From Interventions to Theories: Two Literature Analyses of Knowledge Creation in TEL Design-based Research

Luis P. Prieto[1], Hamed Alavi[2], and Himanshu Verma[3]

[1] School of Educational Sciences, Tallinn University, 10120 Tallinn (Estonia)
[2] CHILI Lab, EPFL, 1015 Lausanne (Switzerland)
[3] Human-IST Research Centre, Universtiy of Fribourg, 1700 Fribourg (Switzerland)
lprisan@tlu.ee, hamed.alavi@epfl.ch, himanshu.verma@unifr.ch

Abstract. One of the main aims of Technology-Enhanced Learning (TEL) research is to aid in the design of educational technologies that are not only effective but also can contribute to the high-level theories of our field. Albeit design patterns or guidelines are not unheard of in TEL research, there is a scarcity of intermediate-level concepts that are not as generalizable as theories, but with an applicability wider than that of a single technology or intervention. This document reports on two focused analyses of TEL literature that investigate such scarcity. The evidence from our analysis illustrates the relative shortage of such intermediate-level contributions, and suggests that the TEL community needs a way to abstract knowledge from multiple design-based research processes, in a more explicit and systematic manner.

Keywords: learning technology, design-based research, intermediary-level knowledge, literature review

1 Introduction

In order to evaluate the relative scarcity and limited variety of intermediary knowledge in TEL research, we turn to a methodological framework specifically proposed to address the problem of theory advancement while staying ecologically-valid, and which is widely used in our field [23]. Design-based research [5] (DBR) is a flexible methodological framework aimed to improve educational practices iteratively, in "collaborations among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories" [35]. DBR is considered specifically adequate for the design and development of TEL environments, due to its potential to bridge the gap between (sometimes opposing) theories and the practical usage of learning technologies [35].

In the two following below, we illustrate this point through two systematic literature reviews. In these reviews, we follow the principles outlined by Kitchenham et al. [19], albeit looking at a very concrete research question (rather than

an overview of an entire field): *what is the nature of the outputs of DBR processes in the European TEL research community?* That is, are these outputs related to the development of the particular system/proposal, or to higher-level concepts and theories, or both?

2 Direct Outputs of Design-based Research in TEL

Methodology. In order to understand the kind of contributions that come as outputs of DBR processes in the European TEL community, we have queried the proceedings volumes of all European Conferences on Technology-Enhanced Learning (EC-TEL) since the conference's beginnings in 2006 (available through SpringerLink[4]). To counter the argument that these conference articles may describe mostly preliminary work and not mature outputs, we added to our database the IEEE Transactions on Learning Technologies journal (TLT, available through IEEExplore[5]), also from its inception in 2008. This journal is not only one of the major outlets for learning technology research; many of the strongest contributions in EC-TEL are often invited to submit extended, more mature versions of their contributions to it. The query string, executed on the 1st March 2017, was (`''design based research'' OR ''design-based research''`). The queries resulted in 26 papers from the EC-TEL proceedings and seven from TLT. Out of these 33 papers, we removed those that only mentioned design-based research but were not themselves describing DBR processes. We also removed demo papers that already had more lengthy descriptions in our dataset.

The remaining 22 papers describing TEL design-based research processes, are listed in Table 1. These 22 papers were analyzed in terms of the outcomes of the DBR process (extracted mostly from the results or discussion/conclusion sections of the papers). These outcomes were then classified in terms of their scope of applicability, between those that were tied to the particular design problem/proposal (e.g., new knowledge about the validity of the proposed system features, or new features that could be added to the system in the future), and those that were higher-level (e.g., guidelines to design future technologies, not necessarily using the same technology or in the same context). It is worth noting that we considered as DBR outcomes only those *explicitly* mentioned by the authors (i.e., we did not consider implicit outcomes that the reader herself could maybe infer from reading the paper).

Results. The results of analyzing these 22 papers in the aforementioned manner are summarized in Table 1. As we can see there, the outputs from most of the 22 DBR processes analyzed are limited to context-bound new knowledge, such as the validation and future improvement of the proposed technology being used in the particular contexts (14 papers, 64% of them). Even in the cases where some kind of higher-level proposal of knowledge is attempted, this often takes

[4] https://link.springer.com/
[5] http://ieeexplore.ieee.org

Table 1. Outputs of DBR papers reviewed, from EC-TEL (top) and TLT (bottom)

Publication	Ref	System / Proposal	Contextualized Outcomes	Higher-level Outcomes
Aristeidou et al., 2014	[2]	Rock Hunters (nQuire)	Validate/New system features	–
Bhatnagar et al., 2016	[3]	DALITE	System proposal	–
Börner et al., 2013	[6]	SURFnet (multi-tool)	Next pilot ideas	Design guidelines
Harrer et al., 2013	[12]	Planning Tool (Metafora)	Validate system features	–
Hernández-Leo et al., 2013	[13]	ILDE	Validate system features	–
Hernández-Leo et al., 2013b	[14]	SOS	Validate/New system features	–
Jermann et al., 2008	[16]	Tinkerlamp	Validate/New system features	–
Kambouri et al., 2006	[17]	–	Correlation factors-learning	Strategies for practice
Kennedy-Clark, 2009	[18]	Virtual Singapura	None (position paper)	–
Lejeune et al., 2016	[20]	FORMID	Validate/New system features	–
Luccioni et al., 2016	[21]	STI-DICO	Validate/New system features	–
Oubahssi et al., 2015	[25]	–	Process for practice/implementation	–
Rick et al., 2012	[27]	Proportion	None (position paper)	–
Sánchez et al., 2016	[29]	PMS	System proposal	–
Schneider et al., 2015	[30]	Presentation Trainer	Validate/New system features	Design guidelines
Sporer et al., 2010	[32]	e3-Portfolio	Validate/New system features	–
Suárez et al., 2016	[34]	DojoIBL	Validate/New system features	Some important concepts
Boticki et al., 2013	[4]	Learning Fractions / Chinese-PP	Validate/New system features	Some important concepts; (Multi-context) system architecture
Charlton et al., 2016	[8]	PELARS (multi-tool)	Validate/New system features; Learning indicators	Some important concepts
Dragon et al., 2013	[10]	Metafora (multi-tool)	–	Lessons learned; Pedagogical model
Marenzi et al., 2012	[22]	LearnWeb 2.0	Validate/New system features	Conceptual design *(initial, not outcome)*
Mulholland et al., 2012	[24]	nQuire	Validate system features	–

the form of (rather vaguely-defined) "important concepts" or "lessons learned". Notable exceptions to this overall trend include the proposal of technology design guidelines [6, 30], the use of a DBR to refine a pedagogical model (in [10]), or the proposal of a generic system architecture after validation in two different subject content areas [4]. Furthermore, in none of the analyzed cases there is an explicit attempt to connect these potential intermediate-level pieces of knowledge with existing general theories of learning. Rather, most higher-level knowledge derived is aimed at later use by designers in practice, with no claim about how or to what extent there is evidence that the application of these pieces of newfound knowledge will enhance learning.

3 Indirect Outputs of Design-based Research in TEL

To counter the picture drawn by the previous literature review, one may argue that such intermediate-level knowledge does not need to be the *direct* output of a DBR process. Rather, the same or different researchers may come afterwards and take the evidence from these documented processes (ideally, from multiple of them), and derive more abstract and general knowledge that is not tied to a single design instance, and is more clearly connected with general theories, maybe even making claims about how this new knowledge can enhance learning. In order to explore whether this is actually happening within the TEL community, we have performed another focused literature review, based on the results of the previous one. More concretely, we searched for the published research works that extracted understandings from *multiple* EC-TEL DBR works.

Methodology. A Zotero database was created to collect all the scientific articles that cited (as indexed by Google Scholar in March 2017) any of the 22 DBR papers analyzed in section 2 (see Table 1). We queried this database, looking for the papers that cite *more than one* of those 22 papers, and then tried to find out whether their contributions extend beyond their studied learning situation or the designed intervention (i.e., a similar analysis to that of the previous section).

Results. Out of 204 papers that cited the aforementioned 22 DBR publications, only six cite more than one of them (see Table 2). Out of those six, one had only outputs at the level of the design instance [9]. The other five provided some kind of intermediate-level knowledge. Again, we see loosely-defined design guidelines or lessons learned as the most common output of these DBR processes [1, 11, 7]. In the other two cases, literature reviews [28, 31], some kind of meta-knowledge about their concerned sub-field is provided. Shawky et al. [31] review computer-supported collaborative learning technologies and their affordances, detecting gaps and future research directions (e.g., kinds of affordances that were under-represented in the literature). Said et al. [28], investigated the connections between the design of CSCL platforms and the (theoretical) model of Knowledge-Building (KB) – as developed by Stahl et al. [33]. Interestingly, these authors report a disconnect between CSCL tools intended to support KB and the high-level theoretical works on KB (similar to our argument in this paper).

Table 2. Papers that cite more than one of the 22 DBR papers in section 2

Publication	Ref	System / Proposal	Contextualized outcomes	Higher-level outcomes
Aristeidou, 2016	[1]	nQuire, nQuire-it	Validate/New system features	Design guidelines
Do-Lehn et al., 2012	[9]	TinkerLamp2.0	Validate/New system features	–
Dragon, 2013	[11]	Rashi (Intelligent Tutoring System)	Validate/New system features	Lessons learned
Cai et al., 2016	[7]	Metafora (semantic diagram tool)	Validate/New system features	Guidelines/Lessons learned
Shawky et al., 2014	[31]	CSCL affordances	–	Meta-knowledge (gaps & directions)
Said et al., 2015	[28]	Knowledge-Building(KB)	–	Meta-knowledge (design/theory gap)

Despite their clear limitations in terms of depth and scope, these two focused literature reviews illustrate a gap in current TEL research. As TEL researchers, we are adopting design-oriented methodologies like DBR, taking advantage of their flexibility and their ability to transfer more easily into contextualized practice/usage. We are successfully using this framework to improve our proposals and (less often) to derive some explicit knowledge that can help fellow designers. However, we are currently failing in connecting our results to more abstract theories of learning and to other DBR efforts, to provide evidence that this new knowledge has been demonstrated in a range of situations and design problems, with evident benefits for the learning experience. We lack a clearer path to go from our contextualized design experiments to the larger theories of our domain.

4 Conclusion

The two literature analyses presented above illustrate the lack of variety in the intermediate-level knowledge that TEL design-based research efforts are generating. To ameliorate this problem, in a parallel publication, we propose the notion of 'strong TEL concepts' as a valid and needed form of intermediary knowledge in TEL [26]: "these concepts are both grounded in research evidence about learning benefits from *multiple* design instances or contexts, and should have clear theoretical implications." In addition, a practical method for developing these concepts is proposed there (based on the one described by Höök and Löwgren [15]), along with an example to seed such discussion within the TEL research community.

Acknowledgements

The research presented here has been partially supported by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 669074.

References

1. Aristeidou, M.: Citizen Inquiry: Engaging Citizens in Online Communities of Scientific Inquiries. Ph.D. thesis, Institute of Educational Technology (2016)
2. Aristeidou, M., Scanlon, E., Sharples, M.: Inquiring rock hunters. In: Open Learning and Teaching in Educational Communities, pp. 546–547. Springer (2014)
3. Bhatnagar, S., Lasry, N., Desmarais, M., Charles, E.: DALITE: Asynchronous peer instruction for MOOCs. In: Adaptive and Adaptable Learning, pp. 505–508. Springer (2016)
4. Boticki, I., Wong, L.H., Looi, C.K.: Designing technology for content-independent collaborative mobile learning. IEEE Transactions on Learning Technologies 6(1), 14–24 (2013)
5. Brown, A.L.: Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. The journal of the learning sciences 2(2), 141–178 (1992)
6. Brner, D., Kalz, M., Ternier, S., Specht, M.: Pervasive interventions to increase pro-environmental awareness, consciousness, and learning at the workplace. In: Lecture Notes in Computer Science, pp. 57–70. Springer (2013)
7. Cai, H., Lin, L., Gu, X.: Using a semantic diagram to structure a collaborative problem solving process in the classroom. Educational technology research & development 64(6), 1207–1225 (2016)
8. Charlton, P., Avramides, K.: Knowledge construction in computer science and engineering when learning through making. IEEE Transactions on Learning Technologies 9(4), 379–390 (2016)
9. Do-Lenh, S., Jermann, P., Legge, A., Zufferey, G., Dillenbourg, P.: TinkerLamp 2.0: designing and evaluating orchestration technologies for the classroom. In: European Conference on Technology Enhanced Learning. pp. 65–78. Springer (2012)
10. Dragon, T., Mavrikis, M., McLaren, B.M., Harrer, A., Kynigos, C., Wegerif, R., Yang, Y.: Metafora: A web-based platform for learning to learn together in science and mathematics. IEEE Transactions on Learning Technologies 6(3), 197–207 (2013)
11. Dragon, T.: The Impact of Integrated Coaching and Collaboration within an Inquiry Learning Environment. ERIC (2013), http://eric.ed.gov/?id=ED558872
12. Harrer, A., Pfahler, K., de Groot, R., Abdu, R.: Research on collaborative planning and reflection – methods and tools in the metafora project. In: Lecture Notes in Computer Science, pp. 139–150. Springer (2013)
13. Hernández-Leo, D., Chacón, J., Prieto, L.P., Asensio-Pérez, J.I., Derntl, M.: Towards an integrated learning design environment. In: Lecture Notes in Computer Science, pp. 448–453. Springer (2013)
14. Hernández-Leo, D., Nieves, R., Carrascal, J.P., Blat, J.: Signal orchestration system for face-to-face collaborative learning flows. In: Lecture Notes in Computer Science, pp. 560–564. Springer (2013)

15. Höök, K., Löwgren, J.: Strong concepts: Intermediate-level knowledge in interaction design research. ACM Transactions on Computer-Human Interaction (TOCHI) 19(3), 23 (2012)
16. Jermann, P., Zufferey, G., Dillenbourg, P.: Tinkering or sketching: Apprentices' use of tangibles and drawings to solve design problems. In: Times of Convergence. Technologies Across Learning Contexts, pp. 167–178. Springer (2008)
17. Kambouri, M., Mellar, H., Logan, K.: Adult learners and ICT: An intervention study in the UK. In: Innovative Approaches for Learning and Knowledge Sharing, pp. 213–226. Springer (2006)
18. Kennedy-Clark, S.: Designing failure to encourage success: Productive failure in a multi-user virtual environment to solve complex problems. In: Lecture Notes in Computer Science, pp. 609–614. Springer (2009)
19. Kitchenham, B., Brereton, O.P., Budgen, D., Turner, M., Bailey, J., Linkman, S.: Systematic literature reviews in software engineering–a systematic literature review. Information and software technology 51(1), 7–15 (2009)
20. Lejeune, A., Guéraud, V., Mandran, N.: Improving usage of learning designs by teachers: A set of concepts for well-defined problem resolution. In: Adaptive and Adaptable Learning, pp. 404–409. Springer (2016)
21. Luccioni, A., Bourdeau, J., Massardi, J., Nkambou, R.: STI-DICO: A web-based ITS for fostering dictionary skills and knowledge. In: Adaptive and Adaptable Learning, pp. 416–421. Springer (2016)
22. Marenzi, I., Zerr, S.: Multiliteracies and active learning in clil – the development of learnweb2.0. IEEE Transactions on Learning Technologies 5(4), 336–348 (2012)
23. Meyer, P., Kelle, S., Ullmann, T.D., Scott, P., Wild, F.: Interdisciplinary cohesion of tel–an account of multiple perspectives. In: European Conference on Technology Enhanced Learning. pp. 219–232. Springer (2013)
24. Mulholland, P., Anastopoulou, S., Collins, T., Feisst, M., Gaved, M., Kerawalla, L., Paxton, M., Scanlon, E., Sharples, M., Wright, M.: nquire: Technological support for personal inquiry learning. IEEE Transactions on Learning Technologies 5(2), 157–169 (2012)
25. Oubahssi, L., Piau-Toffolon, C., Clayer, J.P., Mawas, N.E.: Design and operationalization of learning situations based on patterns for a public in professional development. In: Open Learning and Teaching in Educational Communities, pp. 580–581. Springer (2014)
26. Prieto, L.P., Alavi, H., Verma, H.: Strong technology-enhanced learning concepts. Accepted at the 12th European Conference on Technology Enhanced Learning (EC-TEL 2017)
27. Rick, J., Bejan, A., Roche, C., Weinberger, A.: Proportion: Learning proportional reasoning together. In: Lecture Notes in Computer Science. Springer (2012)
28. Said, T., Shawky, D., Badawi, A.: Identifying knowledge-building phases in computer-supported collaborative learning: A review. In: Interactive Collaborative Learning (ICL), 2015 International Conference on. pp. 608–614. IEEE (2015)
29. Sanchez, E., Piau-Toffolon, C., Oubahssi, L., Serna, A., Marfisi-Schottman, I., Loup, G., George, S.: Toward a play management system for play-based learning. In: Adaptive and Adaptable Learning, pp. 484–489. Springer (2016)
30. Schneider, J., Brner, D., van Rosmalen, P., Specht, M.: Stand tall and raise your voice! a study on the presentation trainer. In: Design for Teaching and Learning in a Networked World, pp. 311–324. Springer (2015)
31. Shawky, D., Said, T., Badawi, A., Hozayin, R.: Affordances of Computer-Supported Collaborative Learning Platforms

32. Sporer, T., Steinle, M., Metscher, J.: Evaluation of the software "e3-portfolio" in the context of the study program "problem-solving competencies". In: Sustaining TEL: From Innovation to Learning and Practice, pp. 584–589. Springer (2010)
33. Stahl, G.: A model of collaborative knowledge-building. In: Fourth international conference of the learning sciences. vol. 10, pp. 70–77. Mahwah, NJ: Erlbaum, 2000a (2000)
34. Suárez, Á., Ternier, S., Prinsen, F., Specht, M.: Nurturing communities of inquiry: A formative study of the DojoIBL platform. In: Adaptive and Adaptable Learning, pp. 292–305. Springer (2016)
35. Wang, F., Hannafin, M.J.: Design-based research and technology-enhanced learning environments. Educational technology research & development 53(4), 5–23 (2005)