Goppold. M., Fenz, M., & Nitsch, V. (2021). Design of work process oriented digital learning systems based on work analysis. In C. Nägele, B.E. Stalder, & M. Weich (Eds.), *Pathways in Vocational Education and Training and Lifelong Learning. Proceedings of the 4th Crossing Boundaries Conference in Vocational Education and Training, Muttenz and Bern online, 8. – 9. April* (pp. 133–140). European Research Network on Vocational Education and Training, VETNET, University of Applied Sciences and Arts Northwestern Switzerland and Bern University of Teacher Education. https://doi.org/10.5281/zenodo.4537155

Design of Work Process Oriented Digital Learning Systems Based on Work Analysis

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Abstract

Digital learning media can extend traditional media concepts beyond the presentation of explicit knowledge. In this paper, a digital learning system for Technical Vocational Education and Training (TVET) is described that integrates the concept of learning from errors into work processes of company-based apprenticeships. The learning system detects action errors at work, simulates error consequences and visualizes possibly hazardous consequences in Augmented Reality. In order to do so, the digital learning system utilizes information gained from work analysis. Work analysis methods help to reveal and communicate variations in work processes. Traditionally, they support qualification research with empirical evidence on changes in work practice and the need for adaption. This article investigates whether work analyses facilitate the development of digital learning media and didactic concepts in TVET. For this purpose, work processes in company-based apprenticeships have been analysed using structural and procedural work analysis methods. The results illustrate the contribution of work analysis on didactic conception using the Hamburg Model of Teaching Practice and Learning Practice and face a critical discussion. The article further provides an outlook on a desideratum, which focusses on the integration of structural and procedural work analysis results in a didactic compatible unified technical development framework.

Keywords

workplace, action research, education technology, didactics

1 Introduction

Education systems are country-specific and differ widely in Europe (e.g. OECD, 2015). Similarly, even in the same occupations, work processes differ due to legal, regulatory, historical and social influences (e.g., Pilz, 2015). Especially in technical vocations, there is a pluralism of national and international standard combinations (e.g., ISO, EN, DIN, BSI, ASI, AFNOR), which skilled workers have to be aware of at their workplace. In addition, Technical Vocational

Education and Training (TVET) qualifies for a national labour market's demand. Work analysis methods help to reveal international variations and to communicate differences in work processes transparently across borders for joint or comparative studies, thus facilitating the development of international didactic concepts.

In dual TVET systems, companies and vocational schools combine the strengths of both, the theory-based and the action-based, teaching approaches within apprenticeships (e.g. Lensjø, 2020). Similarly, research indicates that an integration of theory-based and work-oriented teachings might be the silver bullet of digital media conception in TVET (cf. Howe & Knutzen, 2013).

Different curriculum design approaches exist in TVET, which imply different didactic theories and concepts, as Gessler and Howe (2015) pointed out in their review. In contrast to a science-oriented content perspective, work-oriented curricula incorporate work- and action-based learning theories in TVET. This article focusses on the work-oriented design framework that matches work analysis.

Based on this prise, a learning system is proposed that aims to integrate work-based and theory-based perspectives, what goes beyond knowledge representations in traditional media concepts. For this purpose, the learning system applies learning from errors in work processes in company-based apprenticeships. The learning system detects action errors at work, simulates error consequences and visualizes hazardous situations in Augmented Reality (Atanasyan et al., 2020) in order to use observed actions in work-oriented as well as knowledge-based learning processes.

Hence, this article aims to address the research question: What advantages do work analyses offer to the development of digital work-based learning media and didactic concepts specifically for TVET?

The first section introduces the applied didactic model and reiterates the roots of work analysis in TVET before outlining the methodology. Next, the results are discussed and critically reflected including an outlook on the further development process. Lastly, a conclusion is provided.

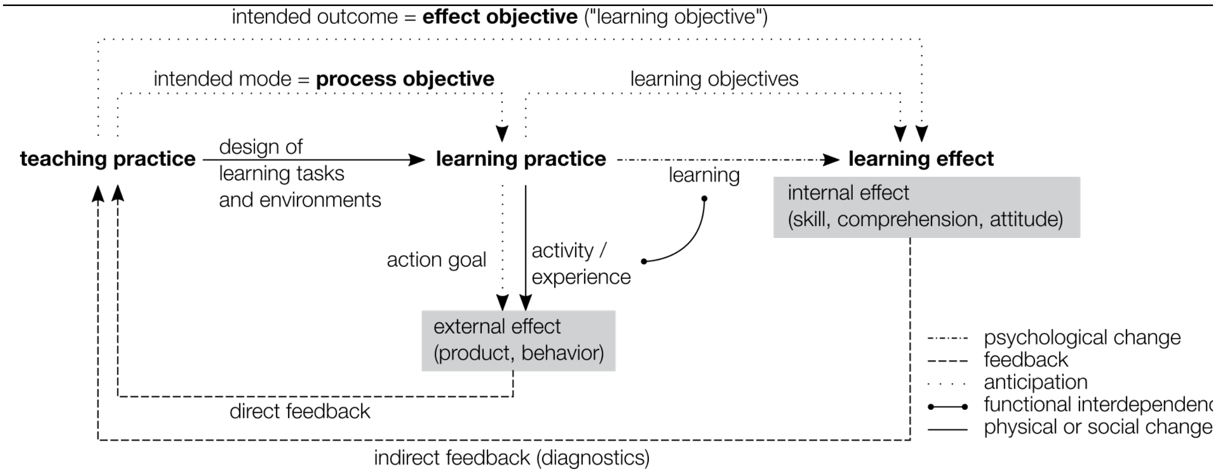
2 Theory

The Hamburg Model of Teaching Practice and Learning Practice (HMTL) (Augsdörfer & Caspar, 2018) is an adequate didactic theory for this context (see Figure 1). Its foundations are in the field of action regulation theory (cf. Zacher & Frese, 2017). It divides the teaching and learning process into an activity that fits work-orientation and into learning, which can align to scientific content-oriented skill and knowledge perspectives, too.

Erroneous paths of task handling in the work process as objectives of the investigation induce a contradictory perspective to usual correct solutions. The learning from errors credo (e.g., Darabi et al., 2018) entails demand for realistic representations of action options in the work process. According to that, the technical learning system needs to detect human actions in the work process. Therefore, the requirement engineering in the development process must specify the underlying work processes for the system usage as well as for the didactic conception.

Based on the ideals of German qualification research (cf. Mickler, 2008), work analyses have been used to support the humanization of work, which includes best qualification of workers. Hence, work analyses deliver empirical evidence and results for curriculum development in the vocational dual education system (Spöttl & Loose, 2019) in Germany and other European countries (cf. Tūtlys & Spöttl, 2017). Results manifest changes in work practice and indicate a need for adaption in curricula.

Figure 1
Hamburg model of teaching and learning (Tramm & Caspar, 2018 translated by Augsdörfer & Casper, 2018)



Traditionally, qualification research applies empirical methods from industrial engineering or work psychology in combination with qualitative studies from social sciences such as sector-specific content analysis, case studies and expert skilled worker workshops (cf. Spöttl, 2020; Spöttl, 2008a, b). Furthermore, they have process descriptions in common similar to technical research and development methods, for instance UML (OMG, 2017). Due to that, they offer a method for information and requirement gathering for three perspectives, which are didactic learning perspective, didactic as well as technical development perspective on the work process and worker's actions.

3 Methodology

First, the paper illustrates important requirements in the development process of the briefly explained digital learning system (cf. Kobelt et al., in print).

Next, there are numerous methods to analyse and model work with multiple directions (e.g. Hackman & Oldham, 1975; Fleishman, 1992) and differing intentions (e.g. Kirwan & Ainsworth, 1999) in industrial engineering and work psychology. Therefore, the methods for work analysis have to complement the conception levels of the HMTL and address the opportunities that arise from it. Ergonomic taxonomies such as the ordering model for structures and processes of working persons (Luczak, 1997) help to match the focus of work analysis methods for digital media development with didactic intentions.

One work analysis method combination is finally applied in one example (out of n=5). By this, a small section of the results from practice assists to discuss strengths and weaknesses of work analysis for didactics and technical learning media development.

4 Findings

Investigating the requirements of the technical part of the learning media development shows that there is a demand for entity-relationship-models when simulating (cf. Chen, 1976; e.g., OMG, 2017) all objects in the work process. The attributes within this model describe all characteristics of materialistic and intellectual objects as well as humans involved in the work process. Furthermore, this structural information needs to be embedded in process descriptions to implement them later on in petri-nets (cf. Kobelt et al., 2020). Petri-nets (Petri, 1962) help to detect and simulate discrete events and states in the work process with its potential errors.

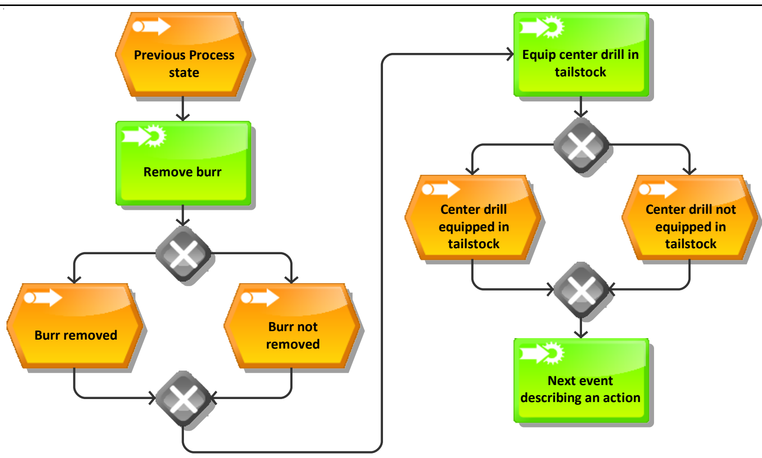
When investigating TVET learning processes of apprentices with action research scope, the focus will be on the goal-oriented and regulated action level to describe procedures of the work process. The investigated work process takes place within a structural environment that includes the level of person's functional means as well as the activity system of the person (Luczak, 1997).

Considering HMTL, the empirical work process descriptions align to the activity and experience description (see Figure 1). Moreover, the technical learning system needs to detect the activity including deviations from action goals for the purpose of external effect prediction. Empirical studies on the work process help to derive action goals and to establish a hierarchical goal structure. In contrast, didactical tasks comprise especially linking the findings with process and learning objectives in order to achieve intended outcomes from the curriculum. Hereby, the empirical action goals, work process descriptions and structural information assist to design the learning task and thereupon the learning.

As published in detail by Goppold et al. (2020a, 2020b), the chosen work analysis methods are Tätigkeits-Analyse-Inventar (TAI) (Frieling, 1993; Luczak, 1997) using structured expert interviews and work observations as well as event-driven process chains (EPC) (Keller et al., 1992) that allow transformations into Petri-nets (Langner et al., 1997). Most methods root in the German approach to humanize work and suit the didactic background of HMTL better than Anglo-American approaches, which had been developed with different guiding ideas (cf. Brannick et al., 2019). The handling of the methods during the survey in industry and central educational facilities in craft had been easily applicable with the help of a prepared instruction.

Overall, the example describes a work process in metal industry and is situated in an artisan workshop. The work task describes the production of a shaft based on a technical drawing by turning a metal workpiece with a manually controlled lathe. For this reason, Figure 2 shows a small excerpt of the EPC documentation.

Figure 2
Excerpt of the lathe process (own contribution)



Removing a burr (see Figure 3) is necessary for safety and functional reasons. This operation might go along with occupational safety aims or functional knowledge in the curriculum that the learning process should establish as an outcome. On the one hand, from a technical perspective it is interesting to get to know, what tools do workers use to remove the burr and how do they detect successful removing. The corresponding information on the used tools are part of the TAI and in this example, they include a turning tool (International Organization for Standardization, 2014) and a file together with sandpaper. On the other hand, the EPC is a description that supports the detection of current system states and information processing of relevant human actions in the technical system. Therefore, the empirical process documentation methods are both relevant for technical and didactical learning system development.

Figure 3
Removing a burr (Klatt, 2020)

5 Discussion

The results illustrate that work analysis methods offer a solid information gathering approach for learning media development as well as for curriculum design TVET. Whereas objective methods such as TAI contribute to structural system levels, the described example shows that process modelling adds the missing process level.

In the example, there had been discussions while objectifying all subjective assessments of the work results for the technical learning system, such as artisan criteria, concerning the work process progression. Additionally, all investigated work processes locate on the same procedural description level. Nevertheless, they are incomparable due to different profoundness and a differing focus on the work activities' transformation processes.

Moreover, didactical interpretations suffer from biases that derive from the survey environment, which is part of inner-firm TVET departments. All work processes already passed through a didactic conception. Therefore, they implicitly consist of underlying learning goals and methodical preparations that contradict a neutral analysis basis.

The HMTL supports the presentation of the benefit of work analysis results for the didactic conception process. Within this framework, the alignment of action goals and learning goals illustrates that the symbiosis of work process and learning. On top of that, the technical development of the learning system can utilize the design tasks for the learning process and its objectives. From a didactic point of view, it is part of a media discussion, where technology needs to follow didactic ideas. On the contrary, didactics have to adapt to technological restrictions and constraints in order to build an optimal learning system in the context of TVET work tasks.

However, it should be noted that there is a gap between information gathering and information processing in the development process. Information from the TAI place on a subordinated level and are only content of the connector constraints in the EPC. Due to that, the results are just the start for the technical development process and present only information gathering solutions. Currently, transcriptions and additional a posteriori interviews connect structural with procedural information, what might be criticized as a methodically weak solution.

6 Conclusion

The selected work analysis methods seem to reflect TVET surveys of real world work activities from a conceptual perspective. All in all, work analysis results mainly correspond to action goals in the Hamburg Model of Teaching Practice and Learning Practice as one didactic framework for the design of TVET learning processes. Reflecting competence descriptions in curricula, a work based didactic concept has to match each action goal to competences. Furthermore, work analysis methods supply relevant information for the design and development process of a technical learning system to foster learning from errors in the dual apprenticeship in German TVET.

Despite all efforts, the last paragraph introduces a new question on the missing piece in the jigsaw puzzle of work process oriented learning system development. How to integrate results of procedural and structural methods in a unified technical development framework?

In order to use the method's results appropriately in the technical development process incorporating didactic conception, there is still a desideratum in research remaining. One possible solution is to use system theoretical methods rooted in engineering design and ergonomics that offer high potential for integrated product development methods in an extended worksystem (Schlick et al., 2018; cf. Kobelt et al., in print). From a technical point of view, this seems to be the Holy Grail, but for didactics, it is a controversial and comes potentially at a price, because one has to argue against an implied interpretation that it might be part of a cybernetic didactic theory.

References

Atanasyan, A., Kobelt, D., Goppold, M., Cichon, T., & Schluse, M. (2020). The FeDiNAR project: Using augmented reality to turn mistakes into learning opportunities. In V. Geroimenko (Ed.), *Springer series on cultural computing. Augmented reality in education: A new technology for teaching and learning* (pp. 71–86). Springer.

Augsdörfer, A., & Casper, M. (2018). Closing the theory-practice gap: Employing authentic video-taped lessons in vocational teacher education. In C. Nägele & B. E. Stalder (Eds.). *Trends in vocational education and training research. Proceedings of the European Conference on Educational Research (ECER),* Vocational Education and Training Network (VETNET). https://doi.org/10.5281/zenodo.1319622

Bader, R. (2003). Lernfelder konstruieren - Lernsituationen entwickeln. *Die Berufsbildende Schule*, *55*(7-8), 210–217.

Becker, M., & Spöttl, G. (2008). *Berufswissenschaftliche Forschung: Ein Arbeitsbuch für Studium und Praxis*. *Berufliche Bildung in Forschung, Schule und Arbeitswelt: Vol. 2*. P. Lang.

Becker, M., & Spöttl, G. (2019). Berufswissenschaftliche Deckungsanalyse zur Prüfung gewerblichtechnischer Berufsbilder auf Industrie 4.0-Eignung. In M. Becker, M. Frenz, K. Jenewein, M. Schenk, M. Friese, S. Seeber, & G. Spöttl (Eds.), *Berufsbildung, Arbeit und Innovation: Vol. 53. Digitalisierung und Fachkräftesicherung: Herausforderung für die gewerblich-technischen Wissenschaften und ihre Didaktiken* (pp. 137–156). wbv Media.

Brannick, M. T., Levine, E. L., & Morgeson, F. P. (2019). *Job and work analysis: Methods, research, and applications for human resource management* (3rd ed.). SAGE Publications.

Chen, P. P.-S. (1976). The entity-relationship model—toward a unified view of data. *ACM Transactions on Database Systems, 1*(1), 9–36. https://doi.org/10.1145/320434.320440

Darabi, A., Arrington, T. L., & Sayilir, E. (2018). Learning from failure: A meta-analysis of the empirical studies. *Educational technology research and development*, *66*(5), 1101–1118. https://doi.org/10.1007/s11423-018-9579-9

Fischer, M., & Bauer, W. (2007). Competing approaches towards work process orientation in German curriculum development. *European journal of vocational training*, *40*(1), 140–157.

Fleishman, E. A. (1992). *The Fleishman-job analysis survey (F-JAS)*. Consulting Psychologist Press.

Frieling, E. (1993). *Tätigkeits-Analyse-Inventar: Theorie, Auswertung, Praxis; Handbuch und Verfahren*. ecomed.

Gessler, M., & Howe, F. (2015). From the reality of work to grounded work-based learning in German vocational education and training: Background, concept and tools. *International Journal for Research in Vocational Education and Training*, *2*(3), 214–238. https://doi.org/10.13152/IJRVET.2.3.6

Goppold, M., Nessau, H., Frenz, M., & Nitsch, V. (2020). Itemanpassung im Tätigkeitsanalyseinventar (TAI) entsprechend aktueller technologieinduzierter Forschungserkenntnisse. In Gesellschaft für Arbeitswissenschaft (Ed.), *Digitaler Wandel, digitale Arbeit, digitaler Mensch?* (A.15.3). GfA-Press.

Goppold, M., Nobis, L., Frenz, M., & Nitsch, V. (2020). Erhebung und Modellierung von Arbeitsprozessen in der metall- und elektrotechnischen Ausbildung als Basis einer didaktischen Konzeption „Lernen mit Fehlern in einer AR angereicherten Lernumgebung". In Gesellschaft für Arbeitswissenschaft (Ed.), *Digitaler Wandel, digitale Arbeit, digitaler Mensch?* (B.17.1). GfA-Press.

Hackman, J. R., & Oldham, G. R. (1975). Development of the job diagnostic survey. *Journal of Applied Psychology*, *60*(2), 159–170.

Howe, F., & Knutzen, S. (2013). *Digitale Medien in der gewerblich-technischen Berufsausbildung: Einsatzmöglichkeiten digitaler Medien in Lern- und Arbeitsaufgaben*. Bundesinstitut für Berufsbildung (BIBB).

International Organization for Standardization (2014). *Tool holders with rectangular shank for indexable inserts - Part 1: General survey, correlation and determination of dimensions* (ISO 5610-1).

Keller, G., Nüttgens, M., & Scheer, A.-W. (1992). Semantische Prozeßmodellierung auf der Grundlage "Ereignisgesteuerter Prozeßketten". *Institut Für Wirtschaftsinformatik Heft*(89).

Kirwan, B., & Ainsworth, L. (1992). Introduction. In B. Kirwan & L. Ainsworth (Eds.), *A guide to task analysis* (pp. 1–3). Taylor & Francis.

Klatt, M. (2020). *Manual removal of protruding burr of a shaft: Manuelle Entfernung des überstehenden Grats einer Welle*. RWTH Aachen University.

Kobelt, D., Goppold, M., Atanasyan, A., Herrmann, J.-P., Tackenberg, S., Frenz, M., & Gamber, T. (in print). Use-Case Studie eines auf der Nutzung von Handlungsfehlern basierenden AR-Lernsystems zur kritischen Reflexion der technischen Umsetzbarkeit. In *Gemeinschaften in neuen Medien. Erforschung der digitalen Transformation in Wissenschaft, Wirtschaft, Bildung und öffentlicher Verwaltung.* TUDpress.

Langner, P., Schneider, C., & Wehler, J. (1997). Prozeßmodellierung mit ereignisgesteuerten Prozeßketten (EPKs) und Petri-Netzen. *Wirtschaftsinformatik*(39), 479–489.

Lensjø, M. (2020). Stories of learning: A case study of Norwegian plumbers and apprentices in TVET at the construction site and in a training agency. *International Journal for Research in Vocational Education and Training*, *7*(2). https://doi.org/10.13152/IJRVET.7.2.2

Luczak, H. (1997). Task Analysis. In G. Salvendy (Ed.), *A Wiley interscience publication. Handbook of human factors and ergonomics* (2nd ed., pp. 340–416). Wiley.

Mickler, O. (2008). Qualification research. In F. Rauner & R. Maclean (Eds.), *Handbook of technical and vocational education and training research* (pp. 187–192). Springer.

Object Management Group (2017). *Unified modeling language* (Specification 2.5.1).

OECD. (2015). *OECD reviews of vocational education and training: Key messages and country summaries.*

Petri, C. A. (1962). *Kommunikation mit Automaten* [Dissertation]. Technische Hochschule Darmstadt, Darmstadt.

Pilz, M. (2016). Training patterns of German companies in India, China, Japan and the USA: What really works? *International Journal for Research in Vocational Education and Training*, *3*(2), 66–87. https://doi.org/10.13152/IJRVET.3.2.1

Schlick, C., Bruder, R., & Luczak, H. (Eds.). (2018). *Arbeitswissenschaft* (4th ed.). Springer Vieweg. https://doi.org/10.1007/978-3-662-56037-2

Spöttl, G. (2008). Expert skilled worker workshops. In F. Rauner & R. Maclean (Eds.), *Handbook of technical and vocational education and training research* (pp. 756–760). Springer.

Spöttl, G. (2008). Sector analyses. In F. Rauner & R. Maclean (Eds.), *Handbook of technical and vocational education and training research* (pp. 169–174). Springer.

Spöttl, G., & Loose, G. (2019). Conducting work-process analyses for the development of advanced detailed curricula. In A. Bahl & A. Dietzen (Eds.), *Work-based Learning as a pathway to competence-based education: A UNEVOC Network Contribution* (pp. 128–146). Barbara Budrich.

Spöttl, G., Loose, G., & Becker, M. (2020). *Work-process based development of advanced detailed curricula*. Peter Lang.

Tramm, T., & Casper, M. (2018). Lernfeldübergreifende Kompetenzdimensionen: Ein gemeinsamer Gegenstand subjektorientierter curricularer Theorie und Praxis. In Tade Tramm, Marc Casper, Tobias Schlömer, & Bundesinstitut für Berufsbildung (Eds.), *Berichte zur beruflichen Bildung. Didaktik der beruflichen Bildung -: Selbstverständnis, Zukunftsperspektiven und Innovationsschwerpunkte* (pp. 89–113). W. Bertelsmann Verlag.

Tūtlys, V., & Spöttl, G. (2017). From the analysis of work-processes to designing competence-based occupational standards and vocational curricula. *European Journal of Training and Development*, *41*(1), 50–66. https://doi.org/10.1108/EJTD-10-2015-0078

Zacher, H., & Frese, M. (2017). Action regulation theory: Foundations, current knowledge and future directions. In D. S. Ones, N. Anderson, C. Viswesvaran, & H. K. Sinangil (Eds.), *The SAGE handbook of industrial, work & organizational psychology: V2: Organizational psychology* (2nd ed., pp. 122–144). SAGE Publications.

Acknowledgement

The contribution of this article is part of the project 'FeDiNAR—Didactical Use of Errors with the Help of Augmented Reality'. It is funded by the Federal Ministry of Education and Research (BMBF) as part of the 'Digital Media in Vocational Education and Training' programme and is supported by the German Aerospace Center (DLR) under the funding code 01PV18005A.

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