

COMMUNICATING COMPLEX INSTRUCTIONAL DESIGNS TO DIFFERENT STAKEHOLDERS

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ABSTRACT

The Royal Netherlands Air Force (RNLAf) is introducing blended learning for their maintenance training of highly advanced technical systems. Blended learning environments should combine modern pedagogical approaches with state-of-the art e-learning technology.

The instructional design for such blended learning solutions is mostly very complex. RNLAf officers that are responsible for the instructional design and managing the subsequent development process face the challenge of communicating this design, with all its pedagogical, technical, and organizational implications, to different stakeholders. Examples of stakeholders are managers that have to approve the design, producers that have to implement the design, or instructors and subject matter experts that want to validate the design and the subject matter information.

The first reason of this problem is the need for *different kinds of information* for particular stakeholders, as these have different interests and therefore different expectations of the design documents. For example, instructors and instructional designers want to be informed about pedagogical implications, by means of textual and schematic descriptions. Also, producers want to be informed about the technical implications, by means of precise, formalized diagrams.

The second reason is the *highly integrated character* of organizational, technical and pedagogical aspects in traditional design documents. This implies that if one detail of particular aspect changes, it is difficult and time-consuming to trace the resulting consequences for other aspects.

This paper describes the efforts of TNO and the RNLAf to create a means—the 3D-model—to improve the representation and structuring of complex instructional designs for optimal communication to different stakeholders. The 3D-model is a decision model, based upon three dimensions. It supports designers in creating design documents that are more or less (a) stratified, (b) elaborated, and (c) formalized. This should guarantee that stakeholders are confronted with (a) one-to-one relations between pedagogical, technical, and organizational design aspects, (b) descriptions with the correct level of detail and (c) unequivocal notation systems for their particular information needs.

ABOUT THE AUTHORS

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INTRODUCTION

Current educational, technological, and organizational innovations are rapidly changing the nature of instructional software, and, thereby, the way it is developed. Recent theories of instruction tend to focus on authentic learning tasks that are based on real-life tasks as the driving force for learning (Merrill, 2002; Reigeluth, 1999). The general assumption is that such authentic tasks help learners to integrate the knowledge, skills, and attitudes necessary for effective task performance; give them the opportunity to learn to coordinate constituent skills that make up complex task performance; and eventually enable them to transfer what is learned to their daily life or work settings.

In addition to educational changes, technological and organizational innovations enable the application of blended learning or integrated e-learning: The combination of face-to-face learning, distance learning, and on-the-job learning. Blended learning is supported by a balanced media-mix of traditional and advanced learning technologies such as books, e-learning, mobile learning, and simulations (Jochems, van Merriënboer, & Koper, 2004).

For organizations such as the Royal Netherlands Air Force (RNLAF), the application of recent theories of instruction as well as blended learning provides the flexibility to enable the integration of working and learning (in terms of time and place independent learning) and provide adaptive learning (in terms of personalization of learning). For the RNLAF, this implies four different modes of learning (see also Boot & Smeulers, 2003). First, multimedia presentations and interactive multimedia instruction that support instructor-led classroom lessons. Second, e-learning modules with interactive multimedia instruction, discussion groups, shared workspaces, etc., that support distributed learning, independent from place, time and pace. Instructors are able to instruct and coach from a distance. Third,

virtual environments such as simulations of processes or emulations of systems that support practicing learning tasks and prepare for exams in realistic but safe environments. Instructors and subject matter experts are able to instruct and coach locally or from a distance. And finally, practice environments in schools and at the work place ('learning docks') that support practicing learning tasks and doing exams with real systems. Instructors and subject matter experts provide instruction or coaching locally. These delivery mechanisms are managed by different e-learning systems. For instance, Learning Content Management Systems (LCMSs) enable efficient creation and management of learning content, whereas Learning Management Systems (LMSs) enable efficient delivery of learning content. Also real work-related materials are used, such as Interactive Electronic Technical Manuals (IETMs).

For the RNLAF, the resulting combination of pedagogical considerations (e.g., "How can authentic learning tasks be implemented in the instructional software?"), technological considerations (e.g., "Which media mix is most optimal?"), and organizational considerations (e.g., "How can working and learning be efficiently integrated by means of instructional software?") makes the development process of blended learning highly complex, requiring a structural approach towards design, production, and implementation.

In this paper, we describe an important bottleneck of this structural approach, namely the communication of the instructional design. First, we identify four important development criteria. Also, it is demonstrated that in order to satisfy these criteria, optimal communication of the instructional design between designers and other stakeholders is required. Second, we introduce a decision model—the 3D-model—to improve the representation and structuring of complex instructional designs for optimal communication. Third, an empirical validation of the 3D-model is described. Finally, the

implications of the 3D-model are discussed and recommendations for further research are described.

CRITERIA FOR DEVELOPING BLENDED LEARNING

The RNLA uses the standard Instructional Systems Development (ISD) model for developing blended learning. The ISD model is an instantiation of the generic Analysis, Design, Development (also called Production; the technical realization of the design), Implementation, and Evaluation model (ADDIE; Dick & Carey, 1996). Every phase in the ISD model identifies specific types of activities and outcomes, for which different specialists (e.g., designers, producers, instructors, and so forth) are responsible. In the RNLA's case, analysis, design and production activities are often outsourced to external companies, but RNLA officers from the ISD Department are responsible for managing the whole development process.

Besides criteria such as time and budget, for the ISD officers of the RNLA it is important that the development process satisfies four criteria, resulting from educational, technological, and organizational consideration. Atkinson and Wilson (1969; for more recent discussions, see Gibbons, Nelson, & Richards, 2000; Parrish, 2004) have identified three criteria that relate to development *flexibility*. First, adaptivity, which is the ability to adjust the blended learning environment to learner needs, learner progress, preferences, and choices, provides personalized learning for individual learners. Second, generativity, which is the ability to assemble the blended learning environment from some combination of parts and sources at the moment of delivery, frees the designer from having to create an infinite variety of products with static designs. Finally, scalability, which is the ability to increase the production capacity without a corresponding increase in costs, enables the serving of more and larger target groups.

The fourth, most important criterion is related to the development *process*, and comes from the design complexity that is introduced by the emphasis on real-life tasks as the driving force for learning (van Merriënboer & Boot, 2005). In literature, most authors introduce some notion of "modeling" to attack this problem (Boot, van Merriënboer, & Theunissen, *submitted*). For example, Achtenhagen's

(2001) notion of "modeling the model" prescribes a two-step approach to modeling, namely modeling reality and then modeling those models of reality from a pedagogical perspective. For developing blended learning, this implies first the *domain modeling* of realistic tasks and systems in such a way that they are simplified (i.e., reduction of complexity) towards the learner's level of ability while at the same time remaining representative for the "real" world. Second, it implies *pedagogical modeling* of these domain models to facilitate learning, such as the use of modeling examples, coaching, and scaffolding attuned to the expertise, progress, and interests of the learner. This modeling of the model for instructional purposes allows the designer to determine which elements of the original model can be omitted, and which elements can be increased (not in the original, but introduced for supporting the functions of the model) (Gibbons, Bunderson, Olsen, & Robertson, 1995). For developing instructional materials, a third facet should be added to this modeling process, namely *functional modeling*. This works out the two previous models in order to transfer them by means of design documents from the design phase to the production phase. Functional modeling allows the designer to determine how each element should be presented to the learner. The development criterion of modeling (consisting of the three sub-criteria domain, pedagogical, and functional modeling) is conditional for the other three criteria, as adaptivity, generativity, and scalability all depend on an adequate modeling process.

There are two main problems with modeling, particularly functional modeling. The first problem is that most instructional designers lack the necessary means to provide information that ensures an unequivocal interpretation by important stakeholders that are involved in the development process. For the ISD officers of the RNLA, managing the development process and communicating the instructional design, the relevant stakeholders are listed in Table 1. Note that learners are also identified as stakeholders: Although they rarely interact with the instructional design directly, they are the most important stakeholders as the whole purpose of the instructional design is to promote their learning processes. The stakeholders' concerns are related to (the integration of) organizational, pedagogical, and technical issues.

Table 1. Relation of Stakeholders to Functional Modeling of Instructional Designer.

| <i>Type of stakeholders</i> | <i>Activities of stakeholders</i> | <i>Focus on</i> |
|-----------------------------|---|---|
| Subject Matter Experts | Validate the domain content | Impact on work floor |
| Instructors | Validate the didactical model | Impact of instructional design on their teaching (e.g., classroom based, coaching in practice) |
| Managers | Approve the instructional design | Impact of instructional design on their organization (e.g., financial, roles, infrastructure) |
| Producers | Translate instructional design into technical specifications | Impact of instructional design on production process (e.g., tool selection, programming, interfacing) |
| Implementers | Use the instructional design as guidelines | Impact of instructional design on infrastructure, roles, school management, etc. |
| Learners | Use the products resulting from the instructional design | Impact of instructional design on their learning processes |
| Evaluators | Use the objectives set in the instructional design as evaluation criteria | Impact of instructional design on assessment process |

There is a need for *different kinds of information* by these particular stakeholders, as these have different interests and therefore

different expectations of the design documents. However, designers have a different background than most of the other stakeholders (e.g., educational vs. management) and use different tools (e.g., analysis and design tools vs. technical production tools), and are therefore unaware or unable (or worse, not interested in) providing the right information to the right stakeholder. More importantly, instructional designers lack a common, explicit notation system for functional modeling (Gibbons, Nelson, & Richards, 2000; Waters & Gibbons, 2004). A notation system is an embedded element of a design language and captures abstract ideas to create transferable designs (Gibbons & Brewer, 2005). Examples are the blueprints of an architect or the musical notation system for composers. Design languages require such notation systems to convey their message by means of symbolic, graphical, textual or other conventions. An example of a graphical modeling language, not bound to the field of instructional design, is the Unified Modeling Language (UML; Booch, 1994). The notation system of UML (i.e., diagrams) enables different stakeholders to describe and understand a design. Recent attempts to introduce design languages in the field of instructional software development are IMS Learning Design (IMS LD; Koper & Tattersall, 2005) and the Educational Environment Modeling Language (E2ML; Botturi, in press). Although both languages are promising, they are not yet able to ensure an unequivocal interpretation by the stakeholders in the development process.

The second problem with functional modeling is the *highly integrated character* of the organizational, technical, and pedagogical aspects in instructional design documents such as training blueprints, scripts, and storyboards. This implies that if one detail of a particular aspect changes, it is difficult and time-consuming to trace the resulting consequences for other aspects. For instance, if a manager decides that instruction by synchronous communication (e.g., with webcams or instant messaging) is not feasible due to relative high costs or security issues, all aspects in the instructional design related to the possibilities of synchronous communication must be traced and modified. This implies reconsidering organizational aspects such as different infrastructure, technical aspects such as different e-learning systems, and pedagogical aspects such as different learning tasks, which are all connected to each other.

The result of these two functional modeling problems is that the intentions of the instructional design are often not sufficiently included in the decisions of other stakeholders. For example, the instructional design will not be represented correctly in the technical specifications created by the producers. Time-consuming reviews and frequent discussions between instructional designers and these stakeholders are often required. In absence of those reviews and discussions, the production process often results in an unsatisfactory outcome, that is, flawed instructional software that requires correction afterwards (“design by debugging”).

Recent software engineering methods attempt to overcome this problem by means of ‘agile’ development methods. Agile methods emphasize iteration in the development process and considerable participation of all stakeholders (see <http://www.agilealliance.com>). For instance, eXtreme Programming (XP) prescribes (a) revisiting preceding phases if information is insufficient, and (b) rapid prototyping of small but representative intermediate products for testing during development (Verstegen, 2003). However, such approaches are often not feasible for the ISD officers of the RNLAf, due to the juridical and financial restrictions of outsourcing the production phase—mostly applied in their blended learning projects—which separates the design and production phases in space and time. Such outsourcing to external parties, particularly if these parties are in foreign countries (“offshore outsourcing”), also limits information exchange due to language problems and cultural differences.

Many of the learning technology projects of the RNLAf (and other Dutch Military branches) are done at TNO’s Learning Technology Laboratory (search for LTLab at www.tno.nl). These projects are characterized by two important starting points. First, the organizational, pedagogical, and technical considerations of stakeholders (see Table 1) are always approached in an integral fashion, as they often strongly interact. The second starting point is that agile and linear ISD methods are combined by applying a phased approach. First, TNO and the different stakeholders work closely together in an agile development process as described above, which does not focus so much on a final, complete product, but on collecting experiences and lessons learned of what works and what doesn’t work with respect to organizational, pedagogical, and technical

issues in a particular learning setting. In the second phase, TNO supports the RNLAf in creating the final instructional design, based upon these experiences and lessons learned.

Therefore, even an agile-influenced development process of blended learning relies heavily on the communicative quality of instructional design documents. An important question is therefore how such design documents can be improved by instructional designers, to increase the probability of an optimal transfer of information from designer to other stakeholders.

THE 3D-MODEL

Summarizing, the difficulties of RNLAf’s ISD officers with communicating instructional design documents have three reasons: (a) different instructional and technical structures are often not meaningfully organized; (b) different levels of detail are mixed up, and (c) different expressions are used in a non-standardized manner. In order to improve this situation, TNO has created the Developing Design Documents model, abbreviated to the 3D-model. This model should improve the representation and structuring of complex instructional designs by instructional designers, for optimal communication to different stakeholders. The 3D-model is a decision model, based upon three dimensions that should guarantee that stakeholders are confronted with (a) one-to-one relations between pedagogical, technical, and organizational design aspects, (b) descriptions with the correct level of detail and (c) unequivocal notation systems for their particular information needs.

First, with regard to meaningful organization of organizational, pedagogical, and technical structures, Gibbons’ model of Design Layers (Gibbons, 2003) is used for *stratification* of the instructional design on seven, interrelated layers: Content, strategy, control, message, representation, media logic, and data management. Each layer is typified by the designer’s selection of design languages pertaining to the solution of different instructional design sub problems. Together, the functional designs at each layer make up the total design. Stratification helps to determine the relations between the functionally different instructional and technical structures, while at the same time staying cognizant of the need for integration of those structures within the complete design.

With regard to mixing up different levels of detail, the three perspectives of Fowler (2004) are used for the *elaboration* of the design: (a) A conceptual perspective, with more or less superficial and descriptive information; (b) a specification perspective, with more or less comprehensive and detailed information, and (c) an implementation perspective, with more or less technical and meticulous information. Elaboration helps to determine the required level of detail, depending on the capabilities of the designer and the needs of the producer.

With regard to the use of non-standardized expressions, designers may reach *formalization* of their design by making their informal and formal design languages explicit. They should strive for (combinations of) formal languages, but depending on their capabilities and the needs of the producer, they can also select (combinations of) informal languages. Formalization helps to determine the required level of standardization.

Figure 1 presents the 3D-model in its full configuration, in which all dimensions are completely utilized.

Designers, together with, or independent from other stakeholders in the development process, can first analyze their design situation in order to determine the optimal configuration of the 3D-model (e.g., What kind of designers and producers are involved? What kind of training is the design made for? Which support tools are available?), and then start their instructional design activities using this configuration to stratify, elaborate, and formalize their design documents. Subsequently, the 3D-model and the instructional design documents based upon the 3D-model provide the other stakeholders with insight in the underlying structure and content of the domain, pedagogical, and functional model, even when the design languages used are deficient.

As a result, the two problems described above should be overcome. First, different stakeholders have easy access to particularly that instructional design information they are interested in.

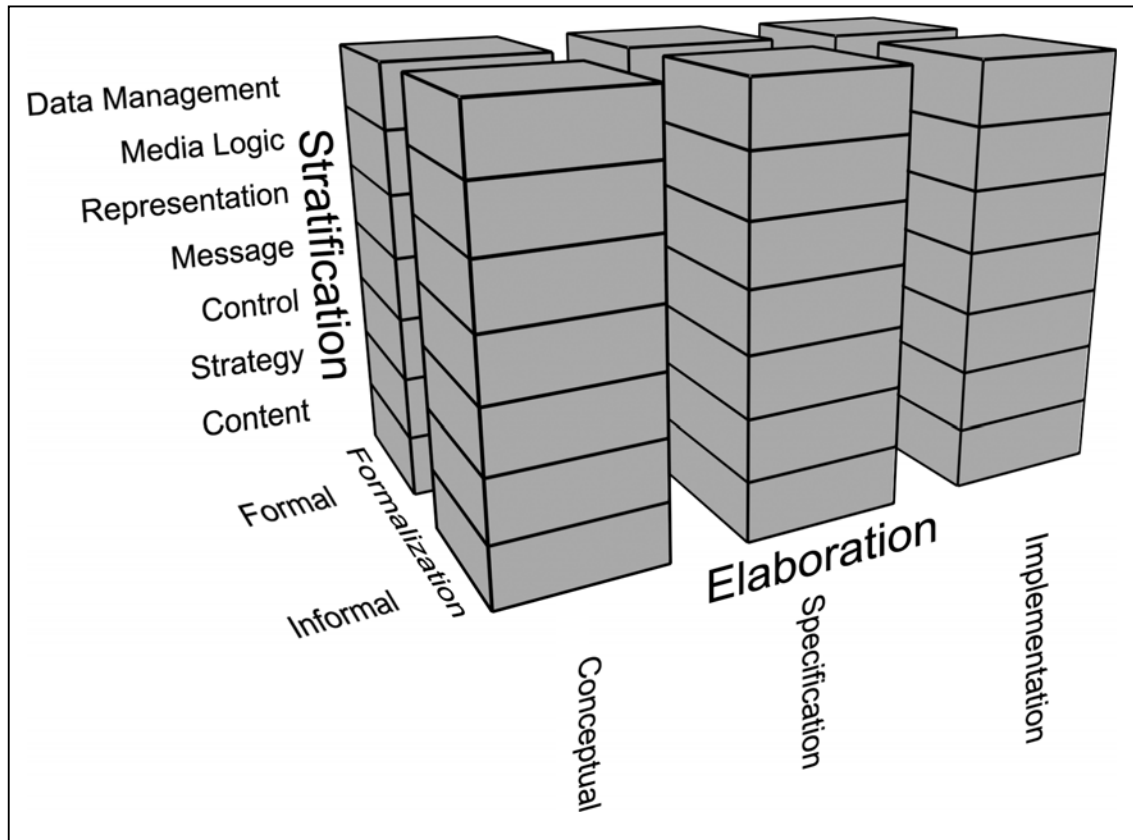


Figure 1. The Developing Design Documents (3D) model.

Second, although the instructional design is still complex, the relations between different educational and technical aspects are now clearly indicated, so consequences of changes are now quicker and better overseen.

VALIDATING THE 3D-MODEL

In order to test the 3D-model, a series of validation studies is set up, ranging from studies with an experimental design to case studies and pilots. This section describes the first, experimental study, which was focused on the communication of the instructional design to one group of stakeholders, namely producers (Boot, Nelson, van Merriënboer, Gibbons, submitted).

Participants

Sixteen Master and Ph.D. students from a university's Computer Science department, with considerable experience in specifying and programming software, participated in this study, acting as producers of instructional software. They were randomly assigned to either the conventional instructional design documents group ($n = 8$) or the improved instructional design documents (based upon the 3D-model) group ($n = 8$).

Materials

The conventional and improved design documents were on an identical topic, learning to drive a car, and had an identical function, providing input for the technical specification process for an advanced car-driving educational simulation.

The conventional design document is based upon informal representations such as text and sketches (formalization dimension in the 3D-model). With respect to the elaboration and stratification dimension, the document is mostly directed at providing much detail (implementation level) at the content and strategy layers, average detail (specification level) on the control, message, and representation layers, and little detail (conceptual level) at the media logic and data management layers. This configuration reflects the traditional approach towards design documents (see for instance (see for instance Driscoll, 1998; Kruse & Keil, 2000; Van Merriënboer, Clark, & de Croock, 2002)).

The improved design document is based upon both informal representations and formal representations. For the informal representations, the document provides the same information as the conventional design

document. For the formal representations, the document is mostly directed at providing average detail on all layers, by means of simple UML diagrams. See Appendix 1 for an example diagram. This configuration reflects the use of the 3D-model to stimulate and support designers to stratify, elaborate, and formalize design documents more than they usually do.

Measurements

Specification questionnaire. The ability to translate the design document into technical specifications, defined as the results of the communication process, was measured by the specification questionnaire. It consisted of 25 open questions, each question on one printed page with sufficient space to note down the answer. There was no time limit for answering the questions, but the experimenter measured the time unobtrusively. Each question addressed a particular aspect of translating the design document into technical specifications. For instance, the participants had to distill from the design document how many databases should be used in the instructional software; what the consequences would be from changing text-based messages into audio-based messages (the so-called "ripple effect"); how a particular program flow should be implemented; what it meant if just-in-time information would be applied in a particular learning task; where the producer would need a subject matter expert to provide additional domain information; which instructional design components should be implemented as reusable learning objects, and so forth. Based on a checklist with correct answers, two reviewers rated all items as correct or incorrect (the Intra Correlation Coefficient, ICC, is .94, which is good, Fleiss, 1981).

Cognitive load questionnaire. This questionnaire measured the perceived cognitive load for each question in the specification questionnaire, defined as part of the costs of the translation process. It used the standard 9-point rating scale developed by Paas (1992; see also Paas, Tuovinen, Tabbers, & van Gerven, 2003). The rating scale was included at the bottom of each page of the specification questionnaire, and ranged from 1 = "very, very low perceived load" to 9 = "very, very high perceived load". The ICC of the questionnaire is .89, which is good.

Satisfaction questionnaire. This questionnaire measured the participants' satisfaction with the design documents. It contained six statements that had to be rated on a 9-point scale (ranging from 1 = "very, very low" to 9 = "very, very high"). The statements concerned (a) the effort

that needs to be invested in the technical specification process, (b) the capability to create technical specifications, (c) the perceived completeness, (d) the level of detail, (d) the understandability, and (e) the quality of the design document.

Results

The results showed that the improved design documents indeed promote a higher level of understanding among producers, which is required to translate the functional model into technical specifications, than conventional design documents (See Table 2). Also, working with the improved design documents required less time. However, there were no differences in perceived less cognitive load and satisfaction with the two kinds of design documents.

Table 2. Means and Standard Deviations for Measures of the Communication Process

| | Conventional design documents group (n = 8) | | Improved design documents group (n = 8) | |
|---|---|------|---|------|
| | M | SD | M | SD |
| Quality of production (0 – 25) ^a | 12.25 | 2.35 | 17.18 | 1.94 |
| Mean time per question (mins.) ^b | 3.46 | 0.89 | 2.75 | 0.71 |
| Mean perceived cognitive load per question | 4.43 | 0.42 | 4.06 | 1.10 |

^a $t = 4.58, p < .001$

^b $t = 1.77, p < .05$

The use of the 3D-model showed a significant increase in efficiency of creating technical specifications. Thus, the 3D-model enables instructional designers to communicate their designs to producers in a faster and more accurate fashion. The study also indicated that instructional designers are in the best position to enhance the efficiency of the translation process through the improvement of instructional design documents. Because there is no relation between producers' perceived cognitive load or satisfaction and the different kinds of design documents, it appears that producers cannot correctly judge the quality of

those documents and are thus not in a good position to improve the transition process.

CONCLUSIONS

The effort of the RNLAf to introduce blended learning in their organization is complex. Particularly for their ISD officers, which have to manage the development process and communicate the complex instructional designs to different types of stakeholders. In this paper, we have discussed the need to improve this communication process. For this purpose, the 3D-model is introduced to support the instructional designer. The first study, described in this paper, shows that communication by design documents based upon the 3D-model is significantly improved for at least one group of stakeholders, namely producers. Using the 3D-model will provide RNLAf's ISD officers more control over the (communication) in the development process. This applies to both the 'normal' configuration of the development process, namely the linear ISD approach, as well more iterative, agile approaches in which some kind of design documentation is used.

An important implication of this paper concerns the schooling of instructional designers. The results of the 3D-model study imply that producers are not in a good position to improve design documents, because they have difficulties in judging the quality of these documents. In addition, they cannot always ask the designer for clarification (e.g., in the case of –offshore—outsourcing). This puts the responsibility for improving design documents predominantly on designers. Besides being knowledgeable and skilled in traditional instructional design activities such as domain and task analysis, strategy selection, and media selection (see Richey, Fields, & Foxon, 2001), our results indicate that instructional designers need to become proficient in at least three new activities. First, they should be able to stratify instructional design documents to describe aspects associated with design as well as production. Second, they should be able to decide for each layer how much detail is required for unequivocal understanding of the design by producers. Finally, they should be able to represent their designs in formal design languages such as UML, IMS LD, or E2ML. Support tools may help them to perform their new activities. For the RNLAf, formal education will not always be feasible due to limitations in budget and time. Communities of practice might offer an alternative option, because they provide designers and producers

with a platform to discuss each others information and training needs.

Further research should investigate if value of the 3D model also applies to other stakeholders than producers. This may be done in studies with an experimental design, but also in case studies and pilots. Furthermore, it is important to study the role the 3D-model can play in creating or improving tools that support instructional designers in communicating their documents. Finally, the 3D-model demonstrates the need for research into more and better design languages for communicating complex instructional designs.

Further TNO – RNLAf projects are now conducted, concerning blended learning environments for training F16 Maintenance personnel in schools, as well as during missions (e.g., recurrency training). The complex combination of organizational issues ('What are the new roles of learners and instructors in a blended learning environment?'), pedagogical issues ('How do we introduce learning task as the core of the training, instead of traditional theory lessons?') and technical issues ('How can we distribute information in a secure manner?') requires the agile method of designing, producing and implementing/testing, to incrementally build a solution that is satisfactory for all stakeholders. Based upon this process, the final instructional design will be created, based upon the 3D-model, as input for production of content and acquirement of a suitable infrastructure (e.g., networks, e-learning systems).

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Appendix I: example of UML diagram from Improved Design document

