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A COMPETENCE DEVELOPMENT APPROACH FOR FLEXIBLE, AUTONOMOUS AND SELF-DIRECTED DEVELOPMENT OF EDUCATION IN TECHNOLOGY CONTEXTS

Abstract:

The vocational education system is affected by the speed of technology and vocational change. Challenges arise for engineering-technology teachers to keep up with the creation of new education. In an ever faster cycle of development and delivery, engineering-technology teachers are to be educated to acquire domain knowledge for new vocational tasks and transform this into relevant learning tasks for students. To contribute to such engineering-technology teacher challenge, the Teacher Training Institute of Fontys University of Applied Sciences designed a competence development approach for self-directed development of competence in the didactisation of new vocational tasks in technology contexts. The approach described in this paper is based on the modelling of knowledge for new vocational tasks and the didactisation of that knowledge through generic technology and engineering concepts, into meaningful learning activities for students. It is the premise of reuse of technology concepts and didactics, transferable across technology contexts, which is important to the flexible development and delivery of new education. The paper describes how the competence development approach is designed, implemented and evaluated at Fontys University of Applied Sciences, Technical Teacher Education Institute.

Keywords:

competence development approach, vocational education, engineering-technology teacher education

JEL Classification: I20, I29

1 Background

Technology is rapidly changing and knowledge development does not pause. Products and services in technology-driven sectors innovate constantly. Companies require technicians that can flexibly learn and collaborate in fluid environments on multidisciplinary and multilevel projects. Rapid technology development has an impact on the tasks and the competence profiles of technicians in all sectors. The vocational education system, which educates and trains students for technical professions in sectors, is affected by the rapid development of technology. The educational system can only remain future proof if it is responsive to task and competence changes and able to flexibly provide for the right vocational programme. Given the speed of technology and vocational change however, challenges arise for engineering-technology teachers. They must be equipped to learn how to obtain domain knowledge and transform this knowledge into education, in an ever faster cycle of development and delivery. Future teachers must be able to analyse technological developments swiftly and identify issues that influence the vocation. Engineering-technology teachers of the future will have to be able to translate technological developments into new vocational tasks and generate appropriate student learning tasks that can satisfy the competence requirements of the changing vocation. Technology literacy and flexible didactisation of domain knowledge will increasingly play a role in a teacher’s ability to generate learning tasks, efficiently and effectively. Teachers must become more responsive to change and more agile in their development and delivery of education. There is a growing importance in quickly identifying the distinguishing properties of technological development with the ability to flexibly generate education and training. It is the objective of this paper to describe for engineering-technology teachers, a competence development approach for self-directed development of competence in the didactisation of (new) vocational tasks, in a changing technology context.

2 Research question

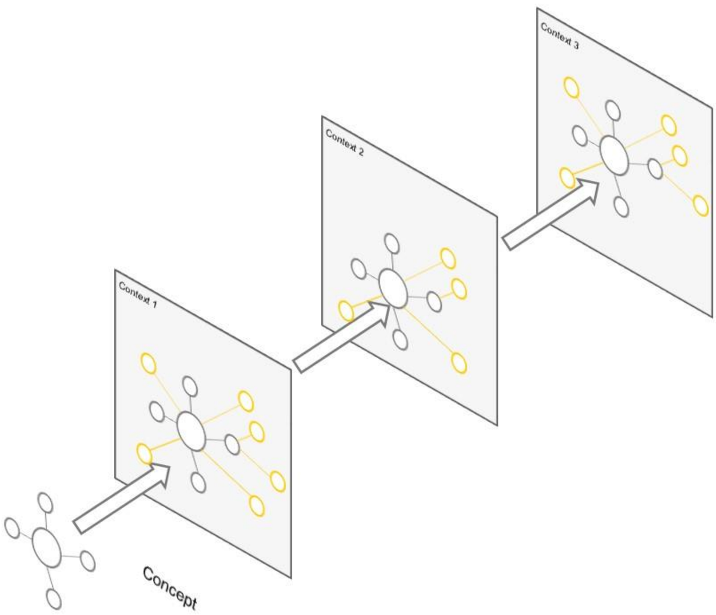
Changing technologies and changing vocational tasks lead to a need for continuing education and training. It is a real challenge for teachers in technology education to (each time) develop subject matter and training for workplace-related vocational tasks, according to the latest technological developments. It would help to constitute a common learning base with generic technology learning concepts for learners in technology contexts. One could think for example of a number of recurring learning concepts in a group of related (technology) vocations onto which a similar learning strategy could be placed and beyond which specific learning tactics could be differentiated. If the premise of reuse of learning concepts is an important objective to achieve learning for vocations in a changing technology context, one needs to identify what learning concepts of technology are generic and what learning concepts of technology are specific. We need to search for a technology language, a common language with generic concepts and conceptual analogies between concepts in contexts: a language that allows us to swiftly identify and explain the common properties of technology among various technology contexts and subsequently a language that allows us to identify lower level concept-descriptors of which the semantics either concur or differ among the contexts. It is by identifying conceptual analogies between the learning concepts applied in technology contexts, that future teachers can identify their learning strategies for (changing) vocations. Teachers need to identify what generic technology concepts for learning exist and how learning activities for new work-tasks may be designed with them. An important precondition would be that one would be able to identify the knowledge organisation of technology concepts of one's own field of discipline first, and then relate thereto the technology concepts identified in the knowledge of (new) work-related tasks. Didactical strategies can (then) be matched to facilitate horizontal and vertical learning transfer between the technology concepts. Mind further that a teacher must also be able to effectively make the right (practice-oriented) didactical translation of knowledge towards the workplace. A teacher needs to be able to distinguish knowledge transfer for academic purposes from transfer of knowledge for vocational tasks and work-process related activities. We arrive at our main research question: What constitutes a competence development approach enabling students of engineering-technology teacher programmes to create (new) education in a changing technology context, more flexible, autonomous and self-directed? With latter requirement(s) in mind, we enter the literature study.

3 Literature review

With the objective of future teachers creating education and training in technology contexts, more flexible, autonomous and self-directed, we set out on explorative research into technology concepts that can be (re-)used in multiple contexts and study the literature for modelling technology herewith accordingly. We started literature review on technology literacy to constitute a common language with generic transferable technology concepts for the engineering-technology teacher curriculum (ITEA, 2002; TOS21, 2008; De Vries, Hacker and Rossouw, 2009). Arguments were found in support of technology literacy and generic concepts. For example, technology literacy could provide a common language for describing the engineering-technology teacher curriculum, it would enable learning strategies based on generic and selective transfer, it would relieve us of the problem of classic curriculum overload, and it would contribute to the continuing professional development challenge: learning strategies grasping control over (technological) developments. Technology concepts in literature, however, are not consistently defined: 'concepts of technology' were found in Mitcham (1994) and De Vries (1997) and 'concepts in technology' were found in Savage & Sterry (1990), ITEA (2002), Compton (2004), Hill (1997) and Banks (1994). We found that generic concepts such as systems, processes, resources and technology assessment and societal values, are helpful in understanding technology: ’knowing what’. Whereas engineering design-concepts such as analysis, design, realisation, control, management, advice, research and professionalization are more important in construction of technology i.e., engineering cycles: ’knowing how’. We are supported in this notion by the contemporary domain competence profiles of engineering education (HBO-Engineering, 2016).

In delivering education to different technological contexts, based on generic technology concepts, we further need information on transfer strategies for teaching and learning. Hence, we extended our explorative research from generic technology concepts towards strategies for transfer learning (Figure 1). We reviewed transfer learning strategies through the concept-context methodology (Bruning and Berince, 2013). The concept-context methodology allows analogies between concepts to be transferred and context-specificities of concepts to be learned. A variety of didactic approaches contribute to the actual didactical implementation of the concept-context approach. Rodríguez (2018), Pumilia-Gnarini et al. (2012) and Valcke (2017) provide an overview of potential (supportive) didactic approaches, from respectively teaching-learning perspective, technology perspective and instructional perspective. Moreover, the education institute must decide whether a concept-context strategy is designed with benefits of a larger hybrid and interacting curriculum in mind, such as is the case with boundary crossing (Akkerman and Bakker, 2011), or whether the application remains on the level of merits of the individual learner.

Figure 1: Concept analogies in technology contexts



Whenever work-tasks, work-processes and associated technology concepts applicable to vocational task have not yet been explicated, an analysis must first take place on the constituents of the vocation in terms of tasks, processes, (theoretic) knowledge, skills and professional behaviour. It is essential to be able to establish a proper representation of the knowledge of the vocation by (researching) appropriate task-modelling methods and codification techniques that can express work-place related tasks and work-processes. We infer that knowledge codification takes place on those concepts which are crucial to the (new) work-tasks and processes. Drawing up competence profiles in engineering-technology vocations, requires adequate analysis and coding of knowledge that one needs in the vocation. We infer the importance of codification: 1) in terms of vocational knowledge, 2) in terms of skills and 3) in term of professional attitude. We studied an overview of knowledge capture methods such as those found in Dalkir (2005) and Blauw (2005) and concur with authors that effective selection of knowledge acquisition techniques and knowledge capture methods are important for the elicitation of knowledge from domain experts and for the successful modelling of tasks and capture and codification of vocational knowledge. Consider, it is on the properties of the explicated knowledge of the vocation, that the subsequent didactic strategies must be matched. Some widely used knowledge engineering and knowledge acquisition tools and techniques are described in Schreiber et al. (2000) and Shadbolt, O’Hara and Crow (1999). In the next section, and based on our experiences derived from our literature study, we describe the competence development approach we realised for our students in the engineering-technology teacher curriculum.

4 Design

The competence development approach has been designed for students of the engineering-technology teacher programme to strengthen their ability to flexibly translate new technological developments into: 1) Knowledge concepts, 2) Learning content and 3) Learning strategies for students in vocational education. Specifically included in the learning process is the development of how to translate technological developments into generic and specific concepts, how to establish what knowledge the identified concepts should contain, and how to facilitate transfer learning by concept-context analogies. Important is the requirement that students learn to manage the overview over their discipline at all times in order to map and position new knowledge properly. When one is novice to teaching in vocational contexts, one must also learn the difference between teaching for general education purposes not aimed at professions, and teaching for vocational purposes, in which specific tasks and work-processes are applicable. Further, included in the design is the need for diversification of learning content, driven by the characteristics of the target group and the specific properties of the workplace-context. This aspect of learning by students in the engineering-technology teacher programme, clearly signifies the importance of skills for research and selection of fitting didactical methods and techniques. It also implies the (pre)condition for teachers to be competent in explicating (new) knowledge i.e., to make (in first instance) new knowledge properly accessible and transferrable. In the design of the competence development approach -for students of engineering-technology teacher programmes to create new education in a changing technology context more flexible, autonomous and self-directed- we grouped our observations into five distinct development steps.

The future (engineering-technology) teacher:

1. Identifies and performs an analysis of a problem, challenge or critical situation, which must be dealt with in the professional activities of the technician at the workplace.

2. Construct an overview of the knowledge domains relevant to the profession and guided by an analysis of the vocational organisation of tasks and work-processes in the profession, diagnoses which knowledge domains and concepts are relevant to tasks and contribute to solving the situation of the technician.

3. Determines in the context of the work-situation, the package of requirements in terms of knowledge concepts, learning outcomes and learning performance for the actual development of education and training for the technician.

4. Develops for use in the profession of the technician and on the required professional competences, a description of the (conceptual) learning content with suitable knowledge representation for purposes of education and training.

5. Based on a vision on transfer learning, is able to flexibly recast learning content to different target groups and technology contexts, by target group analysis, implementation of relevant didactical strategies and the organisation of learning in more practical terms.

The different steps of the competence development approach described here, serve as learning outcomes for the students of the engineering-technology teacher programme. We have defined a rubrics instrument for assessment of the learning outcomes, using a three point scale: unsatisfactory, satisfactory, and good. Accordingly, we defined relevant aspects on which the performance on the learning outcomes can be measured. Next, for each learning outcome we describe the relevant aspects in the rubrics:

Ad 1. In the first learning outcome ‘Identifies and performs an analysis of a problem/challenge or critical situation, which must be dealt with in the professional activities of the technician at the workplace’, the aspects ‘problem identification’ and ‘problem analysis’ are important. It implies, the learner must be able to provide a clear description of the problem/challenge or critical situation at hand and must be able to explicate causal consequences to the problem whilst explaining the background and the causes of these consequences.

Ad 2. In the second learning outcome ‘Construct an overview of the knowledge domains relevant to the profession and guided by an analysis of the vocational organisation of tasks and work-processes in the profession, diagnoses which knowledge domains and concepts are relevant to tasks and contribute to solving the situation of the technician’, the aspects ‘knowledge domains’, ‘diagnosis’, ‘vocational organisation’ and ‘knowledge concepts’ are important. It implies, the learner must be able to provide a clear overview of the knowledge domains involved in the profession of the technician and must be able to determine which knowledge domain(s) to focus on to improve the situation. To determine which knowledge concepts are meaningful to improving the situation, a task analysis must be performed and essential knowledge concepts must be identified.

Ad 3. In the third learning outcome ‘Determines in the context of the work-situation, the package of requirements in terms of knowledge concepts, learning outcomes and learning performance for the actual development of education and training for the technician’, the aspects ‘knowledge concepts’, ‘learning outcomes’ and ‘learning performance’ are important. It implies, the learner must be able to identify on which knowledge concepts education must take place, which learning outcomes need to be fulfilled and which performance requirements are put on the learning (outcome) realisation.

Ad 4. In the fourth learning outcome ‘Develops for use in the profession of the technician and on the required professional competences, a description of the (conceptual) learning content with suitable knowledge representation for purposes of education and training’, the aspects ‘learning content’ and ‘knowledge representation’ are important. It implies, the learner must be able to detail the knowledge concepts on which the education takes place, in terms of (theoretic) knowledge, skills and professional behaviour and must be able to model the different knowledge with (semantic) representation techniques for education and training transferability.

Ad 5. In the fifth learning outcome ‘Based on a vision on transfer learning, is able to flexibly recast learning content to different target groups and technology contexts, by target group analysis, implementation of relevant didactical strategies and the organisation of learning in more practical terms’, the aspects ‘recast’, ‘target group analysis’, ‘didactical strategies’, organisation of learning’ are important. It implies, that the learner is able to re-interpret learning content to serve the requirements of different target groups i.e., assistant, basic skilled worker, independent professional and specialist. He is capable of flexibly recasting learning content according to requirements of different target groups. He is able to perform didactisation of learning content into teaching methods, learning materials and learning arrangements, honouring properties of the different knowledge concepts, target groups and vocational contexts. He is also able to organise the learning more practically, in terms of coherent blocks, lessons and time-schedules. Finally, he must be able to legitimise the developed strategy with a vision on transfer learning and literature references and he must be able to evaluate whether his (schooling) intervention has been effective and contributed to solving (part of) the problem in the workplace.

5 Implementation issues

With the objective for students of engineering-technology teacher programmes, to become more flexible, autonomous and self-directed in creating education for specific (changing) vocations, we described in this paper a stepwise competence development approach. Along the lines of the learning outcomes, students develop competence in three main areas: 1) technology literacy and generic concepts, 2) task analysis and knowledge modelling, and 3) generic and selective transfer learning by selection of didactical methods and techniques. The competence development approach described in the paper was implemented in the second year of the engineering-technology teacher curriculum at Fontys University of Applied Sciences. In the implementation of the competence development approach we left open much flexibility on the part of learning pathways. Students could for example apply for, or find themselves, a meaningful work-context with which to achieve their learning outcomes.

For students lacking this option, the engineering-technology teacher programme would provide scaffolding of students. Scaffolding was implemented using a problem-based (project) approach (Barrows,1986; Savery and Duffy, 1995; Boud and Feletti, 1997; Barrows,1996). We provided students with project-based work and a mix of classes with collaborative assignments. Students could attend classes, on: 1) Technology literacy and generic concepts, 2) Methods for task analysis and knowledge modelling, and 3) Transfer learning with different didactical methods and techniques. Students would learn these subjects while engaging actively with real and meaningful problems identified in vocational contexts. Students would problem-solve in a collaborative setting and create mental models for learning. In working on project-based work, students would go into the technical domain, research a problem and gather knowledge from vocational experts to learn specific requirements and pathways to solutions. The mix of both project-based work and classes were aimed to create self-directed learning habits, through practice and reflection.

6 Evaluation

We evaluated the competence development approach by assessing the students' compliance with the learning outcomes, through the implementation of the project and the classes. We wanted to determine whether the learning outcomes with the project-based approach and classes, contributed to more flexibility in students in creating education for problem-based, uncharted vocational situations. The following observations were noted from student and teacher evaluations. Students favoured the scaffolding through the implementation of classes and project-based approach. The students find the learning outcomes by themselves quite difficult to interpret in terms of what they really need to provide as material evidence to prove that they satisfy the learning outcomes. This especially goes for the students that do not follow classes or do not use the supplied project as a ‘save’ learning pathway. Such students typically lack the contextual knowledge from teacher and project description. The description of the project provides context and provides insight into the deliverables that serve as proof for the learning outcomes. Sometimes students find it difficult to interpret the learning outcomes because of the subject-specific terms especially when not visiting the classes. With the project-based approach, students analyse real-life problems. Being helped by the overall learning outcomes, students decide for themselves what knowledge is relevant to acquire in the project, as part of formulating their own learning goals. Herewith, the learning becomes self-guided but at the same time it is collaborate and constructive with the help of (other) project members or the field-experts. The project-based approach in combination with the learning outcomes, proves to be a more satisfactory approach rather than using an approach with learning outcomes but without the project description. Students in the project learn more than just facts, they learn to work in a solution-focused way and learn to conduct research: essential 21st century skills. Moreover, the learning is experienced to be more relevant to the purpose now, i.e., fitting the specific context or the workplace situation. Students are training themselves in the acquisition and selection of knowledge to solve problems. This requires other, different skills as compared to learning of charted knowledge for a test or examination. For the teachers, the change from classical teaching to project-based work with learning outcomes, is a professional learning experience. Their role as classical knowledge provider has diminished. Their new role as tutor and coach, in helping students to develop skills to search, assess and value knowledge in a more solution-oriented manner, has grown.

References

Akkerman, S.F. & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research*, 81, 132-169.

Banks, F.(1994) , Teaching Technology, The Open University Press, U.K.

Barrows, H. S. (1986). A taxonomy of problem-based learning methods. Medical education, 20(6), 481-486.

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. New directions for teaching and learning, 1996(68), 3-12.

Blaauw, G. (2005). Identificatie van cruciale kennis. Groningen: Proefschrift Rijksuniversiteit Groningen,vakgroep Bedrijfskunde. Ridderkerk: Labyrint Publications.

Bruning, L. and Berince, M. (2013). Concept-contextvenster: zicht op de wisselwerking tussen concepten en contexten in het bèta-onderwijs. Enschede: SLO, Nationaal expertisecentrum leerplanontwikkeling.

Boud, D. and Feletti, G. (1997). The challenge of problem-based learning. Psychology Press.

Compton, V., (2004). Technological Knowledge: A developing framework for technology education in New Zealand http://www.tki.org.nz/r/nzcurriculum/docs/technological-kn.doc

Dalkir, K. (2005). Knowledge Management in Theory and Practice. McGill University.

HBO-Engineering (2016). Domeinprofiel Bachelor of engineering. Domein HBO engineering.

Hill, A. M., (1997). Reconstructions in Technology Education. *Journal of Technology and Design Education.* Vol.7 No (1-2).

ITEA (2002). Standards for technical literacy: content for the study of technology. Third edition.

International Technology Education Association.

Mitcham, C. (1994). Thinking through technology. The University of Chicago Press.

Pumilia-Gnarini, P.M., Favaro, E., Pacetti, E., Bishop, J., Guerra, L. (2012). Handbook of Research on Didactic Strategies and Technologies for Education: Incorporating Advancements (2 Volumes). IGI Global

Rodríguez, L.M. de los Ángeles Martínez (2018). Ddidactic strategies for students and teachers of the 21st century. Independently published.

Savage E. and Sterry, L. (1990). A conceptual framework for technology education. International

Technology Education Association.

Savery, J. R., & Duffy, T. M. (1995). Problem based learning: An instructional model and its constructivist framework. Educational technology, 35(5), 31-38.

Shadbolt, N., O'Hara, K., and Crow, L. (1999). The experimental evaluation of knowledge acquisition techniques and methods: history, problems and new directions. *International Journal of Human-Computer Studies.* 51(4): 729–755.

Schreiber, G., Akkermans, H., Anjewierden, A., de Hoog, R., Shadbolt, N., Van de Velde, W., and Wielinga, B. (2000). Knowledge engineering and management: the commonKADS methodology. Cambridge, MA: MIT Press.

TOS21 (2008). Techniek op school voor de 21ste eeuw - technische geletterdheid voor iedereen,

standaarden & referentiepunten. Brussel: departement onderwijs & vorming en departement economie wetenschap & innovatie.

Vries, M. de, Hacker, M. and Rossouw, A. (2009). CCETE project, concepts and contexts in engineering & technology education. National Science Foundation.

De Vries, M. J. & Tamir, E (1997). Shaping Concepts of Technology: What Concepts and How to Shape them? *International Journal of Technology and Design Education.* Vol.7 (1-2).

Valcke, M. (2017). Onderwijskunde als ontwerpwetenschap: een inleiding voor ontwikkelaars van instructie en voor toekomstige leerkrachten. Gent, Academia Press.