a victim is suffering from a heart attack or is severely choking and the first aid provider simply positions him on one side in recovery, the victim will eventually die due to the misused technique. It is important not only to skill the attendant in a certain psychomotor constituent technique,

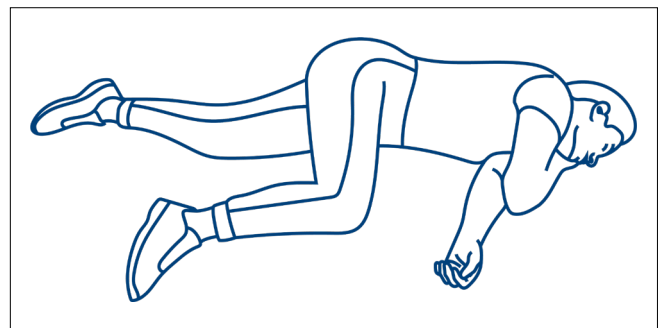


FIGURE 4. The recovery position.

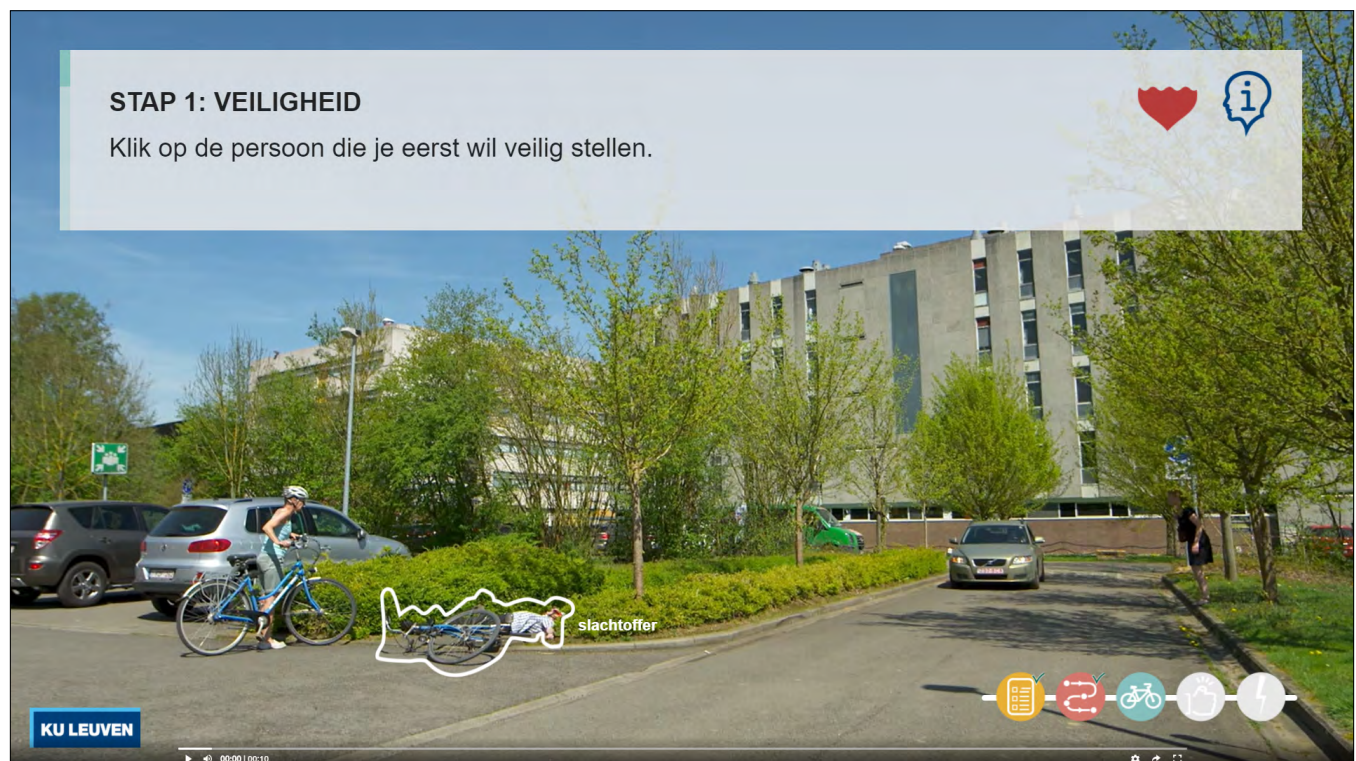


FIGURE 5. Example of a learner task in the online learning environment.

i.e., the recovery position, but to support the transformation of a learner into a competent professional who incorporates the technique into a whole practice.

Variety in learner tasks and justification of the authenticity are priorities (Clarebout & Elen, 2011), and achieving this can be seen as one of the challenges of this design. As such, real examples were used as learner tasks and thus can be considered variable and authentic. The developers promoted their search for real cases of job accidents through social media and e-mail, whereupon a great number of prevention consultants and occupational health physicians in Belgium responded, providing a diverse set of anonymous cases. The cases were organized in 11 job-subdomains posing each a relative amount of cases: commerce (1.59%), construction (19.84%), education (3.97%), farming and environment (3.17%), fashion and styling (0.79%), general/finances/government (4.76%), industry/production (14.29%), medical care/nourishment/sports (3.97%), pubs and restaurants/catering (2.38%), techniques and facility services (2.38%), transport and logistics (42.86%). The designers selected 14 suitable cases based on (1) authenticity, (2) variety, (3) integration of the proper recurrent and non-recurrent skills, knowledge and attitudes and (4) feasibility to shoot the case with a professional film crew.

In the next phase the elected cases were outlined in a script, filmed with the support of a professional audiovisual service and converted to visual and interactive authentic learning tasks in the software program of Blue Billywig © (Blue Billywig strategic online video, 2021). Real-life accidents that might happen at work were staged in an online learning environment asking learners what to do in that particular situation. Step by step, learners answer multiple choice questions by clicking the right option (example in Figure 5). After each response, the learner receives feedback if wanted. Each learner task contains a timer reproduced by an emptying red heart (right corner Figure 5) to emphasize the importance of executing first aid as fast as possible (Abella et al., 2005; Holmberg et al., 2004; Valenzuela et al., 1997) and thus enhances the reality of the learner tasks.

**Step 2: Set performance objectives.**

According to the Ten Steps (van Merriënboer & Kirschner, 2007), the following section serves to clearly outline the goals of the task class in order to achieve effective task performance. In this particular case, setting objectives was straightforward due to the clear psychomotor character of the skill and the already existence of international legislation.

At the beginning of each task class, the performance objective is clearly outlined in a general information screen, for example: "After having completed the first task class, the attendant will be able to conduct and justify the first steps in first aid". Hereinafter the learner completes a self-assessment quiz, which was also used to survey the prior knowledge

of the learner. Next, a worked example, showing a perfect performance of the psychomotor skill, allows the learner, along with the performance objectives and test, to become acquainted with the quality of the performance and standards to be met (Vandewaetere et al., 2015). In summary, after processing the task class, the learner is able to perform the predetermined psychomotor skill.

**Step 3: Sequence learning tasks.**

In order to optimize the learning process, learning tasks are ordered by increasing complexity in different subsequent task classes and, at each level of complexity within a task class, by decreasing support and guidance, a process called scaffolding (Vandewaetere et al., 2015). In this particular case, to perform the recovery position, one must know the underlying basic cognitive principles of first aid, e.g., recognizing a life-threatening situation and referring adequately to the emergency services, before performing a recovery position or any other technique on a person in need. Based on this reasoning, we decided to create three 'recovery position' task classes (Table 2) differing in complexity.

The task classes are organized from simple, e.g., four steps in first aid, to complex, e.g., performing a recovery position in specific cases. The increase in complexity is valid in our on-line learning environment as in every task class, the learner integrates new skills from the current task class with skills learned in previous ones. Within one task class, the learner tasks are sequenced by means of decreasing support and guidance. To secure learner control and thus the motivation of the learner, the degree of support and guidance in each learner task is marked in the options menu by means of icons (Figure 6a). In this way, the designers suggest a clear sequence of learner tasks but learners can still follow their own preferences. As for the current task class the learner task containing most guidance and support entails the study of a case where the learner must mark the steps in first aid through the process of multiple choice questions showing the same recurring answer options. The next two learner tasks, one about a bike accident and another concerning the amputation of a thumb, contain multiple choice questions with more detailed and distractors. The learner task with minimal guidance and support, a case about electrocution, shows a completion task in Dutch where the learner has to fill out the blanks with a possible correct answer (example in Figure 6b).

<b>MODULE 1 (30 MIN)</b>	Task class: 4 steps in first aid
<b>MODULE 2 (30 MIN)</b>	Task class: CPR or recovery position?
<b>MODULE 3 (30 MIN)</b>	Task class: recovery position in specific cases

**TABLE 2.** Different task classes concerning the recovery position.

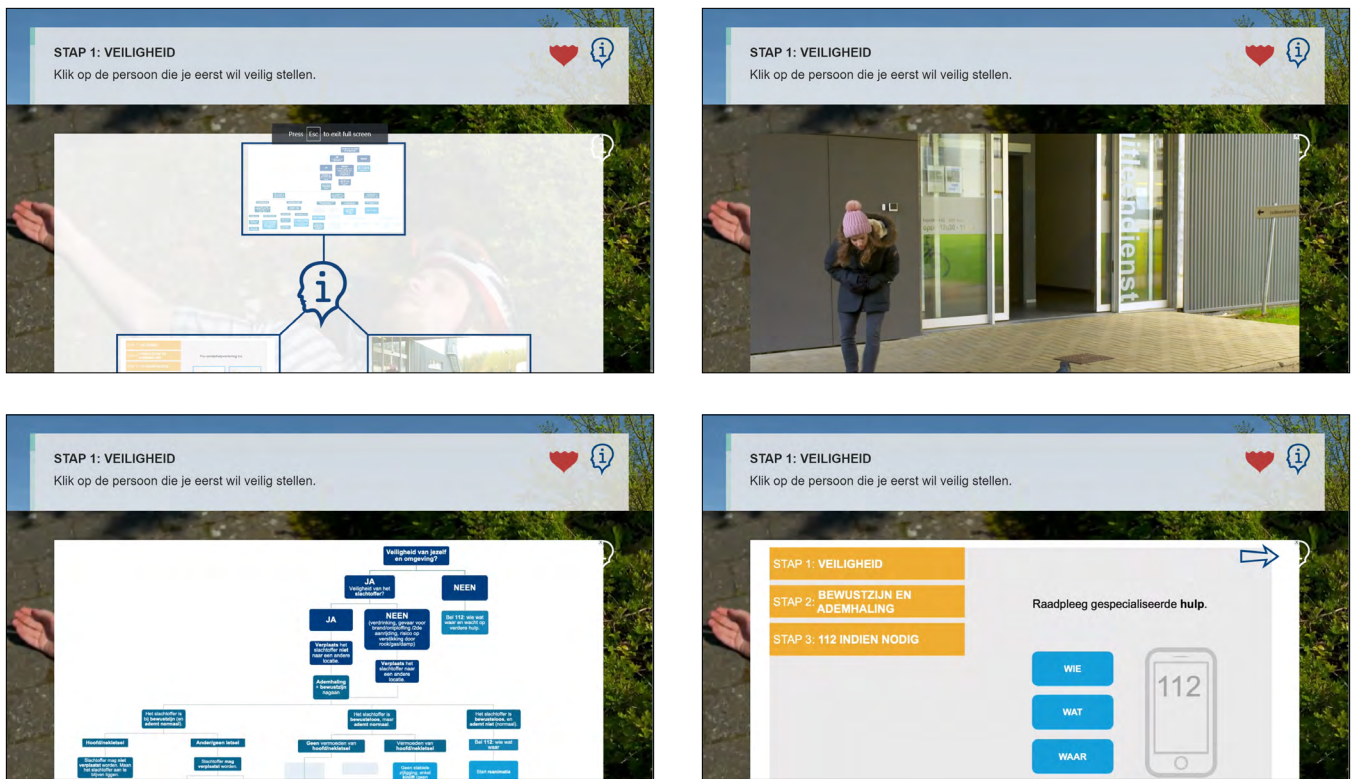


**FIGURE 6.** (a, top) Options menu and (b, bottom) example of a completed task in the online learning environment.

*Step 4: Design supportive information.*

The content of the supportive information consists of a variety of knowledge gathered through evidence-based literature in medical education combined with PCK of the designers regarding commonly made mistakes. It consists of

a decision tree (step 5), information sheets (step 6), and a video worked example showing, for instance, an unconscious victim lying breathless on the sidewalk with an attendant performing the constituent skills in first aid as a correct solution for this case (examples in Figure 7).



**FIGURE 7.** Examples of supportive information (clockwise from top left): (a) option menu, (b) whole example (video): correct application of first aid on an unconscious victim, (c) decision tree: sequence of first aid and (d) information sheet: how to inform specialized authorities. Step 6: Analyze mental models.

At the beginning of each task class, it is mandatory for a learner to process all the supportive information. The way of presenting this information is crucial (van Merriënboer et al., 2002). Therefore, in this design, the supportive information is presented in an inductive manner since this approach is considered reasonable, time-efficient, and effective for learners with little prior knowledge. This implies that first, the whole example is introduced, followed by the more abstract decision tree and more conceptual information sheets, which explicitly present the relationships between pieces of information shown in the example.

When conducting the learner tasks, supportive information must be available at all times. In this case, an icon representing a human's head containing the letter "I" of "information" is visible at all times in the right corner of the screen. When clicking on it, an option menu appears where learners can choose which particular part of the supportive information they want to review, adding learner control to the supportive information as well (see Figure 7a).

#### Step 5: Analyze cognitive strategies.

Cognitive strategies allow one to perform tasks and solve problems in a systematic manner (van Merriënboer & Kirschner, 2007). Typically, problem-solving phases and rules are presented as cognitive strategies. In this design, a decision tree was used. The learner answers closed-ended

questions and follows the preferred path in order to choose the correct first aid technique such as resuscitation, recovery position, or wound care for a particular case at a proper time. Because the responses are downsized to "yes" or "no", a decision tree is considered a clear tool. Moreover, it can be seen as useful within medical education as intervention can be lifesaving if executed with quality and fastness (Abella et al., 2005; Holmberg et al., 2004; Valenzuela et al., 1997).

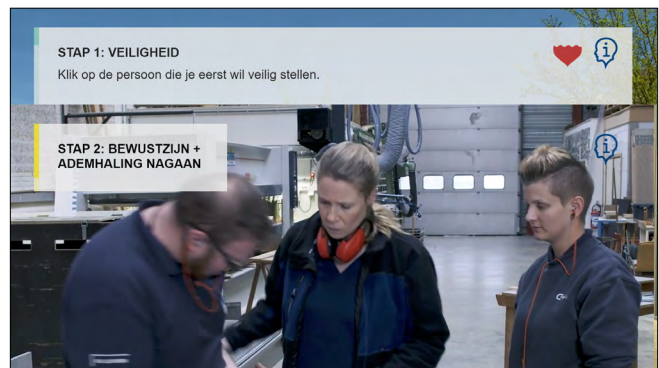
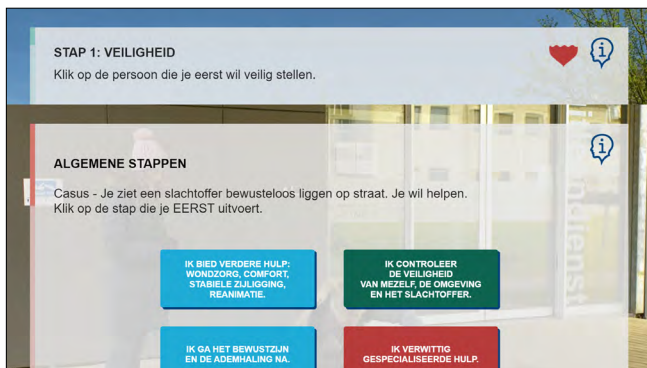
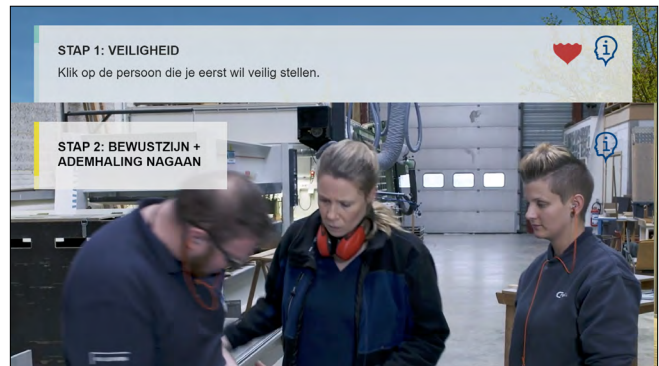
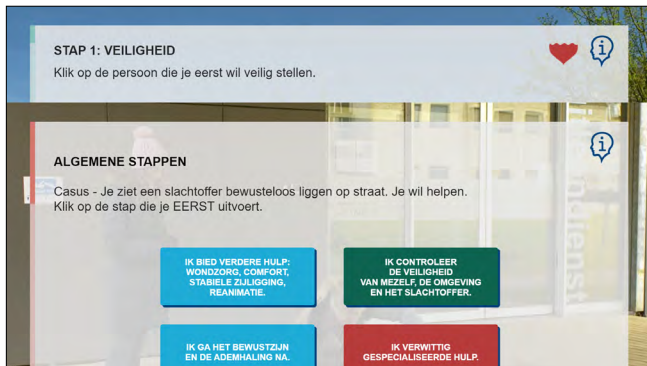
Compiling such a decision tree is not an easy task. The designers analyzed evidence-based medical literature, commonly made mistakes and used professional experience to denote general questions raising when solving any sort of medical case. Next, they outlined all the solution steps and possible outcomes, i.e. first aid techniques, needed to solve any case in a logical scheme. Examples of closed-ended questions in the decision tree are "Is safety of the victim guaranteed?" or "Do you observe any breathing or consciousness?" (Figure 7c).

Besides cognitive strategies, mental models which facilitate reasoning in the task domain are considered part of the supportive information, too (van Merriënboer & Kirschner, 2007). Van Merriënboer and colleagues (2002) distinguished three varieties: (1) conceptual, (2) structural, and (3) causal models. Conceptual models respond to the question, "What is this?". An example can be found in the developed information sheets where the differences between breathing

and non-breathing, consciousness and unconsciousness, and how to check both vital functions are explained. A structural model answering the question “What happens when?”, is shown in the information sheets regarding safety. For example, a victim should be replaced when a building has the possibility of collapsing. The third variety is causal models, “How does this work?”. In the online environment, an explanation can be found on how to inform specialized authorities and which information to provide.

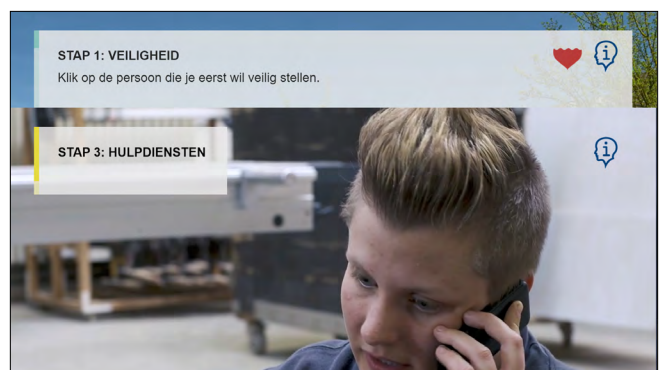
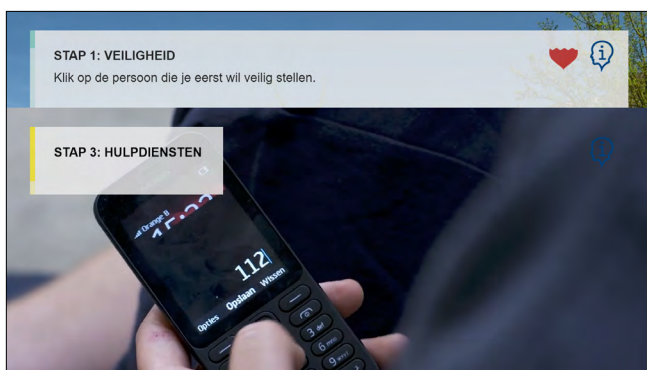
The supportive information in the three task classes is delivered through the use of multimedia such as PowerPoint,

video and voice-overs and developed considering the principles of Mayer (Mayer, 2017). In order to prevent cognitive overload, only the essential material was shown (coherence principle), and on-screen text was minimized (redundancy principle) and replaced by a human voice-over (modality and voice principle). Within the supportive information, proceed, close, and replay options were added. In this way, the learner can self-pace and thus process sufficient information before continuing (segmenting principle). Transitions in PowerPoint whereby content is shown step by step were added to harmonize visual and auditive information (embodiment principle).



*When a learner responds incorrectly, the answer turns red and the correct answer turns green. A trombone sound emphasizing the fault can be heard.*

*Voice-over: “A limb may have been partially or completely torn off in a serious accident. (...) Have someone alert the emergency services via the emergency number 1-1-2.”*



**FIGURE 8.** Examples of procedural information: (a) corrective feedback, (b) description of a cognitive rule by means of voice over, (c+d) demonstration of the application of the rule by means of video..

More complex task classes require more elaborated supportive information (Vandewaetere et al., 2015). Therefore, in the subsequent and thus more complex task classes, the decision tree and information sheets are more extensive. For example, in the decision tree of the second task class, an extra distinction was made between resuscitating a baby, child, or adult.

#### Step 7: Design procedural information.

Procedural information can be seen as (1) information for recurrent aspects, (2) demonstrations, or (3) corrective feedback (van Merriënboer et al., 2002). Most procedural information in the online learning environment is represented as corrective feedback after solving a certain piece of a learner task. An example is shown in Figure 8.a. The corrective feedback is provided immediately after answering the question and very briefly shows the wrong (red) and right (green) answers in corresponding colors while playing an (in)correct sound. Due to the importance of recognizing errors and how to recover from them (van Merriënboer et al., 2002), the designers did not allow the learner a second chance to respond correctly as they wanted the learners to learn from their mistakes. Other procedural information, such as information typically represented by means of voice-overs and distinct applications of demonstrations through video, is shown in Figure 8.

Because procedural information is directed to the lowest-level ability learner and some learners might need less

information on the recurrent aspect as they already know, the designers decided that adding choice options or learner control was, in this case, legitimate.

#### Steps 8 and 9: Analyze cognitive rules and prerequisite knowledge.

In order to design high-quality procedural information, the designers needed to identify condition-action pairs, i.e., “If this happens, then I’ll do ...”, that cause routine behaviors as well as the information needed for correctly applying that particular rule or procedure (van Merriënboer & Kirschner, 2007). In our online learning environment, the next cognitive rule can be seen as an example: “If a victim suffers from an amputated limb due to a severe accident, then the first aid attendant urges the victim to press down on the wound and keep the limb in its normal position, places the victim on the ground and asks someone to call for medical assistance.” Prerequisite knowledge was provided to the learner by means of explicit video material filmed and edited in a lucid way. In this case, the learner is shown an amputated and severely bleeding thumb. After noticing this bleeding, the learner can apply the described cognitive rule earlier for solving the case.

#### Step 10: Design part-task practice.

Within our design, all the part-task practices entail a certain psychomotor skill, such as “check for breathing in a victim”. One could do this by (1) carefully tilting the head back and



FIGURE 9. Example of part-task practice.

lifting the chin to open the airway, (2) looking whether the chest is moving up and down, listening for sounds of breathing at the victim's mouth, feeling for breath by presenting the cheek and (3) securing this action for no more than 10 seconds (How to Check for Breathing, 2018). To ensure high-quality training of this psychomotor skill, it is ought to be practiced in an authentic environment on a real person but faked victim (Parker & Grech, 2018). Given that the learner is working through the learning environment online and alone, this might be impossible and some design-creativity was necessary to maximize the learner process and ensure that a learner can apply the psychomotor skills when in practice. The designers in this paper maximized the interactivity by adding buttons to insure full participation of the learner in conducting the psychomotor skill and to imitate it as it would be practiced in a real-life situation. Doing so, the designers tackled the challenge of using a cognitive model, i.e. the 4C/ID-model for a psychomotor skill in their online learning environment. As an example, the part-task practice "check for breathing in a victim" is presented in Figure 9.

### **Failure Analysis**

The online learning environment was entirely completed and thoroughly tested by a group of 22 participants chosen from the 'developers' circle of acquaintances in a first pilot study. Feedback on the online learning environment was solicited after each task class via a feedback form. These forms were exported to Excel. Positive feedback was marked in green, and feedback that showed room for improvement was marked in red. After a first failure analysis, the designers adjusted the online learning environment to conform feedback. Next, the task classes were completed by the second group of participants consisting of employees of the KU Leuven who attended their annual first aid in-service training. In this second pilot study, feedback was solicited and noted during their practical first aid session. In what follows, the designers discuss the useful feedback of both piloted groups and implemented adaptations in the online learning environment.

### *Loading difficulties*

Loading videos and widgets in the online learning environment seemed to be a recurring failure among participants in both piloted groups. This problem was probably caused by an overload of widgets per video used to create interactivity in the online learning environment, combined with the powerless internet connection of some participants. As a solution, the designers added videos to the task classes and divided widgets more equally across the learning environment. In order to reduce further loading issues, all used widgets were set to preload mode, and the template displaying the supportive information was transferred to run on the entire project instead of on the separate videos.

### *Indistinct information*

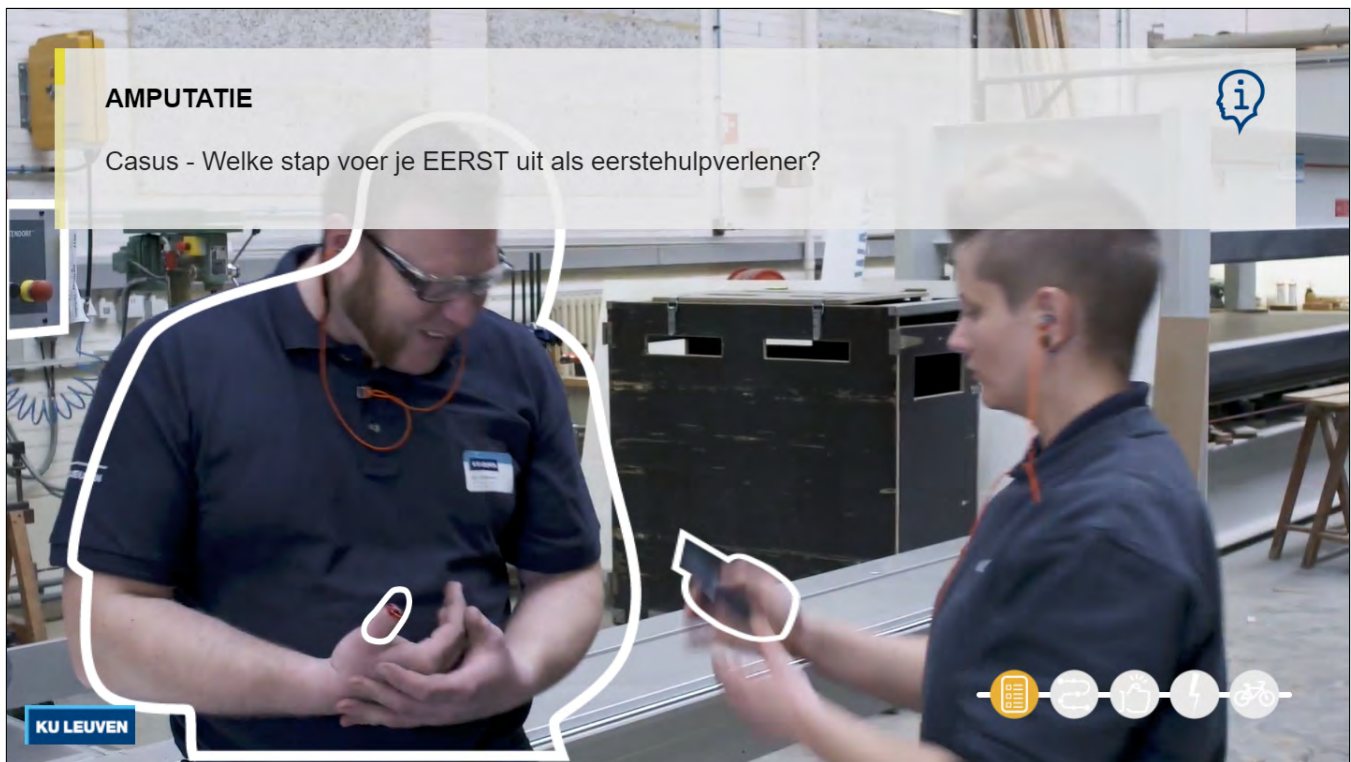
Clearly visible and clickable response options in interactive videos and corresponding expected actions of participants were not always distinct throughout the online learning environment. The designers tackled this failure by clarifying task descriptions in more detail and surrounding response options with white frames in the videos to accentuate the possibilities (Figure 10). Another malfunction in the learning environment was caused by an automatic screen adaptation according to the computer size of each participant. For some participants, this resulted in a disappearance of the bottom half of the screen, which made full interactivity impossible. To address this problem, the designers embedded the learning environment in a course management system, so navigation through the online learning environment as possible within the same frame size for every participant.

### *Time pressure*

In general, participants experienced an emptying heart while solving a learning task as too stressful and too short in duration to comprehend the task and possible answers thoroughly. As a result, wrong answers were chosen more often. To address this problem, the designers extended the duration of the emptying heart where necessary. However, the pressure was still felt to be very disruptive by the second piloted group. Because the function of the emptying heart is not considered crucial for instructing psychomotor skills, the designers decided to remove this element from the online learning environment. On top, the designers noted a similar problem of time pressure. Each participant should complete one task class within a predefined time frame of 30 minutes. Because this is currently not the case, finding new ways to shorten the learning tasks is needed in order to meet the time limit in the future.

### *Equivalent words*

Throughout the task classes, participants are, in some learning tasks, asked to complete a diagram. Answer values are validated by the use of JavaScript. Due to the multi-faceted nature of fill-in-the-blank answers, the designers included several correct possibilities for one answer box in JavaScript. For example, when the correct answer in general embraces "check for own safety and safety of bystanders", the answer values "own safety", "your safety", "safety of the environment", and "safety of bystanders" are all considered correct. In the first piloted group some participants provided answer values that, after reconsideration, also proved to be correct but were scored as incorrect because their answers had not been included in the JavaScript yet. Therefore, the developers further expanded the list of equivalent words and added in this example, "own safety" and "other's safety" to the JavaScript.



**FIGURE 10.** Example of several response options.

### *The use of Graphics interchange formats*

GIFs, or graphics interchange formats, were often used throughout the online learning environment to maximize interactivity and authenticity, especially during part-task practices. However, when the same GIF was used for the second time in the online learning environment, it malfunctioned and caused a failure. To solve this problem, the designers had to copy the GIF file on their computer, rename it, and upload it into the development platform again.

## **Implementation**

### *The software*

The online learning environment was developed by the use of the software of a Dutch company named Blue Billywig © (Blue Billywig strategic online video, 2021). Their expertise lies in creating interactive videos for commercial objectives. The software offers an extensive range of possibilities, so almost any blueprinted design is realizable going from multiple-choice options to complete tasks or from on click buttons in any form to personalized voiceovers.

### *The process*






Our online learning environment is accessible via the blackboard-based management system for all KU Leuven employees enrolled in the educational program about first aid. Participants log in with their personnel number and password, whereupon the online environment opens. After

a brief welcome video, participants can read an informed consent and fill in a questionnaire concerning some personal details. The designers want to assure privacy and continuity throughout the entire online environment. The next screen points out the learning goals and expectations of the course shows the contact details of the designers, and explains all the icons throughout the environment (Table 3).

After this, participants complete task class after task class in which, by means of solving learner tasks, their competence in acquiring psychomotor skills is trained. At the start of every new learner task, an options menu appears where the learner can select the next task. At the end of every learner task, the participant receives a total score for achievement on the task and feedback about how to proceed through the learning environment, for example: "Review the supportive information before continuing with the learner tasks in this task class.". When finished with a particular task class, learners can move on to the next.

### *The graphical elements, illustrations, audio, and video material*

All of the multimedia material was customized by the designers. Videos and voice-overs were produced in cooperation with a professional audiovisual service. All elements and illustrations such as icons emphasizing task content as the bike in Figure 6, an emptying red heart to underline the importance of undertaking fast action in Figure 5, and a human body to exercise the part-task practice "check

	If the learner wants to proceed to the next screen, this icon can be mouse clicked. If not available, advancement occurs automatically
	Supportive information is available throughout the entire task class by clicking on the head-shaped icon.
	By selecting this button, the part-task practice opens and can be executed.
	The volume in the drops shows the level of support in the respective learner task (full = maximum support, empty = minimal support).
	Not everywhere JIT- information is provided automatically. If needed, this icon can be used and feedback will be granted.

**TABLE 3.** Icons in the learning environment.

forbreathing” in Figure 9, were designed through the use of Adobe Illustrator 2020 ©.

#### *Potential users*

This specific online learning environment was developed for initial and refresher training in first aid at KU Leuven but can be extended to the employees of other companies as well. The designers aim to develop a general online learning environment based on the 4C/ID model that can be used to instruct all kinds of psychomotor skills.

## **CONCLUSION**

To meet the need and demand for time-efficient training sessions in first aid, the designers in this paper created a dedicated online learning environment for teaching psychomotor skills. The ultimate goal lies in enabling the learner to, after transiting the online learning environment, perform the psychomotor skill fluently in practice. This proved to be no easy task as an effective instructional method for the acquisition and retention of psychomotor skills in practice is lacking (Alken et al., 2019; Nicholls et al., 2016). What did emerge from the literature was that, when teaching a new psychomotor skill online, two motifs are of high importance. First, when the online learning environment for acquiring psychomotor skills is not properly constructed, cognitive overload may occur (Sweller, 1988). Second, the learner’s motivation should be monitored throughout the entire process (van Merriënboer & Sweller, 2010).

To tackle the first problem of minimalizing cognitive overload, the designers used an already proven to be effective reference framework as the basis for their online learning environment, namely the 4C/ID model (Bennett et al., 2011;

van Merriënboer 2002, 2007; Vandewaetere et al., 2015). However, this model was originally designed for learning cognitive skills, whereas the current online learning environment emphasizes learning psychomotor skills for practice. Due to the motoric nature of such psychomotor skills, where students normally acquire competence through frequently practicing a given task live in small groups, the designers had to be extra creative when replacing hands on teaching by an online alternative. To comply to this issue, part-task practices were designed to mimic the psychomotor nature in an online manner as close as possible, and learning tasks were almost all presented via authentic video cases clarifying the psychomotor skill to its maximum.

In order to keep the ‘learners’ motivation high while transiting the task classes, the designers added learner control to some parts of the online learning environment, also called shared control. By doing so, learners are able to choose, among other things, in which sequence they want to carry out the learning tasks. However, in order to comply with the scaffolding principle within the 4C/ID model, icons that indicate the amount of support in a certain learning task were added so that the most recommended sequence, in terms of reduced support and guidance, is distinct and a learner can elect a proper learning task from the range. Because not every learner is at the same skill level at the same time, learners can also choose when and which specific part of supportive information they wish to review and whether, after completing a part of a learning task, they desire feedback on this subpart or not. Besides, burdening learners with time-consuming and unnecessary information they already know would definitely diminish their motivation. Noticeably, since too much choice can encourage cognitive overload, no learner control was built into the part-task practices.

As this paper only presents the design of an online learning environment for learning psychomotor skills and the problems encountered in the design process, there is a need for further research to be able to conclude whether, in this case, the 4C/ID model proves to be an effective instructional model. In addition, it should be investigated whether the amount and configuration of learner control within such an online learning environment is considered effective. Therefore, the designers of this paper plan a study to determine whether learner control has a positive effect on the acquisition of psychomotor skills via a 4C/ID-based online learning environment within the health sciences and, if so, what kind of learner control and exactly how much of it is needed. This research will also map the influence of the 'learners' characteristics and the retention of the acquired psychomotor skills learned in an online learning environment. Finally, future research must also consider whether the learning of psychomotor skills via this online method can be extended to other domains.

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