ASCILITE 2021
Back to the Future

Supporting teaching staff through data analytics: A systematic review

Dirk Ifenthaler, Jane Yin-Kim Yau
University of Mannheim, Curtin University

Higher education institutions and its stakeholders are just about to catch up with the rapid pace at which educational data are being generated. While recent learning analytics research and applications are mainly focused on learning, there is an increased awareness that data analytics may provide teaching staff with evidence-based insights for enhancing teaching processes. The aim of this systematic review is to gain a deeper understanding on how data analytics in the educational context may play a role in helping teaching staff to leverage their own teaching A total of $N = 18{,}723$ articles were located and screened resulting in a final sample $N = 35$ key publications. Findings indicate that empowering teachers with data from educational contexts may support pre-active, interactive, and post-active reflection phases of teaching. However, teaching staff are required to further develop their educational data literacy in order to avoid biased pedagogical decision-making.

Keywords: data analytics; higher education; teaching analytics; learning analytics

Introduction

Since Skinner's (1954) distinction between the science of learning and the art of teaching, there has been a significant growth of theories, concepts and empirical evidence focussing on teaching practices in higher education (Tight, 2018). Dimensions for successful teaching and their potential relationship for supporting learning processes and outcomes have been identified (Shulman, 1986). More recently, additional dimensions for successful teaching with a specific focus on educational technologies have been introduced (Mishra & Koehler, 2006). Still, the teacher's way of designing learning environments and acting in teaching processes largely remains a result of his or her disposition (Peterson, 2016).

Advances in data analytics play a vital role in change processes of higher education institutions and are set to boost the transformation of the educational sector (Bates et al., 2020). Nevertheless, higher education institutions and its stakeholders are just about to catch up with the rapid pace at which educational data are being generated and the extent to which the potentials of data analytics can be used effectively (Buckingham Shum & McKay, 2018). Recent empirical research demonstrated the potential of learning analytics for supporting learning processes, related interventions and increasing study success (Larrabee Sønderlund et al., 2018). The main drivers of utilising learning analytics for higher education institutions include (a) understanding students' learning and motivation, thus reducing dropout rates (or inactivity) (Glick et al., 2019) and (b) supporting the student's learning process by providing adaptive learning pathways toward specific goals (Gašević et al., 2015).

While initial learning analytics research and applications mainly focused on enhancing learner's retention or engagement (Gašević et al., 2019), there is an increased awareness that analytics in the context of education may also provide teaching staff with evidence-based insights for enhancing teaching processes. However, Ndukwe and Daniel (2020) claim that research in data analytics for supporting teachers appears to be sporadic and underdeveloped. Therefore, the aim of this research is to gain a deeper understanding on how data analytics in the educational context may play a role in helping teaching staff to leverage their own teaching. The guiding research question is therefore: *Can data analytics support teaching staff to make evidence-based pedagogical decisions?*

Background

Teaching staff in higher education are required to utilise pedagogical means to guide and support learning processes of learners. Moreover, Calderhead (1996) refers to the complexity of teaching as it includes 'pre-active', 'interactive' and 'post-active reflection' phases. The pre-active phase comprises the curriculum

development and learning design of learning environments, the interactive phase refers to teaching activities (in classroom or online) and the post-active phase includes the critical evaluation of learning processes and outcomes as well as related experiences. Hence, teaching is regarded as a dynamic pedagogical activity which should be planned, adjusted and (self-)reflected with regard to the context of the individual learner and the context in which learning takes place (Hativa & Goodyear, 2002). However, evidence for helping teachers to plan, reflect on and improve their own teaching are often limited (Prieto et al., 2020).

Data analytics in the context of higher education draw on an eclectic set of methodologies and data to provide summative, real-time and predictive insights for supporting learning, teaching, organisational efficiency and decision-making. Hence, the field of learning analytics is receiving a lot of attention for its capacity to provide lead indicators related to learning processes and learning outcomes (Ifenthaler & Yau, 2020). For instance, Wong (2017) presents several case studies utilising learning analytics for (a) improving student retention, (b) supporting informed decision making, (c) increasing cost-effectiveness, (d) helping to understand learning behaviour, (e) providing personalised assistance, and (f) delivering feedback and interventions. More recently, the field of learning analytics established conceptual variations, including school analytics (Sergis & Sampson, 2016), academic analytics (Long & Siemens, 2011), assessment analytics (Nouira et al., 2019), social learning analytics (Gašević et al., 2019), multimodal learning analytics (Blikstein & Worsley, 2016), and teacher or teaching analytics (Sergis & Sampson, 2017).

However, the relevance of data analytics for teaching staff is less conceptually developed and lacks a rigorous understanding of teaching staffs' expectations of analytics services (Kollom et al., 2021). Accordingly, teaching analytics refers to the tools and methods utilised by teaching staff to help analyse, reflect on, and improve their learning and curriculum design (Sergis & Sampson, 2017). Teaching analytics provides teachers access to rich insights about (a) the context of teaching, (b) the development of curricula and the design of learning environments, (c) the impact of teaching on learning processes and outcomes, as well as (d) their own teaching practice. Accordingly, data analytics may provide benefits for the pre-active, interactive and post-active reflection phases of teaching. This assumption is in line with the teaching outcome model (data collection, data analysis, data visualisation, data action) which is expected to enable teachers to use data to inform their teaching practice (Ndukwe & Daniel, 2020). Therefore, the purpose of this systematic literature review was to identify empirical evidence demonstrating how data analytics have been successful in facilitating the different phases of teaching.

Method

The systematic review was conducted from May to June 2021. We followed Okoli's (2015) eight steps in the preparation of this systematic review. The inclusion criteria for the articles to be included were defined as follows: (a) were situated in the higher education context, (b) were published between January 2013 and May 2021 (2013 marks the rise of LA research publications), (c) were published in the English language, (d) had an abstract available, (e) presented either qualitative or quantitative analyses and findings, and (f) were peer-reviewed. The search criteria included a combination of search terms with "*learning analytics*" in connection with "*teaching*", "*curriculum development*", "*learning* or *instructional design*" and "*academic design*" in titles, keywords, abstracts, and full texts. The *literature search* strictly followed the pre-defined research protocol:

- The identification of international databases: GoogleScholar, ACM Digital Library, Web of Science, Science Direct, ERIC, and DBLP;
- Specific search in relevant scientific peer-reviewed journals including *Computers & Education, British Journal of Educational Technology, The International Review of Research in Open and Distributed Learning, The Internet and Higher Education, Journal of Educational Technology & Society, Journal of Computer Assisted Learning, Education and Information Technologies, Educational Technology Research and Development, Language Learning & Technology, Interactive Learning Environments, TechTrends, The Turkish Online Journal of Educational Technology, Learning@Scale, Learning, Media and Technology, International Journal of Artificial Intelligence in Education Computer Assisted Language Learning, IEEE Transactions on Learning Technologies International Conference on Technological Ecosystems for Enhancing Multiculturality, Australasian Journal of Educational Technology, Journal of Learning Analytics, Computers in Human Behavior, and Technology, Knowledge.*

A total of $N = 18{,}723$ articles were located and screened. A final set of $N = 50$ publications were identified and analysed in detail to ensure their quality and relevance. The full text analysis of the remaining publications focused on the theoretical rigor of the key concepts (i.e., learning analytics, teaching related focus), substantiality of sampling technique and methodological procedure, and the empirical evidence presented.

Hence, the final sample included $N = 35$ key publications for this systematic review.

Results

Summary of the Key Publications

A full list of classifications of the key publications including references and related data is available from the authors, however, cannot be included in this concise paper due to limited space available. The 35 key publications included in this systematic review were conducted in the USA (*n*=5), Australia (*n*=5), Singapore (*n*=3), Taiwan (*n*=2), Netherlands (*n*=2), Hong Kong (*n*=2), Japan (*n*=2), Brazil (*n*=1), Philippines (*n*=1), Bulgaria (*n*=1), Morocco (*n*=1), Spain (*n*=1), Saudi Arabia (*n*=1), South Africa (*n*=1), Ecuador (*n*=1), Switzerland (*n*=1), Estonia (*n*=1), Finland (*n*=1), Greece (*n*=1), Austria (*n*=1) and Canada (*n*=1). The year of publications and their corresponding number of key studies are as follows (in ascending order): 2013 (1), 2014 (6), 2015 (7), 2016 (1), 2017 (7), 2018 (6), 2019 (7), 2020 (0), 2021 (0).

Leveraging Teaching through Data Analytics

We categorised the findings of the key publications in terms of their perspective being related to the pre-active, interactive, and post-active reflection phases of teaching. Evidence directly impacting the teaching activities include, 1) to determine if the suggested interventions help the teaching staff to enhance students' learning activities and investigate if the use of a dashboard help inform effectively their subsequent teaching steps; 2) to discover new aspects that affect students' learning outcomes and inform/improve current/future teaching practice; 3) to identify potential problems in their students' learning as well as to incorporate improvements to the teaching process; 4) to propose a measurable set of indicators which help teachers to be more reflective in their teaching practice; 5) to utilise teachers' discussion strategies to make learner interactions, engagement and performance deeper and more meaningful; 6) to use assessment data for needs analyses and to improve data representation; and 7) to assist teachers and leverage data to author criteria for improving different teaching and learning cases. Further evidence focussing on the curriculum development and learning design include, 8) to provide insights to curriculum review including assessment of subject grades, student satisfaction and cohort comparisons as well as strategic curriculum decision-making, design, analysis and evaluation and recommendation; 9) to investigate online curricula mapping as a form of analytics for collecting learning and curricular design data; 10) to provide curriculum committees with analytics-based evidence to determine whether curricula should be modified; 11) to generate the competency scores for the entire curriculum across cognitive and progression levels in order to analyse degree programs. A final set of studies included, 12) to analyse the qualitative feedback from students to guide learning design practices and curriculum development; and 13) to help teachers reflect on their teaching design and teaching practices in relation to requirements of the curriculum.

In summary, the findings of the key publications provide evidence of data analytics related to teaching processes, such as i) teachers are successfully supported to accurately analyse learning designs and receive meaningful insights to improve and personalise students' learning experiences (Sergis et al., 2019); ii) teachers were able to keep track on activity and progress of their students, and adhere to the learning schedule as well as quickly identify at-risk students (Gaftandzhieva et al., 2019); iii) teachers could ensure that learner's motivation is maintained throughout their learning task, which was particularly important for learning achievement (Hernández-Lara et al., 2019); iv) teachers gained an increased understanding of students' learning behaviour and how the pedagogical structure of their courses should be changed to adapt to the students better (Corrin et al., 2015); and v) to understand the strengths and weaknesses of the curriculum and therefore aided improvements to the curriculum redesign (Gottipati & Shankararaman, 2018).

Discussion and Conclusion

A number of benefits arising from data analytics in the context of education include the identification of at-risk students (Lawson et al., 2016), the possibility of constructing adaptive support of students' learning journeys (Larrabee Sønderlund et al., 2018) or providing students with additional support for coping with academic requirements and expectations (Ifenthaler & Yau, 2020). Data analytics algorithms and methods can also be used in helping teaching staff to understand, reflect and improve teaching processes and related learning designs (Ndukwe & Daniel, 2020). The key publications of this systematic review highlight that teachers may benefit from data visualisations and dashboards specifically designed for teachers and teaching processes (Corrin et al., 2015). Such visualisations help to effectively reveal patterns and trends of learning processes and related phenomena of the learning context. Informative teacher dashboards help to identify groups of students that

might need help or require immediate feedback. Other tools implemented in dashboards assist teachers in imitating collaborative learning processes. Hence, data analytics on learning processes and learning outcomes, which may be available in real-time or when needed, support teaching staff in pedagogical decision-making (Gaftandzhieva et al., 2019) and help to critically reflect and improve their teaching process (Prieto et al., 2020). As a result, teaching processes are likely to transform from being driven by individual dispositions or beliefs (Peterson, 2016) toward evidence-based pre-active, interactive and post-active reflection phases of teaching.

However, empowering teachers with data from educational contexts does not only include benefits. The incomplete nature, fragmentation and interaction of data being available for analytics and their contextual idiosyncrasies requires caution to avoid biased pedagogical decision-making. Thus, data analytics for supporting teaching staff has its obvious limitations and data collected from various educational sources can have multiple meanings. Further, ethical and privacy issues are associated with the use of data from educational context, that implies how personal data is collected and stored as well as how it is analysed and presented to different stakeholders (Slade & Prinsloo, 2013). Accordingly, as advances in data analytics related to teaching practice have been documented in this systematic review, teaching staff are required to further develop their educational data literacy (Papamitsiou et al., 2021), which is the ethically responsible collection, management, analysis, comprehension, interpretation, and application of data from educational contexts.

References

Bates, T., Cobo, C., Mariño, O., & Wheeler, S. (2020). Can artificial intelligence transform higher education? *International Journal of Educational Technology in Higher Education*, *17*(42), 1–12. https://doi.org/10.1186/s41239-020-00218-x

Blikstein, P., & Worsley, M. (2016). Multimodal learning analytics and education data mining: Using computational technologies to measure complex learning tasks. *Journal of Learning Analytics*, *3*(2), 220–238. https://doi.org/10.18608/jla.2016.32.11

Buckingham Shum, S., & McKay, T. A. (2018). Architecting for learning analytics. Innovating for sustainable impact. *EDUCAUSE Review*, *53*(2), 25–37.

Calderhead, J. (1996). Teachers: Beliefs and knowledge. In D. Berliner & R. Calfee (Eds.), *Handbook of educational psychology* (pp. 709–725). MacMillan.

Corrin, L., Kennedy, G., Barba, P. D., Bakharia, A., Lockyer, L., Gasevic, D., Williams, D., Dawson, S., & Copeland, S. (2015). *Loop: A learning analytics tool to provide teachers with useful data visualisations* ascilite Conference, Perth, WA, Australia.

Gaftandzhieva, S., Doneva, R., & Pashev, G. (2019). Learning analytics from the teacher's perspective: A mobile app. In *13th International Technology, Education and Development Conference*. Valencia, Spain.

Gašević, D., Dawson, S., & Siemens, G. (2015). Let's not forget: Learning analytics are about learning. *TechTrends*, *59*(1), 64–71. https://doi.org/10.1007/s11528-014-0822-x

Gašević, D., Joksimović, S., Eagan, B. R., & Shaffer, D. W. (2019). SENS: Network analytics to combine social and cognitive perspectives of collaborative learning. *Computers in Human Behavior*, *92*, 562–577. https://doi.org/10.1016/j.chb.2018.07.003

Glick, D., Cohen, A., Festinger, E., Xu, D., Li, Q., & Warschauer, M. (2019). Predicting success, preventing failure. In D. Ifenthaler, D.-K. Mah, & J. Y.-K. Yau (Eds.), *Utilizing learning analytics to support study success* (pp. 249–273). Springer. https://doi.org/10.1007/978-3-319-64792-0_14

Gottipati, S., & Shankararaman, V. (2018). Competency analytics tool: analyzing curriculum using course competencies. *Education and Information Technologies*, *23*, 41–60. https://doi.org/10.1007/s10639-017-9584-3

Hativa, N., & Goodyear, P. (Eds.). (2002). *Teacher thinking, beliefs and knowledge in higher education*. Kluwer Academic Publishers. https://doi.org/10.1007/978-94-010-0593-7.

Hernández-Lara, A. B., Perera-Lluna, A., & Serradell-López, E. (2019). Applying learning analytics to students' interaction in business simulation games. The usefulness of learning analytics to know what students really learn. *Computers in Human Behavior*, *92*, 600–612. https://doi.org/10.1016/j.chb.2018.03.001

Ifenthaler, D., & Yau, J. Y.-K. (2020). Utilising learning analytics to support study success in higher education: a systematic review. *Educational Technology Research and Development*, *68*(4), 1961–1990. https://doi.org/10.1007/s11423-020-09788-z

Kollom, K., Tammets, K., Scheffel, M., Tsai, Y.-S., Jivet, I., Muñoz-Merino, P. J., Moreno-Marcos, P. M., Whitelock-Wainwright, A., Calleja, A. R., Gasevic, D., Kloos, C. D., Drachsler, H., & Ley, T. (2021). A four-country cross-case analysis of academic staff expectations about learning analytics in higher education. *The Internet and Higher Education*, *49*, 100788. https://doi.org/10.1016/j.iheduc.2020.100788

Larrabee Sønderlund, A., Hughes, E., & Smith, J. (2018). The efficacy of learning analytics interventions in higher education: A systematic review. *British Journal of Educational Technology*, *50*(5), 2594–2618. https://doi.org/10.1111/bjet.12720

Lawson, C., Beer, C., Rossi, D., Moore, T., & Fleming, J. (2016). Identification of 'at risk' students using learning analytics: the ethical dilemmas of intervention strategies in a higher education institution. *Educational Technology Research and Development*, *64*(5), 957–968. https://doi.org/10.1007/s11423-016-9459-0

Long, P. D., & Siemens, G. (2011). Penetrating the fog: Analytics in learning and education. *EDUCAUSE Review*, *46*(5), 31–40.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017–1054.

Ndukwe, I. G., & Daniel, B. K. (2020). Teaching analytics, value and tools for teacher data literacy: a systematic and tripartite approach. *International Journal of Educational Technology in Higher Education*, *17*, 22. https://doi.org/10.1186/s41239-020-00201-6

Nouira, A., Cheniti-Belcadhi, L., & Braham, R. (2019). An ontology-based framework of assessment analytics for massive learning. *Computer Applications in Engineering Education*. https://doi.org/10.1002/cae.22155

Okoli, C. (2015). A guide to conducting a standalone systematic literature review. *Communications of the Association for Information Systems Research*, *37*(43), 879–910. https://doi.org/10.17705/1CAIS.03743

Papamitsiou, Z., Filippakis, M., Poulou, M., Sampson, D. G., Ifenthaler, D., & Giannakos, M. (2021). Towards an educational data literacy framework: enhancing the profiles of instructional designers and e-tutors of online and blended courses with new competences. *Smart Learning Environments*, *8*, 18. https://doi.org/10.1186/s40561-021-00163-w

Peterson, B. R. (2016). The development of a disposition for reflective practice. In A. G. Welch & S. Areepattamannil (Eds.), *Dispositions in teacher education* (pp. 3–30). Sense Publishers. https://doi.org/10.1007/978-94-6300-552-4_1

Prieto, L. P., Magnuson, P., Dillenbourg, P., & Saar, M. (2020). Reflection for action: designing tools to support teacher reflection on everyday evidence. *Technology, Pedagogy and Education*, *29*(3), 279–295. https://doi.org/10.1080/1475939X.2020.1762721

Sergis, S., Sampson, D., Rodriguez-Triana, M., Gillet, D., Pellicione, L., & de Jong, T. (2019). Using educational data from teaching and learning to inform teachers' reflective educational design in inquiry-based STEM education. *Computers in Human Behavior*, *92*, 724–738. https://doi.org/10.1016/j.chb.2017.12.014

Sergis, S., & Sampson, D. G. (2016). School analytics: a framework for supporting school complexity leadership. In J. M. Spector, D. Ifenthaler, D. G. Sampson, & P. Isaias (Eds.), *Competencies in teaching, learning and educational leadership in the digital age* (pp. 79–122). Springer. https://doi.org/10.1007/978-3-319-30295-9_6

Sergis, S., & Sampson, D. G. (2017). Teaching and learning analytics to support teacher inquiry: a systematic literature review. In A. Peña-Ayala (Ed.), *Learning analytics: fundaments, applications, and trends* (pp. 25–63). Springer. https://doi.org/10.1007/978-3-319-52977-6_2

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14. https://doi.org/10.3102/0013189X015002004

Skinner, B. F. (1954). The science of learning and the art of teaching. *Harvard Educational Review*, *24*, 86–97.

Slade, S., & Prinsloo, P. (2013). Learning analytics: Ethical issues and dilemmas. *American Behavioral Scientist*, *57*(10), 1510–1529. https://doi.org/10.1177/0002764213479366

Tight, M. (2018). Systematic reviews and meta-analyses of higher education research. *European Journal of Higher Education*, *9*(2), 133–152. https://doi.org/10.1080/21568235.2018.1541752

Wong, B. T. M. (2017). Learning analytics in higher education: an analysis of case studies. *Asian Association of Open Universities Journal*, *12*(1), 21–40. https://doi.org/10.1108/AAOUJ-01-2017-0009

Ifenthaler, D., & Yau, J. (2021). Supporting teaching staff through data Analytics: A systematic review. In Gregory, S., Warburton, S., & Schier, M. (Eds.), *Back to the Future – ASCILITE '21. Proceedings ASCILITE 2021 in Armidale* (pp. 37–41). https://doi.org/10.14742/ascilite2021.0105