International Journal of Mobile and Blended Learning
Volume 15 • Issue 2

Multidisciplinary Educational Design Framework to Facilitate Cross-Boundary Educational Design:

Closing Gaps Between Disciplines

Mirjam Selhorst-Koekkoek, Windesheim University of Applied Sciences, The Netherlands*
Ellen Rusman, Open University of the Netherlands, The Netherlands

ABSTRACT

The development of multidisciplinary education requires people to communicate, learn, and design beyond the boundaries of their own domains. In this research, an education design framework is developed to facilitate and support university teachers in multidisciplinary educational design. In addition, it serves as an aid to potentially transform domain-specific action-oriented knowledge into domain-integrated action-oriented knowledge by supporting knowledge co-construction across domain boundaries. The educational design framework, grounded in seamless and hybrid learning paradigms and theory on wicked problem solving, is being developed in a design-oriented educational research. This resulted in a multidisciplinary educational design game, which aims to facilitate cross-border communication, knowledge co-construction, and educational design processes during multidisciplinary educational design and improve the quality of the resulting multidisciplinary educational design.

KEYWORDS

Action-Oriented Knowledge, Boundary Crossing, Co-Construction, Co-Creating, Collaborative, Educational Design, Hybrid Learning, Multidisciplinary, Seamless Learning, Wicked Problems

INTRODUCTION

Complex societal problems such as energy transition and climate change are a challenge for various professional domains as well as for education. Complex societal problems inevitably impact the necessary competences expected from skilled professionals. Competences are defined as an integrated and situated set of skills, knowledge and talents to successfully solve problems in practice (Bunk, 1994).

As Universities of Applied Sciences prepare novice professionals for their roles, these societal changes and challenges should naturally affect their curricula. However, currently these curricula are often strongly focused on, and designed from, the perspective of a specific domain of expertise, with increased specialization during their studies (Akkerman & Bakker, 2011). This leads to gaps in the competencies of novice professionals to enable them to jointly work on complex societal problems.

DOI: 10.4018/IJMBL.319021

*Corresponding Author

As students mainly learn to look at problems from the perspective of their own domain of expertise, there is insufficient awareness of the application of their own expertise in relation to other relevant domains. As a result, students do not learn that the choices they make from the perspective of their own domain of expertise also influence, and in many cases strongly impact, the range of potential actions from professionals in other domains. As a result, there is often no multidisciplinary integration of knowledge and skills when solving a particular problem in practice (Gulikers & Oonk, 2016). To educate students for this awareness and to teach them how to integrate knowledge and skills between the domains in daily job settings, an alternative approach to curriculum design is needed. Teachers are the key to successful innovations in educational practice (Anderson & Helms, 2001). Therefore, it is important that university teachers are able to educate students and make them aware of these interdependencies and to change curricula accordingly. This is difficult for lecturers, because they are also often trained as experts in their own domain of expertise, meaning that they may not automatically and naturally be aware of perceptions and insights of other domains. This also makes it difficult for university teachers to design multidisciplinary education. It appears that they need support and want to be facilitated when designing multidisciplinary education (Veltman et al., 2021). That is why, in this educational design study, an intervention has been developed in the form of an educational design framework and associated design game for designing multidisciplinary education beyond the boundaries of one's own domain of expertise. To develop this multidisciplinary educational design framework, several relevant theories and approaches to social systems analysis and boundary crossing, such as cultural-historical activity theory, seamless learning, hybrid learning and wicked problem solving, were used. In the next section these theories and approaches are described further and brought into relation with the multidisciplinary educational design framework.

BACKGROUND

Multiple domains are often required for the solution of complex societal issues, because they rarely occur in isolation. There is often an interdependency between the different domains. These are often at the boundaries between the different domains and a reflection of the differences that exist in higher education and in the professional field (Bakker et al., 2015). A systems approach can be used to cross the boundaries between domains (Caris et al., n.d.). There are interdependencies between the different systems that are not always visible. These interdependencies must be identified and made explicit in order to subsequently transform action-oriented knowledge in such a way that the interdependencies can be explored and eventually gaps can be jointly bridged by the various professionals. Thus, multidisciplinary problem solving can be improved. Transformation, based on boundary crossing, leads to changes and the creation of intermediate or sometimes new action-oriented knowledge. In this way, better solutions for complex societal issues may be achieved, because they are approached integrally from the various domains (Wenger, 1998).

To explore the phenomenon of knowledge co-construction from a theoretical perspective, the different domains are seen as activity systems in this study. Engeström based his work on the Activity Theory of Vygotsky (1978) (Roth & Lee, 2007), which led to a new model of Cultural-Historical Activity Theory (CHAT) that can be seen as a socio-cultural framework. Engeström (2001) describes how professionals should not only learn vertically (within the discipline), but that they should also learn horizontally by collaborating with other disciplines or in a different context. This process can be interpreted as crossing the boundaries of one's own activity system. Boundary-crossing involves two or more activity systems finding a way to jointly develop a solution for a shared problem (Engeström et al., 1995). In order to be able to contribute to complex societal problems, the various activity systems must develop and identify conceptual and practical conflicts and tensions. This is where, potentially, the identified action-oriented knowledge is transformed into new action-oriented knowledge. It is important that each domain of expertise retains its own expertise but transforms where the different fields of expertise influence each other. This transformation can occur when there is an exchange of knowledge, interaction and knowledge co-creation between university teachers of the various disciplines. The constructive interaction between university teachers from different activity systems can lead activity systems to move towards the combined goal (Engeström et al., 1995). This goal can be achieved by identifying conflicts/tensions between the application of domain-specific action-oriented knowledge and transforming it, so that a multidisciplinary perspective can emerge across the boundaries of current disciplines. Transforming the various disciplines is a process that does not happen automatically and does not always occur (Akkerman & Bakker, 2011). Development takes place on the boundaries (Star & Griesemer, 1989). Akkerman & Bakker (2011) identify four learning mechanisms at the boundaries that play a role here, namely: (1) Identification, when it comes to the differences between the domains and how they relate to each other. The boundaries between the different domains are made explicit and a way is found to deal with those boundaries without eliminating differences. (2) Coordination, here the differences are explored. New or existing resources and procedures are also found to achieve effective coordination between the domains. (3) Reflection, this is about the process with regard to the perspective of one's own domain and that of other domains. (4) Transformation is the final learning mechanism and indicates the formation of the new shared practices or identity. The transformation process is characterized by confrontation, recognition of a mutual problem, development of new boundary objects, hybridization (contents from different domains are combined to something new), and crystallization (the development of new routines or procedures). Because university teachers jointly design education across the boundaries of their own domain, learning mechanisms can develop and university teachers learn from each other. It is possible that a transformation of the action-oriented knowledge will then take place. However, while boundary crossing is a process that does not happen automatically, it is important to support lectures with an educational design framework during the design process of multidisciplinary education. This is done to facilitate boundary crossing and improve multidisciplinary educational design. This intention led to the following research question:

What are the characteristics and criteria of an education design framework, which supports university lectures during the educational design process, to enable multidisciplinary education design across the boundaries of different domains?

METHOD

To design and develop the intervention, a desk research process was carried out by collecting and analyzing literature to inform and develop the educational design framework.

Three perspectives were included, where the first one also can be considered as a selection criterion, in the analysis of the literature: (1) substantial criterion, (2) how the educational design framework can be offered to educational professionals and (3) how the interaction between university teachers of the different domains can be supported in such a way that boundary crossing learning mechanisms will be facilitated and that the process of identifying is stimulated to transform. These three perspectives were used to determine what theory should inform a multidisciplinary educational design framework with the design intention to facilitate boundary-crossing between educational domain experts.

PROCEDURE

A search was made within EBSCOhost, ScienceDirect, and Springer data bases with the following terms: seamless learning, framework, teacher as designer, education design framework, technology, learning design frameworks, hybrid education, hybrid learning, transboundary, cross over learning, transversal learning, boundary crossing, collaboration, higher education. These terms were combined by adding AND or OR. In addition, the searches were refined by adding the following: collaboration, collaborative learning, design, higher education, literature reviews, mobile learning, teachers, technology integration, technology used in education, professional development and a limitation for the period 2011 - 2021. These search terms and selection criteria yielded a total of 10,538 hits. The first fifty hits were scanned on the abstract and selected when they contained: (1) interdisciplinary (educational design) issues, (2) a bridge between theory and practice, (3) higher education, (4) collaboration between different domains of study, (5) education design models, (6) collaboration between university lectures in the curriculum, (7) education design, (8) learning mechanisms (identifying, coordinating, reflecting and transforming), (9) interdisciplinary, (10) communication.

In addition, relevant articles from the books: *Collaborative Curriculum Design for Sustainable Innovation and Teacher Learning* and *Seamless Learning perspectives, challenges and opportunities* have been selected. Finally, the website of the International Association for Mobile Learning (https://www.iamlearn.org/) and the website Seamless Learning (https://seamless-learning.eu/seamless-learning/seamless-learning/) were consulted. These websites were used to search by using the snowball technique (Creswell, 2014). This mainly involves looking backwards on the basis of references. After the literature had been selected, it was subdivided into the chosen perspectives as mentioned in the method paragraph. A selection was made of the possibly relevant literature. Table 1 shows the selection criteria used for each perspective.

ANALYSIS

The Context-Interventions-Mechanisms-Outcomes logic (CIMO-logic) (Denyer, Transfield & van Aken, 2008) was used to analyze which contextual criteria the educational design framework, the intervention, had to meet to make adoption and use in practice most likely (Denver, Transfield & van Aker, 2008). It was used as a tool to structure literature found and to inform the design of the educational design framework. The criteria for the educational design framework were determined or derived using the CIMO-logic. As a starting point for the analysis, the CIMO-logic as used in this study is shown in Table 2.

Criteria Per Perspective

The first approach is the substantial criterion. Several relevant educational design paradigms have been found in the literature that can mediate the process of boundary crossing between the different disciplines. Each of these paradigms contain different design principles, elements and guidelines, which partly overlap and sometimes complement each other. The different design principles are expected to facilitate multidisciplinary educational design across the boundaries of different domains of expertise. To ensure that all curriculum components are discussed during the design sessions of the multidisciplinary educational design teams, the design principles were related and translated to

Table 1. Overview of selection criteria literature by perspective

Perspectives	Selection criteria
Substantive criterion	Design principles / elements / guidelines, inter- / multidisciplinary, specific contexts, bridge between theory and practice, higher education
User Adoption Strategy	Matching the Need(s) of Education Professionals, Collaborative Design
Supporting the process of interaction and transformation of action-oriented knowledge between university teachers from different domains	Collaboration, learning mechanism, interdisciplinary, communication.

Table 2. Overview of the CIMO-logic for this multidisciplinary educational design intervention

CIMO-logic in the context of this research	
Context	In Universities of Applied science, education is currently designed with a strong focus on individual domains of expertise. As a result, students learn insufficiently about the application of their own domain of expertise in relation to another domain (E&W installation technology, 2021). This creates gaps in the competences of skilled professionals when they start working (together) on complex societal problems. In practice, decisions are currently often made from within one's own domain of expertise, without checking whether the decisions may inadvertently influence the other domains of expertise. Education must respond to this and innovate. Teachers are often the key to successful innovations in educational practice, so it is important to start with the teachers (Anderson & Helms, 2001). In Universities of Applied Science, they are often trained as experts in their own domain of expertise. As a result, they often do not see the gaps in the competences and action-oriented knowledge of young skilled professionals. This is because they may not see the perceptions and insights of the other domains of expertise. An intervention has been developed to bridge these gaps.
Intervention	Development of an educational design framework, as an instrument based on specific design characteristics and relevant theory. Applying these in the design of multidisciplinary education for university teachers from different domains.
Mechanisms	The intervention aims to provoke the following mechanisms: (1) effect on the quality of the multidisciplinary education design because the university teachers are supported in the process of education design (2) effect interactions between university teachers and their knowledge construction process, in which domain-specific action-oriented knowledge is transformed into new action-oriented knowledge. The interactions between the university teachers make the gaps between the domains visible. This potentially influences the university teachers' views of their domains of expertise and the others, possibly causing them to make other domain-specific decisions to bridge the gaps.
Outcomes	Based on the intervention, it will be analyzed whether the design dialogue between university teachers and their specific design decisions in the design process were influenced, so that there may be dialogical interaction and an agreed upon multidisciplinary educational design. This dialogue may have an effect on the transformation and integration of action-oriented knowledge and field-specific decisions.

the various curriculum components of a curriculum design framework by Van den Akker (2003). The design principles are linked to the various curriculum components. Table 3 provides an overview of this analysis per education design paradigm. Depending on the context and the socio-cultural framework of a design problem, the design principles can be selected. Based on this, in combination with the expected outcomes of this research, a selection of relevant design principles was made. The selection was made based on the following criteria: complex assignment, multidisciplinary, cross-border, authentic tasks whose solution transcends, contribution to innovation and transition issues, collaboration, knowledge-co-construction processes, cognitive dissonance and reflection. The selected principles are visible in the table in bold text, the conditions are shown in italics and the normal text is less relevant in this context. The design principles and (pre)conditions in combination with the curriculum components have been used in the development of the educational design framework. This was done in the form of question for every curriculum component.

The second perspective was how the educational design framework can be offered to educational professionals, so that the framework is more readily adopted, thus facilitating and supporting joint design of multidisciplinary education. Voogt et al. (2016) researched which circumstances influence the joint design of education. It is important to provide organizational support and process support. This can be done by providing templates, guiding the process or by supporting the design process with the ADDIE (Analysis, Design, Development, Implementation and Evaluation) model (Reigeluth & Nelson, 1997; Peterson, 2003). Bowers and Vlachopoulos (2018) have developed guidelines for model makers based on this. These guidelines have been used in this research. In addition, research

Table 3. Design principles derived from the various design paradigms appropriate to the context and outcomes of this research

Curriculum components and associated key questions (Van den Akker, 2003)		Design elements seamless learning (Rusman, 2019)	Design elements hybrid learning (Cremers et al., 2016)	Design elements wicked problems (Veltman et al., 2019)
Elements	**Key questions**			
Base vision	Where are they learning to?	**Continuous learning across existing boundaries and connecting (learning) experiences in different contexts. Such that the individual also consciously bridges multifaceted learning efforts with a combination of locations, times, technologies or social environments.**	Learning and working are integrated, by working on authentic (work) environment. This represents the professional practice. Learning takes place at the edge between school and workplace. **A social exercise around poorly defined, authentic tasks or problems whose solution is transcendent**. Supports the design of so-called hybrid learning configurations located at the intersection of school and workplace.	**Constructive role (role that adds value) in addressing complex tasks, challenges, and problems by collaborating interdisciplinarily and conducting cross-border activities.** **Three dimensions: The complexity, uncertainty and value differences in the problem context.**
Learning objectives	To which direction do they learn	Focused on the individual so that he or she is continuously learning across the boundaries of different contexts (adaptive and connective). To support the individual, "social solutions" are used, such as peer feedback or through participation in a learning community. **Authentic tasks, contextualized with possible technological applications.** **Applicable knowledge and awareness of types of knowledge and different perspectives on the world. Supporting behavioral changes through this awareness. Learning complex skills. Personal growth of person, with lifelong learning attitude and sustained motivation.** Transfer of learning to other situations Involving "third parties" in learning processes (e.g., parents, alumni, experts)	Development takes place for the individual, the team and an organization. **Contribute to innovation, sustainable learning and or transition issues. Outputs are knowledge, advice, products in the form of procedures, guidelines, design/ prototype.** **Integrate authentic tasks, learning and working.**	**To promote skills for solving complex issues across the boundaries of different disciplines.** *These should be explicitly formulated with respect to crossing boundaries and how to deal with them.*

continued on following page

Table 3. Continued

Curriculum components and associated key questions (Van den Akker, 2003)		Design elements seamless learning (Rusman, 2019)	Design elements hybrid learning (Cremers et al., 2016)	Design elements wicked problems (Veltman et al., 2019)
Elements	**Key questions**			
Learning content	What do they learn?	Not explicitly stated. Depends on learning objective and learning activity.	**Any poorly defined, authentic task or problem whose solution requires boundary crossing learning.**	**An open process with boundaries being crossed and collaboration with different stakeholder groups (e.g., across organizational boundaries). Finding solutions to complex issues involving interdisciplinary collaboration. Because it is about acting (“handling” the issues) as well as observing and learning about the complexity, uncertainty and value differences.** *Prerequisite: Thorough exploration of the problem and the context.*
Learning activities	How do they learn?	**Bridging discontinuities at boundaries.** Adaptive and Connective. Didactic forms of work to make the most of personal experiences in and between different contexts and locations. Learning and guidance processes supported by technology.	By performing real tasks supported by educational interventions tailored to the individual learner. **By reflecting on the tasks and experiences.**	**Through collaborative learning and working on authentic problems or simulations whose endings are open and unpredictable, in which multiple roles and perspectives are offered to the students, as well as external stakeholders. By reflecting on the learning process and eliciting learning experiences at the boundary.**
Lecturer roles	What is the lecturer’s role in their learning?	**Supporting, facilitating and assessing the continuity of learning in different contexts. The learning processes of the learner and the guidance processes of the lecturer.**	Supporting, facilitating and embedding in the environment.	**Supporting and facilitating. Creating, balancing and using constructive tensions.** Explicit emphasis by lecturers on the learning process and outcomes rather than on the results of the problem-solving process.

continued on following page

Table 3. Continued

Curriculum components and associated key questions (Van den Akker, 2003)		Design elements seamless learning (Rusman, 2019)	Design elements hybrid learning (Cremers et al., 2016)	Design elements wicked problems (Veltman et al., 2019)
Elements	**Key questions**			
Sources and materials	What are they learning with?	**Deployment of technological tools that support personal learning pathways, as a method for individual and collective knowledge construction processes.**	Dependent on environment. Leverage diversity by using networks.	**Learning is done from the "boundary objects". The various perspectives that exist on authentic issues.**
Grouping forms	With whom are they learning?	**Individual's learning is central. Provides opportunities for collaborative or networked learning.**	**Members of the learning community. Each at their own level.**	**Together with students, lecturers, and (sometimes) stakeholders, i.e., those involved and interested in the problem context. Zone of Current Development (ZCD) for balance in constructive tensions.**
Learning environment	Where do they learn?	In different contexts (formal and informal). Physical and/or virtual. Contextualized learning. **Closing the gaps between different learning environments. This may be within formal education.** One connects and relates one's experience in different contexts of participation in time, place/space and pace.	Mix of workplace learning, educational activities and self-directed learning, peer and expert learning in the work practice or studio. **Reflecting work practices.**	Not explicitly mentioned. *Prerequisite: A safe learning environment, so that students dare to experiment and take risks. In the context of authentic issues.*
Time	When do they learn?	**Space/place and practice independent and dependent. Synchronous but also asynchronous.**	Not explicitly mentioned.	Not explicitly mentioned.
Assessment	How is their learning assessed?	**Formative assessments through tools, providing immediate feedback. Summative assessment.**	Not explicitly mentioned.	Not explicitly mentioned. **Rewarding learning rather than focusing on the end result.** *Point of Attention: The intended learning outcomes, assessment of learning outcomes, and activities of students and lecturers by different lecturers should be aligned.*

Note: Expansion and merging of design elements seamless learning (Rusman, 2019) hybrid learning (Cremers et. al, 2016) and wicked problems (Veltman et. al, 2019).

shows that there are gaps in the design expertise of university teachers (Huizinga et al., 2019). These gaps can potentially be bridged by applying the educational design framework.

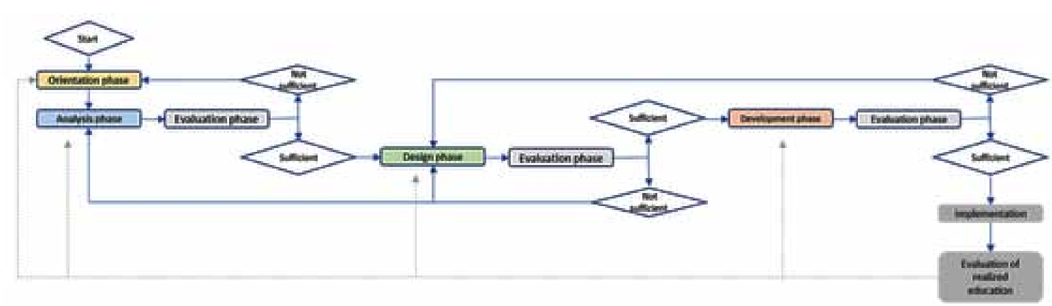
The last perspective was about how to support communication and interaction between university teachers of the different disciplines, so that the process from identification to transformation of domain-and action-oriented knowledge is stimulated. A study by Voogt et.al. (2016) confirms that professional development in the form of collaborative educational design influences university teachers' knowledge and teaching practice. The study identifies several conditions that influence joint educational design. In addition, the learning mechanisms of Akkerman and Bakker (2011) were used to support the university teachers in the process of identifying action oriented knowledge to transforming it into new action-oriented knowledge. These learning mechanisms are used to develop questions as part of the educational design framework. They increase professionals' awareness of their communication process and stages to stimulate dialogical interaction and to promote the process from identification to transformation.

RESULTS

The literature provided input to determine which criteria were important for the development of the educational design framework. This development was done by creating a derived CIMO-logic for each perspective: (1) substantial criterion, (2) how the educational design framework can be offered to educational professionals and (3) how the interaction between university teachers of the different domains can be supported. Each CIMO-logic analysis (Appendix B) shows which interventions are needed to activate the correct mechanism, so that it supposedly leads to the desired outcome. The literature, underlying the intervention, was used to determine which design elements should become part of the first prototype of the educational design framework. This first prototype was assessed and provided with feedback by five educational experts. The feedback was given by both answering individual questions about the framework and a focus group session. This led to the second prototype of the multidisciplinary design framework. From the educational experts, consistent feedback was received to make it more attractive by presenting it in the form of a game, as included in Appendix A. The result is an educational design framework that is divided into four phases: (1) orientation phase, (2) analysis phase, (3) design phase and (4) development phase. Each phase concludes with an evaluation. This guarantees the quality of both the educational design as well as the educational design, communication and interaction process. Figure 1 shows the process diagram that is followed during multidisciplinary educational design.

The framework has been designed in such a way that each phase may provoke a learning mechanism (Akkerman & Bakker, 2011) within the group of the university teachers from various domains. For example, based on the desk research, the orientation phase is linked to the learning-mechanism 'identification', the analysis phase to 'coordination', the design phase to 'reflection' and

Figure 1. Process diagram associated with the educational design framework for designing multidisciplinary education



the development phase to 'transformation'. In order to help university teachers in structuring the design choices, the ten curriculum components of van den Akker, 2003 have been divided over the four phases. Table 4 gives an overview of the distribution.

The outcome of the education design framework is included Appendix A. It has been developed in the form of a game with a card for each curriculum component with questions for help. The phases correspond with the colors on the game board and the cards with questions. Figure 2 shows the game board and Figure 3 shows two cards with questions for the analysis phase and design phase. These supporting questions can be used by the university teachers to facilitate them during their multidisciplinary educational design process and to help them to identify conflicting domain-related action-oriented knowledge and possibly transform it into new action-oriented knowledge. The questions

Table 4. Curriculum components of van den Akker, 2003 divided over the multidisciplinary design phases

Phases	Curriculum components
Orientation phase	Basic vision
Analysis phase	Learning objectives Learning content Assessment
Design phase	Learning activities Lectures roles Resources and materials Grouping methods Learning environment Time
Development phase	All ten curriculum components brought together

Figure 2. Education design framework as a game board

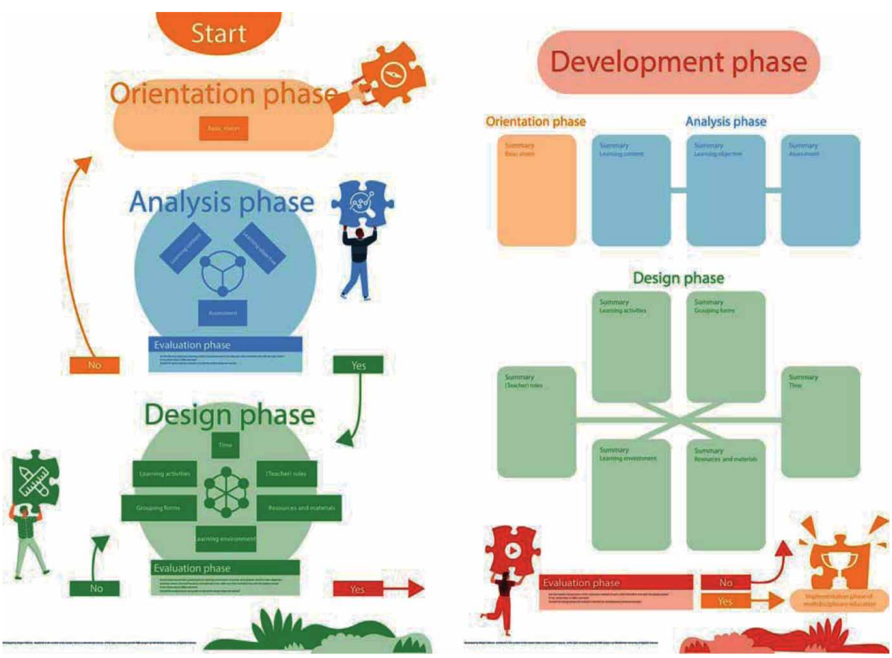
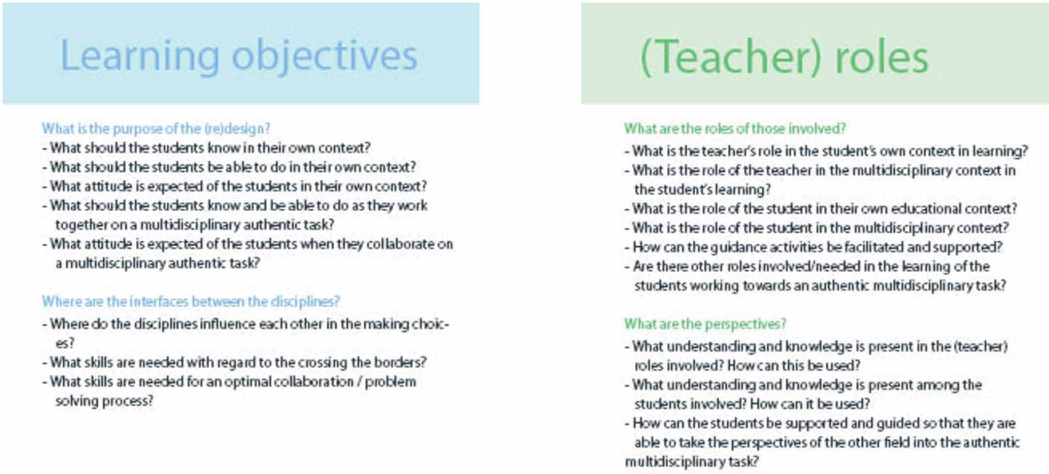


Figure 3. A card with questions for the analysis phase and design phase are shown



are split in two categories. The first category relates to the substantial criterion, the second one relates to how the interaction between university teachers of the different domains can be supported.

This game has been used during the workshop with the intervention. The full version of the game can be found in Appendix A including two photos that were taken during the workshop.

CONCLUSION

This theory-informed educational design framework was designed and developed with the intention to facilitate boundary crossing and closing gaps between domains during multidisciplinary educational design. It is expected that the framework will affect the types of interaction between university teachers, so that the identified domain-specific action-oriented knowledge is transformed into new and integrated action-oriented knowledge. Additionally, it is expected that it will affect the quality of the multidisciplinary educational design across the boundaries of different domains. The framework is also expected to support and facilitate university lectures in designing multidisciplinary education. The next step is further research to study whether the framework has the desired effects on both the educational design process as well as its outcome: the quality of the multidisciplinary educational design. This will be done by studying both the multidisciplinary educational design process as well as the quality of the educational design as an outcome in various design workshops.

ACKNOWLEDGMENT

The authors wish to acknowledge the help provided by the educational experts who gave feedback on the first prototype of the educational design framework and the participants for attending the workshops. They would also like to thank those who gave feedback on the connection between the curriculum components and the proposed design principles.

Note: The peer review process for this article was handled independent of the guest editors of the special issue to preserve the integrity of the double-blind peer review process. The acceptance of the article was handled by the leadership of the journal.

REFERENCES

Akkerman, S. F., & Bakker, A. (2011a). Boundary Crossing and Boundary Objects. *Review of Educational Research*, *81*(2), 132–169. doi:10.3102/0034654311404435

Anderson, R., & Helms, J. V. (2001). The ideal of standards and the reality of schools: Needed Research. *Journal of Research in Science Teaching*, *38*(1), 3–16. doi:10.1002/1098-2736(200101)38:1<3::AID-TEA2>3.0.CO;2-V

Bakker, A., Zitter, I., Beausaert, S., & de Bruijn, E. (2015). *Tussen opleiding en beroepspraktijk: Het potentieel van boundary crossing*. Koninklijke Van Gorcum.

Bower, M., & Vlachopoulos, P. (2018). A critical analysis of technology-enhanced learning design frameworks. *British Journal of Educational Technology*, *49*(6), 981–997. doi:10.1111/bjet.12668

Bunk, G.P. (1994). Competentie-ontwikkeling in de Duitse beroepsopleidingen. *Beroepsopleiding, 1*, 8-15.

Caris, J., Poiesz, T., & Lapré, F. (n.d.). *Complexe Sociale Vraagstukken vragen om een Integraal Analyse Model*. Retrieved op 29 januari 2021 from https://www.ubuntusociety.nl/public/files/ComplexeSocialeVraagstukken_%20Prof_%20Dr_%20Jo%20Caris.pdf\

Cremers, P. H. M., Wals, A. E. J., Wesselink, R., & Mulder, M. (2016). Design principles for hybrid learning configurations at the interface between school and workplace. *Learning Environments Research*, *19*(3), 309–334. doi:10.1007/s10984-016-9209-6

Creswell, J. W. (2014). *Educational Research: Planning, Conducting and Evaluating Quantitative and Qualitative Research* (4th ed.). Pearson Education Limited.

Denyer, D., Tranfield, D., & Van Aken, J. E. (2008). Developing Design Propositions though Research Synthesis. *Organization Studies*, *29*(3), 393–413. doi:10.1177/0170840607088020

Engeström, Y. (2001). Expansive learning at work: Towards an activity theoretical reconceptualization. *Journal of Education and Work*, *14*(1), 133–156. doi:10.1080/13639080020028747

Engeström, Y., Engeström, R., & Kärkkäinen, M. (1995). Polycontextuality and boundary crossing in expert cognition: Learning and problem solving in complex work activities. *Learning and Instruction*, *5*(4), 319–336. doi:10.1016/0959-4752(95)00021-6

Gulikers, J., & Oonk, C. (2016). Het waarderen van leren met partijen buiten de school. *OnderwijsInnovatie*, *3*, 17–26.

Huizinga, T., Nieveen, N., & Handelzalts, A. (2019). Identifying Needs for Support to Enhance Teachers Curriculum Design Expertise. In J. Pieters, J. Voogt, & N. Pareja-Roblin (Eds.), *Collaborative Curriculum Design for Sustainable Innovation and Teacher Learning* (pp. 115–138). SpringerOpen. doi:10.1007/978-3-030-20062-6_7

Newell, C., & Bain, A. (2018). *Team-based collaboration in higher education learning and teaching: A review of the literature*. Springer. doi:10.1007/978-981-13-1855-9

Newell, C., & Bain, A. (2020). Academics' perceptions of collaboration in higher education course design. *Higher Education Research & Development*, *39*(4), 748–763. doi:10.1080/07294360.2019.1690431

Peterson, C. (2013). Bringing ADDIE to Life: Instructional Design at Its Best. *Journal of Educational Multimedia and Hypermedia*, *12*(3), 227–241. https://www.learntechlib.org/primary/p/2074/

Rapp, C., & Gommers, L. (2018). *Theoretical and practical insights from IBH Seamless Learning Lab* [Keynote]. The Seamless Learning Conference, Welten Institute, Open Universiteit, Maastricht. Retrieved from: https://youlearn.ou.nl/documents/49299733/49302083/Rapp%2BGommers/4a3c8fc0-3089-b972-3821-b9ebab87a2d7

Reigeluth, C. M., & Avers, D. (1997). Educational technologists, chameleons and systemic thinking. In R. Branch & B. Minor (Eds.), *Educational media and technology yearbook* (pp. 132-137). Libraries Unlimited. Retrieved from: https://www.researchgate.net/publication/234568784_Educational_Technologists_Chameleons_and_Systemic_Thinking_87

Roth, W. M., & Lee, Y. J. (2007). Vygotsky's Neglected Legacy: Cultural-Historical Activity Theory. *Review of Educational Research*, *77*(2), 186–232. doi:10.3102/0034654306298273

Rusman, E. (2019). Ensuring learning continuity everywhere: Seamless learning in the Netherlands. In *Proceedings of 18th World Conference on Mobile and Contextual Learning 2019* (pp. 132-140). Retrieved from: learntechlib website: https://www.learntechlib.org/p/210612/

Rusman, E., Ternier, S., & Specht, M. (2018). Early Second Language Learning and Adult Involvement in a Real-World Context: Design and Evaluation of "he "ELENA Goes Shoping" Mobile Game. *Journal of Educational Technology & Society*, *21*(3), 90–91. https://www.jstor.org/stable/26458510

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, "translations" and boundary objects: Amateurs and professionals in Berkeley's museum of vertebrate zoology, 1907-39. *Social Studies of Science*, *19*(3), 387–420. doi:10.1177/030631289019003001

Sun, D., Looi, C.-K., Yang, Y., & Sun, J. (2020). Design and Implementation of the Boundary Activity Based Learning (BABL) Principle in Science Inquiry: An Exploratory Study. *Journal of Educational Technology & Society*, *23*(4), 147–162. https://web-s-ebscohost-com.ezproxy.elib11.ub.unimaas.nl/ehost/pdfviewer/pdfviewer?vid=1&sid=9abba02c-e58a-4159-bcd4-e0bf5caa1836%40redis

Van den Akker, J. (2003). Curriculum perspectives: An introduction. In J. J. H. van den Akker, W. A. J. M. Kuiper, & U. Hameyer (Eds.), *Curriculum landscapes and trends* (pp. 1–10). doi:10.1007/978-94-017-1205-7

Veltman, M. E., Van der Cingel, P., & Brandon, A. (2021). *Multidisciplinair werken aan complexe praktijkvragen: opbrengsten onderzoeksfase*. Hogeschool Windesheim.

Veltman, M. E., Van Keulen, J., & Voogt, J. M. (2019). Design principles for addressing wicked problems though boundary crossing in higher professional education. *Journal of Education and Work*, *32*(2), 135–155. doi:10.1080/13639080.2019.1610165

Voogt, J., Laferrière, T., Breuleux, A., Itow, R. C., Hickey, D. T., & McKenney, S. (2015). Collaborative design as a form of professional development. *Instructional Science*, *43*(2), 259–282. doi:10.1007/s11251-014-9340-7

Voogt, J., Pieters, J. M., & Handelzalts, A. (2016). Teacher collaboration in curriculum design teams: Effects, mechanisms, and conditions. *Educational Research and Evaluation*, *22*(3-4), 121–140. doi:10.1080/13803611.2016.1247725

Wenger, E. (1998). *Communities of Practice: Learning, meaning, and identity*. Cambridge University Press. doi:10.1016/j.compedu.2011.06.007

Wong L. H., & Looi C. K. (2011). What seams do we remove in mobile-assisted seamless learning? A critical review of the literature. *Computers & Education*, *57*(4), 2364–2381. doi:10.1016/j.compedu.2011.06.007

APPENDIX A

Education Design Framework

Figure 4 in this appendix shows the game board for designing multidisciplinary education. Each phase has its own color and is concluded with the evaluation phase to test the consistency between the different curriculum components. The game board has been designed in such a way that each phase may provoke a learning mechanism (Akkerman & Bakker, 2011). The orientation phase is linked to the learning-mechanism 'identification', the analysis phase to 'coordination', the design phase to 'reflection' and the development phase to 'transformation'. The ten curriculum components of van den Akker, 2003 have been divided over the four phases. The colors on the game board correspond with the colors on the cards with questions in Figure 5. These supporting questions can be used by the university teachers to facilitate them during their multidisciplinary educational design process and to help them to identify conflicting domain-related action-oriented knowledge and possibly transform it into new action-oriented knowledge. The questions are split in two categories. The first category relates to the substantial criterion, the second one relates to how the interaction between university teachers of the different domains can be supported. Finally, in Figures 6 and 7, there are two photos that were taken during the first workshop.

The group consisted of eight college teachers, three of whom were female and five male. The following disciplines were represented in this workshop: construction engineering, electrical engineering, mechanical engineering, industrial engineering, spatial development, circular economy and HBO ICT.

Figure 4. Game board for designing multidisciplinary education

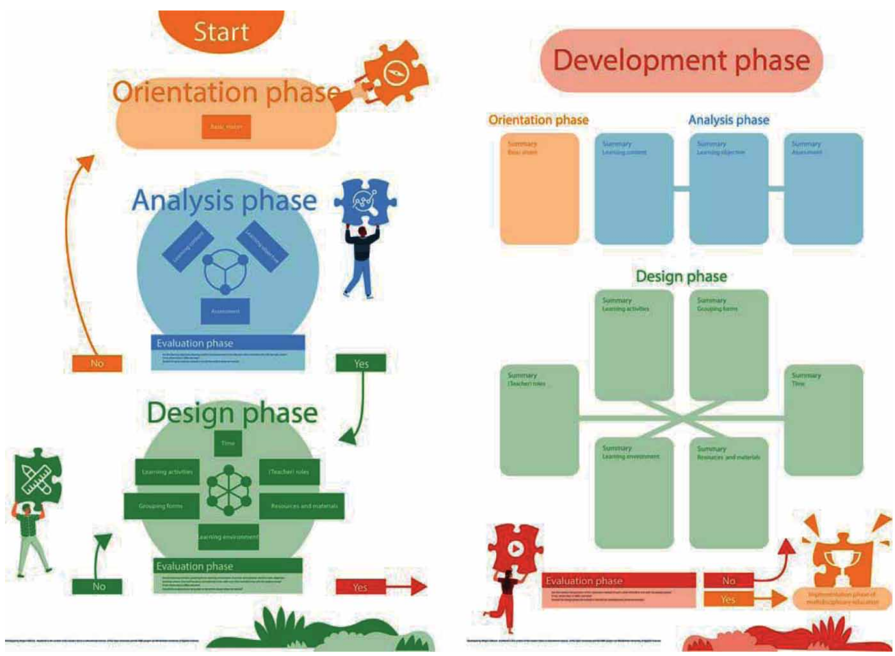


Figure 5. Game cards with supporting questions associated with game board

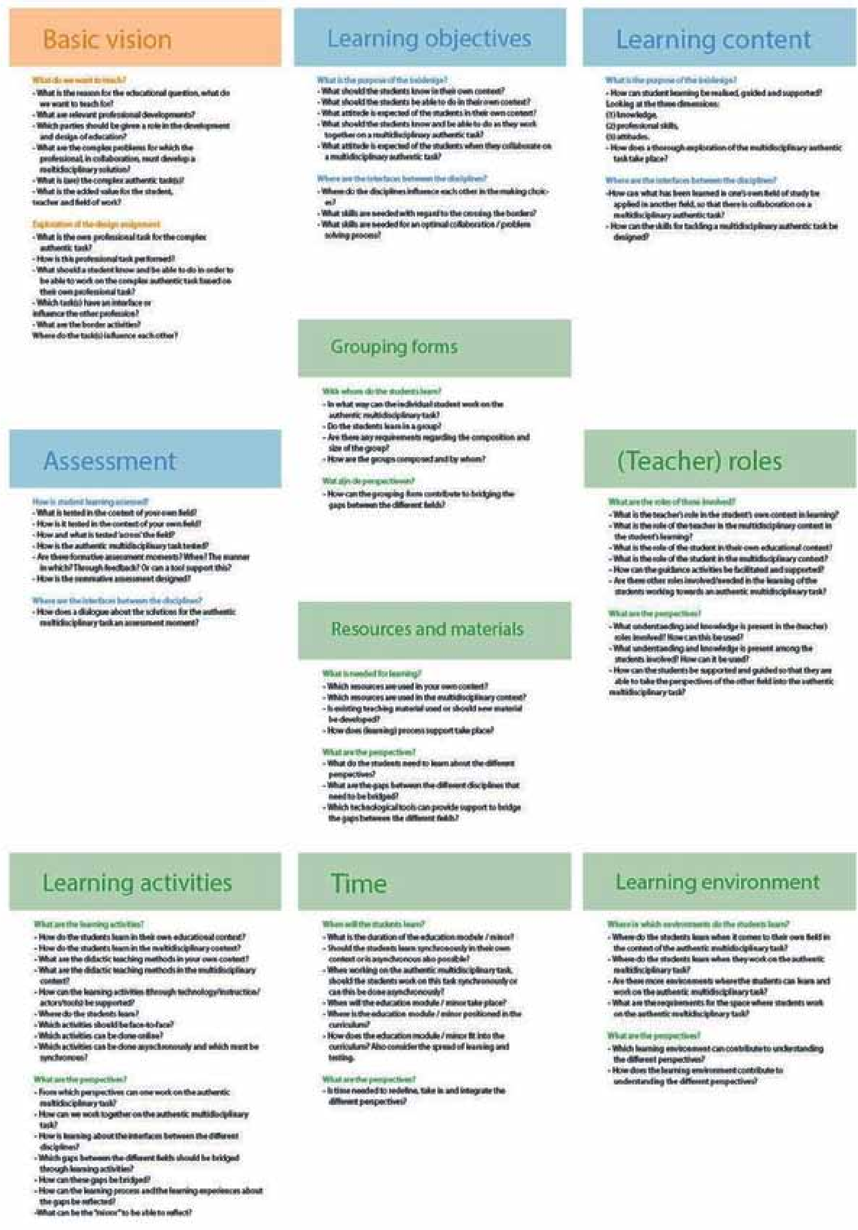


Figure 6. Use of the framework during the first workshop

Figure 7. Use of the framework during the first workshop

APPENDIX B

CIMO-Logic Per Perspective

The three CIMO logic per perspective are listed below in Figure 8 (substantial criterion), Figure 9 (How the educational design framework can be offered to educational professionals) and Figure 10 (How the interaction between university teachers of the different domains can be supported). Each CIMO logic shows which interventions are needed to activate the right mechanism, so that it leads to the outcomes.

Figure 8. Development of the intervention and the mechanisms with regard to the substantive approach

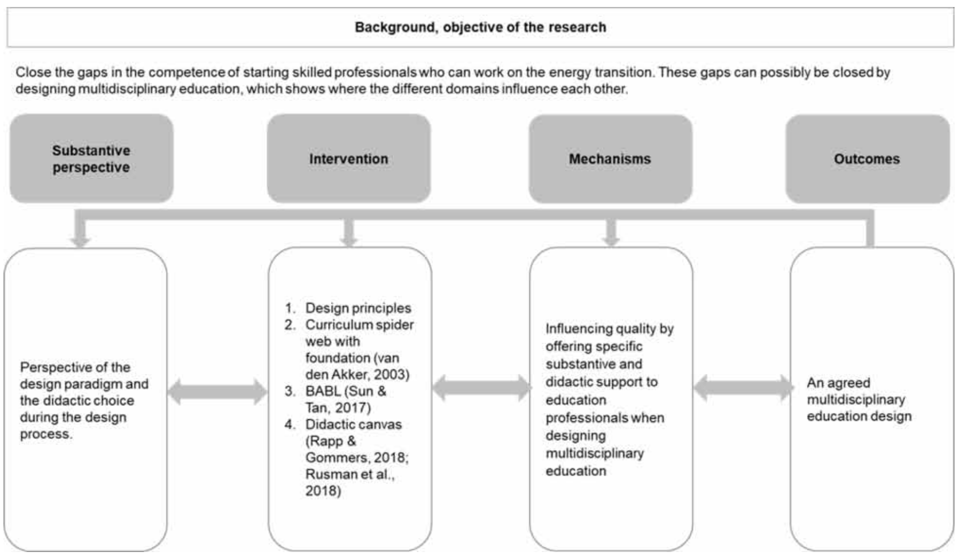


Figure 9. Development of understanding of the intervention and the mechanisms of how it is delivered to educational professionals

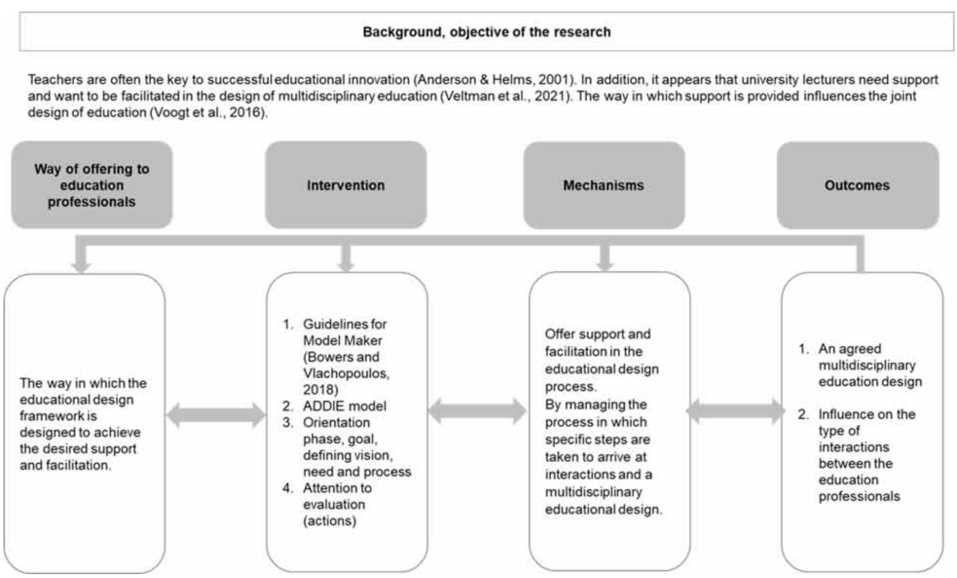
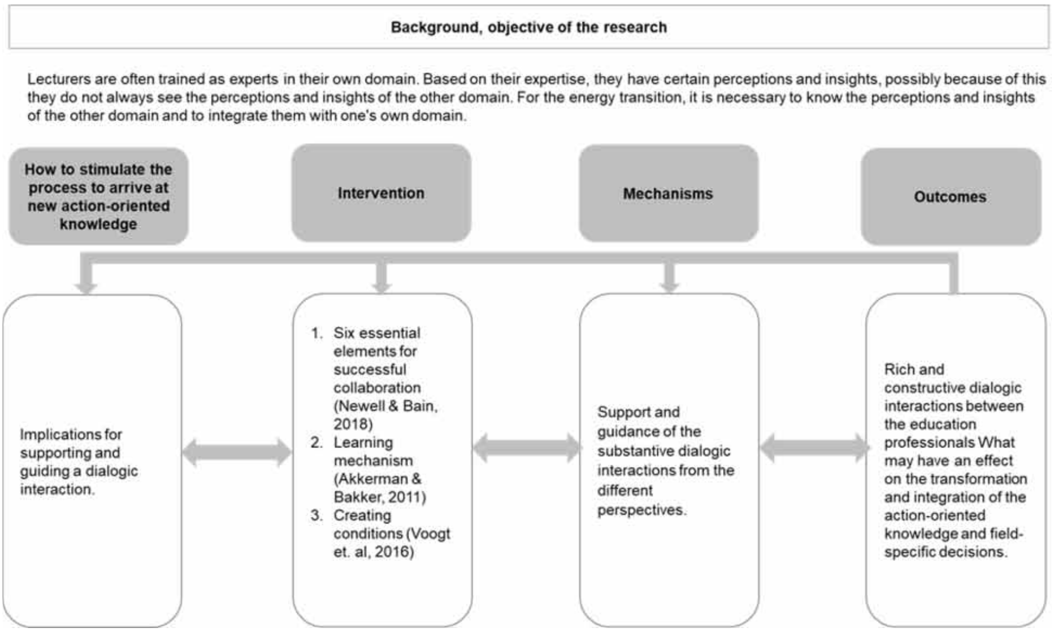


Figure 10. Development of the intervention and the mechanisms with regard to how the process from identification to transformation is stimulated



Mirjam Selhorst-Koekkoek is a lecturer in Construction Engineering and Construcion Management at Windesheim University of Applied Sciences. She does research for the Lectorate Energy Transition of Windesheim University of Applied Sciences on sustainable construction, the integration of building and technology and the training of skilled engineers that are aware of the energy transition. The energy transition can be characterized as a complex project. Her personal conviction is that a successful transition for all stakeholders is only possible through an integrated approach. In her Master's thesis from the Faculty of Education Sciences at the Open University, she therefore focused on Multidisciplinary Education Design, to fill in the gaps between disciplines. In this research, an educational design framework was developed: Case study of the influence of an educational design framework for "seamless learning" on the quality of dialogue between teachers as well as of the multidisciplinary design framework. In addition, she is involved in a Comenius project related to the theme: Education in connection with society. This project aims to train all engineers at Windesheim University of Applied Sciences as energy transition aware and skilled engineers.

Ellen Rusman is Associate Professor at the Faculty of Educational sciences at the Open University of the Netherlands. She is an expert in (seamless) learning design, networked learning and technology-enhanced learning and leads the group on Mobile & Seamless Learning Design (MSLD). A common thread in her work is connecting people and their experiences in different (learning) contexts through (mobile) technology, so that developing competences becomes more meaningful, appropriate, fun, effective and efficient. Ellen has a broad experience in large national and international TELI design research projects and gained several awards, both with her scientific work (e.g., best paper/presentation awards, Best research & practice award of the Dutch National Research Council), as well with (research) project outcomes (e.g., European Language Label and Nuffic Orange Carpet Award with the ELENA-app). In her projects Ellen loves to work closely with different stakeholders (e.g., teachers, learners). She highly values and balances both the scientific as well as the practical relevance of initiated projects.