# Considering the credibility of technology education research: A discussion on empirical insights and possible next steps

Jeffrey Buckley, Technological University of the Shannon
Jeffrey.buckley@tus.ie

## ABSTRACT

Technology education is a maturing research field. If studies are conducted which lead to suggestions for practice – which many are – as such changes can impact a substantial number of learners and require significant resources, it is essential that the underpinning results are credible. Therefore, much like there are standards for educational practice, standards in research are equally as important. Such standards help ensure that findings are valid and trustworthy.

There are several dimensions to research credibility, such as replicability, reproducibility, the clear presentation of research questions and/or hypotheses, and reporting transparency, and it is important that the credibility of technology education research is considered for several reasons. In addition to ensuring sufficient empirical support for recommendations for practice, credibility is important to ensure trust in findings from both researchers and the wider community of stakeholders. It is also important for new studies which build upon prior work, that the evidential strength of the prior work is clearly understood.

Over the past two years, several studies have been conducted to examine current levels of credibility dimensions, specifically replicability and transparency, in technology education research. In this paper, the results of these will be briefly summarised with a view towards suggesting general areas for improvement and in providing practical ways in which to do so. More importantly, through this paper a broader discussion can be started around what standards should be considered for technology education research across different dimensions of credibility. Finally, other ways in which research credibility can be examined will be considered with a view towards gaining an understanding of what the technology education research community consider as more or less important within this research agenda.

*Key Words: Research credibility, Trustworthiness, Research standards, Replicability, Transparency.*

## 1. INTRODUCTION

As a research field technology education is relatively young, at least in comparison to its science, technology, engineering, and mathematics (STEM) counterparts. There are several indicators of the emergence of a field of study, such as the establishment of higher education programmes, academic conferences, and academic journals. Taking the first publication[1] of a field specific academic journal with a research dissemination aim as a proxy indicator due to the accessibility of information, the *Journal of Technology Education* was first published in 1989 and represents the first journal with a function dedicated solely to technology education. This was closely followed by the first issue of the *International Journal of Technology and Design Education* in 1990, which together would indicate that technology education as a research field is now just over 30 years old. That said, the earliest related academic journal with a field related remit was *Research in Science and Technological Education* in 1983, meaning technology education research is now 40 years old by this measure. This journal however notably includes a dedicated aim of publishing science education research as well, and while there are technology education research articles published within its initial issues, they are sporadic amongst the largely natural science education literature base. In comparison, the journal *Science Education* published its first issue in 1916, the *Journal of Engineering Education* was first published in 1924, and the journal *Educational Studies in Mathematics* was first published in 1968.

When looking back at the nature of technology education research over the past three to four decades, loose trends are visible. In its first two decades (the 1980's and 1990's), several articles which describe practice internationally were published. For example, Williams (1993) described technology education in Australia, Ankiewicz (1995) in South Africa, Owen and Heywood (1990) in Ireland, and Zuga (1997) in the United States. These descriptions were not just limited to national practice holistically, but also included descriptions of facets of practice. For example, Payne et al. (1993) described the use of portfolios for assessment and Kimbell (1994) spoke about types of tasks in technology. The next decade (the 2000's) saw a shift from a descriptive focus to what could be considered a framing agenda. Several articles which presented argument or debate concerning "big ideas" in and for technology education were published. For example, Turnbull (2002) presented an argument for the place of authenticity within technology education, Zuga (2004) and de Miranda (2004) frame the need to give consideration to cognition within technology education research and practice, de Vries (2005) reflects on the nature of technological knowledge, and Williams et al. (2008) framed problem-based learning as an appropriate pedagogy for the field. Following this, in the 2010's there appears to be another shift towards broad empirical generalisations to underpin advances in practice. Seitamaa-Hakkarainen et al. (2010), for example, present a study on learning by collaborative designing, there was a substantial initiation on the use of adaptive comparative judgement (ACJ) for assessment (Williams & Kimbell, 2012), Kallio and Metsärinne (2017) explored how learning orientations were related to learning outcomes, and Garikano et al. (2019) presented a study on a strategic knowledge-based approach for computer aided design (CAD) learning. Taking some of the most recent publications as an example, in the first few years of this decade (2020-2023) published empirical work appears to be focussed on more specific aspects of education than in the previous decade. For example, Ye et al. (2023) present an eye-tracking study on the processing of a dovetail

[1] This commentary relates to English speaking journals only, as this the only language that the author is proficient in.

joint, Larsson and Stolpe (2023) examine teachers use of gesturing when teaching programming lessons, and Liu et al. (2023) explore the use of a specific underwater robot construction kit. Of course, this is a very broad characterisation of the types of studies published over time and does not reflect all publications during this period, omits any form of review of the subject or topic areas of the studies themselves, and is limited to works published within the *International Journal of Technology and Design Education* due to the journals' size, but it does present a growth in the field from description in the early establishment years through to examination of specific theories and practices.

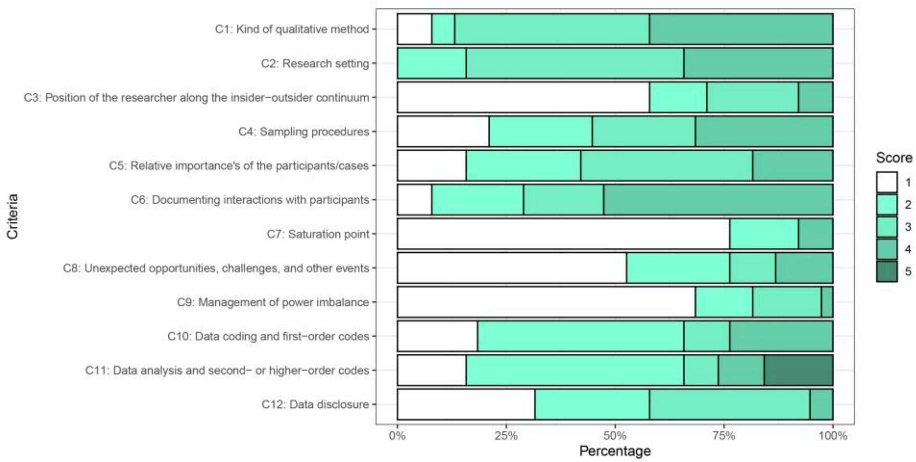
Parallel to a visible shift towards specificity has also seen a natural rise is the conduction and publication of meta-research, typically undertaken with a consolidation and future progress objective. One of the largest meta-research initiatives undertaken to date in technology education has been by Williams with colleagues where the aims and trends of related research have been characterised with changes over time being documented. Beyond this, there have been several reviews of the field (de Vries, 2003; Petrina, 1998; Reed & LaPorta, 2015; Sherman et al., 2010; Wells, 2015), however the two conducted by William's (2013, 2016) are broader in scope and/or remit, and were further built upon recently by a review of research trends from Xu et al. (2020). Collectively, these three reviews describe trends holistically in technology education research from 2000 to 2018. As the field has progressed, there has been an increase in review articles on more specific topics which often now include a degree of systematicity either in the search process, the review process, or both. For example, Gómez Puente et al. (2013) presented a review of design-based learning in technology education with a systematic characterisation of the included studies. Since this, however, it was not until 2021 that a review article has been published in an issue the *International Journal of Technology and Design Education* which has been explicitly described as systematic in some degree, and there have now been five such reviews (Bartholomew & Jones, 2021; Brosens et al., 2023; Chu et al., 2023; Eliasson et al., 2023; Jackson et al., 2022). This increase in systematic reviews is another indicator of the ongoing maturation of the field.

Meta-research goes beyond reviewing research trends and summarising topic related findings. It includes all works where the aim is to review, evaluate, or synthesise aspects of prior research. To take an example, research on the use of ACJ for assessment in technology education has grown in recent years. Bartholomew and Jones (2021) conducted a systematised review of associated findings with a view towards making suggestions for future research directions, however Buckley et al. (2022) reviewed the methodological validity of the included studies with an aim of informing the design of future studies. Both are meta-research projects on the same topic, with one aiming to inform future research questions and the other future research designs. This plurality is important as over the last decade several fields of study have been undergoing a "crisis of confidence" due to findings failing to replicate in replication studies (Anvari & Lakens, 2018). These fields, which include psychology, medicine, and experimental economics, are typically much older than technology education. As technology education has arguably entered or is entering quite a mature phase where research is becoming more explicit and systematic in terms of process, it is essential that meta-research with a focus on improving research practices becomes routine and translational. While a new agenda in technology education, in this paper two such projects are described and are followed by a discussion on possible next steps. These projects related to meta-studies on research transparency and result replicability.

## 2. TRANSPARENCY IN TECHNOLOGY EDUCATION RESEARCH

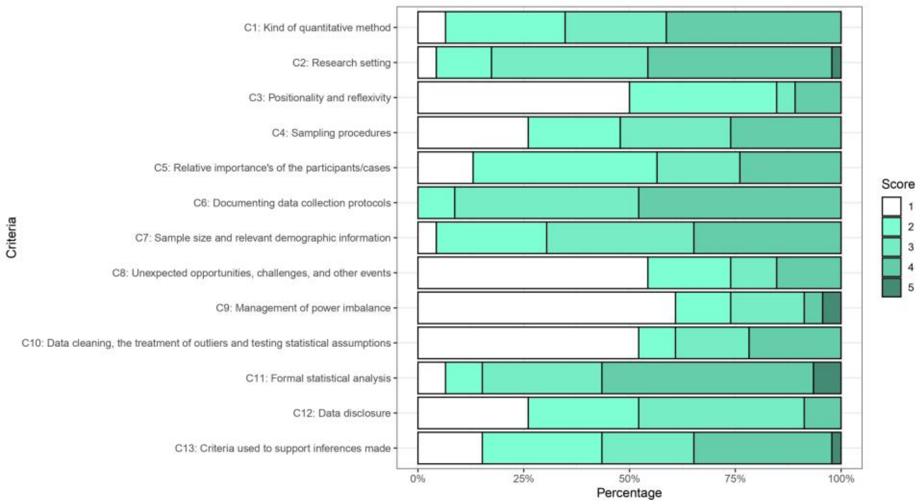
Making research transparent involves making all decisions made by researcher, particularly those relating to data, clear when reporting empirical studies (Closa, 2021). Typically, this involves researchers ensuring that methodology sections in their publications are comprehensive and unambiguous to the point where an exact replication attempt would be possible (assuming access to required resources) by an independent researcher. High levels of transparency are needed both to permit replication attempts, but also to ensure reported findings can be fully understood so they can be evaluated perhaps for contextual relevance or utility. There are several aspects of studies which need to be made clear for this to be possible, such as the type of methodology, sampling procedure, and analytic strategy. Aguinis and Solarino (2019) performed a systematic review across several fields to develop their behaviourally-anchored rating scales (BARS) instrument. Designed for qualitative studies, the BARS instrument included 12 criteria against which aspects of reported research methodologies can be scored to evaluate their transparency on a four-point nominal scale ranging from "criterion not mentioned" to "criterion is met". Buckley, Adams, et al. (2022) subsequently adopted this instrument to code a sample of 38 qualitative studies reported in the *International Journal of Technology and Design Education and Design and Technology Education: An International Journal*. The inclusion criteria were that articles must report an interview-based methodology and be published between 2019 and 2020. The aggregated results for the transparency criteria are shown in Figure 1.

*Figure 1.*
*Aggregated transparency levels of 38 interview-based studies in technology education published between 2019 and 2020 (Buckley, Adams, et al., 2022). Scoring codes were (1) "criterion not met", (2) "criterion mentioned but not elaborated", (3) "criterion partially met", (4) "criterion is met", and (5) "criterion not relevant". Figure available from [https://osf.io/aczbj/?view_only=1459b606c62d4f63b5a8e1d6ea049505](https://osf.io/aczbj/?view_only=1459b606c62d4f63b5a8e1d6ea049505).*




Subsequent to this, Buckley et al. (2023) adapted the BARS instrument for quantitative research. They conducted a similar analysis where the transparency of a sample of 46 quantitative studies, again from the International Journal of Technology and Design Education and Design and Technology Education: An International Journal published between 2019 and 2020 were coded. The aggregated results of this study are presented in Figure 2.

*Figure 2.*
*Aggregated transparency levels of 46 quantitative studies in technology education published between 2019 and 2020 (Buckley et al., 2023). Scoring codes were (1) "criterion not met", (2) "criterion mentioned but not elaborated", (3) "criterion partially met", (4) "criterion is met", and (5) "criterion not relevant". Figure available from [https://osf.io/wh735/?view_only=2eae17d333194430a10d2d4c8467d10f](https://osf.io/wh735/?view_only=2eae17d333194430a10d2d4c8467d10f).*




What is immediately clear is that the result distributions from both studies are broadly similar, and across each criterion there are published studies which are not fully transparent which would prevent an exact replication attempt without contacting original authors. Beyond this there are certain aspects of methodologies which researchers, both for quantitative and qualitative studies, tend to not make transparent to a greater degree than others. These included researcher positionality and reflexivity, unexpected opportunities, challenges, and other events, management of power imbalance, data cleaning, the treatment of outliers, and testing statistical assumptions (quantitative studies) and data saturation (qualitative studies). Together, these present guidelines which are immediately translatable into research practice, where authors can be cognisant of transparency and so too can journal reviewers and editors.

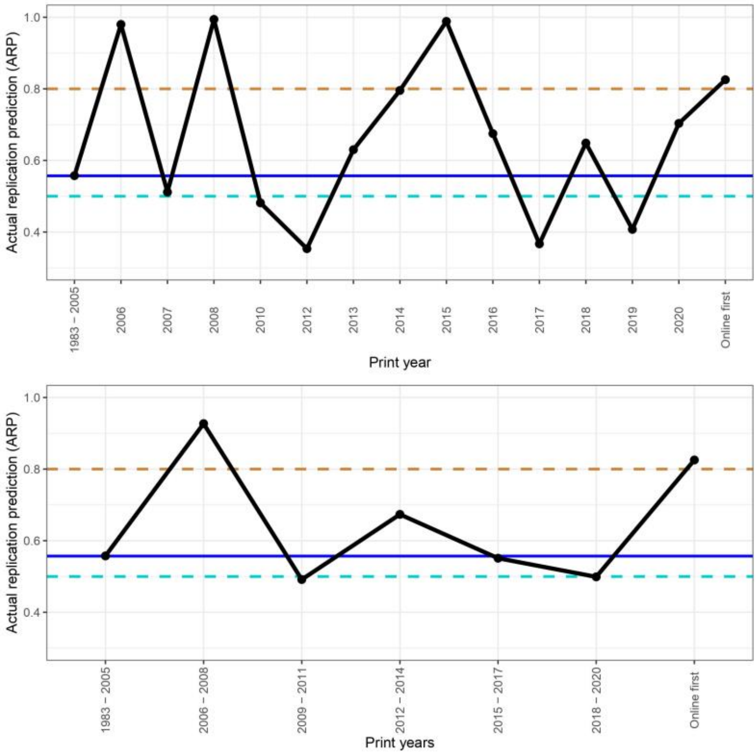
## 3. REPLICABILITY OF TECHNOLOGY EDUCATION RESEARCH

Buckley, Hyland, et al. (2022) examined the replicability of previously published technology education studies using a z-curve analysis (Bartoš & Schimmack, 2020). Replicability refers to the probability that a result in an original study will be observed in an independent replication attempt, which could either be a conceptual or direct replication study. As a goal of quantitative research is typically generalisability, which is in contrast to inductive qualitative research which instead often focuses on transferability, replicability is usually, but not always (cf. Makel et al., 2022), related to quantitative research. It is directly related to statistical power and the sample size of the original study, with a larger sample size reducing the probability of a Type II error (a false negative result) being committed. In their work, Buckley, Hyland, et al. (2022) built upon a previous small-scale examination of technology education research replicability (Buckley et al., 2021) to quantify the replicability rates of quantitative technology education studies from 1983 to 2021 across five relevant academic journals (627 reported statistical tests). The results of their work are presented in Figure 3.

*Figure 3.*

*Actual replication values (ARP) for quantitative studies in technology education (Buckley, Hyland, et al., 2022). Figure available from [https://osf.io/zbp5s/?view_only=b9c45f4bf1f54c859bc342de98ece370](https://osf.io/zbp5s/?view_only=b9c45f4bf1f54c859bc342de98ece370)*

.




They observed an overall "actual replication prediction" rate (ARP), a prediction of the percentage of results to replicate in actual replication attempts (Schimmack, 2022), to be 55.7%. Interestingly, the ARP from 2009 to 2020 was quite low, the decade previously described as being associated with quite broad empirical studies, whereas for 2021 onwards (indicated by online first articles) where studies have become more explicit the ARP value was much higher (> 80%). This is useful information as it shows both improvement but also indicates a need to examine the validity of findings from the previous decade upon which much current research is being built upon.

## 4. DISCUSSION ON FUTURE STEPS

Technology education research is maturing and from a number of perspectives and this progression appears to be going in a positive direction. It is important now that as the field continues to grow that good research practices continue to be embedded and become the norm such that the social contract between researchers and the general public is only strengthened. To this end, in addition to ongoing basic and applied research on technology educational phenomena, and to meta-research such as systematic reviews, meta-research on research practices to guide methodological refinement is essential. From the two projects previously described a number of future directions emerge. With respect to transparency, it is not clear whether this has improved over time as both studies were cross-sectional and relate to the same time period. It would be valuable to aim to improve the observed rates such that future publications become more transparent. In line with this, one concept which has not been examined to date in technology education is that of reproducibility. Reproducibility relates to an independent analyst being able to obtain consistent results with an original study using the same input data (Barba, 2018). This requires original study authors to make their original data accessible for reproducibility analyses and is an important dimension to observe the impact of decisions made by researchers (researcher degrees of freedom) on results. Given different researcher positionalities, from an epistemological perspective it would not necessarily be expected to observe consistent interpretations of qualitative studies, and therefore this generally relates to quantitative studies where researchers can share analytic code or analytic steps increasing the transparency of the results and allowing for the robustness of results to be examined.

With respect to building on the prior examination of technology education research replicability, it is immediately apparent that replication studies should be conducted. A big question which needs to be considered though is which previously reported results should be subjects of replication attempts. The z-curve analysis performed by Buckley, Hyland, et al. (2022) only goes so far as to denote average predictions of replicability rates. For example, the overall ARP of 55.7% suggests that 44.3% of published findings would not replicate – but it is not clear which results fall within this 44.3%. Replication attempts of individual studies with adequate sample sizes to give a desired level of statistical power would allow for individual results to be examined. However, such studies would require an investment of effort, both time and financial, and thus a process for determining replication value would be useful within the field. Isager et al. (2020) proposed a formal definition of replication value, inclusive of variables such as the cost in performing a replication attempt, uncertainty about the claim/result before a replication attempt is made, the value of the claim/result, and the expected utility or useful of the claim/result before any replication attempts. Based on this, it would be useful to engage in discourse within the technology education community to contextually define what these variables could mean within the field, and it is likely that this discourse would require input from a broad range of stakeholders such as educators and policy makers to which certain claims or results are relevant. Subsequently, the conduction of formal replication attempts would add significant value to technology education as a practice, with the field's credibility being enhanced and the validity of results being more certain.

## 5. REFERENCES


Aguinis, H., & Solarino, A. M. (2019). Transparency and replicability in qualitative research: The case of interviews with elite informants. *Strategic Management Journal*, *40*(8), 1291–1315. https://doi.org/10.1002/smj.3015

Ankiewicz, P. (1995). The planning of technology education for South African schools. *International Journal of Technology and Design Education*, *5*(3), 245–254. https://doi.org/10.1007/BF00769906

Anvari, F., & Lakens, D. (2018). The replicability crisis and public trust in psychological science. *Comprehensive Results in Social Psychology*, *3*(3), 266–286. https://doi.org/10.1080/23743603.2019.1684822

Barba, L. (2018). Terminologies for reproducible research. *ArXiv*. https://arxiv.org/pdf/1802.03311

Bartholomew, S., & Jones, M. (2021). A systematized review of research with adaptive comparative judgment (ACJ) in higher education. *International Journal of Technology and Design Education*. https://doi.org/10.1007/s10798-020-09642-6

Bartoš, F., & Schimmack, U. (2020). Z-curve.2.0: Estimating replication rates and discovery rates. *PsyArXiv*. https://doi.org/10.31234/osf.io/urgtn

Brosens, L., Raes, A., Octavia, J. R., & Emmanouil, M. (2023). How future proof is design education? A systematic review. *International Journal of Technology and Design Education*, *33*(2), 663–683. https://doi.org/10.1007/s10798-022-09743-4

Buckley, J., Adams, L., Aribilola, I., Arshad, I., Azeem, M., Bracken, L., Breheny, C., Buckley, C., Chimello, I., Fagan, A., Fitzpatrick, D. P., Garza Herrera, D., Gomes, G. D., Grassick, S., Halligan, E., Hirway, A., Hyland, T., Imtiaz, M. B., Khan, M. B., … Zhang, L. (2022). An assessment of the transparency of contemporary technology education research employing interview-based methodologies. *International Journal of Technology and Design Education*, *32*(4), 1963–1982. https://doi.org/10.1007/s10798-021-09695-1

Buckley, J., Araujo, J. A., Aribilola, I., Arshad, I., Azeem, M., Buckley, C., Fagan, A., Fitzpatrick, D. P., Garza Herrera, D. A., Hyland, T., Imtiaz, M. B., Khan, M. B., Lanzagorta Garcia, E., Moharana, B., Mohd Sufian, M. S. Z., Osterwald, K. M., Phelan, J., Platonava, A., Reid, C., … Zainol, I. (2023). How transparent are quantitative studies in contemporary technology education research? Instrument development and analysis. *International Journal of Technology and Design Education*. https://doi.org/10.1007/s10798-023-09827-9

Buckley, J., Hyland, T., & Seery, N. (2021). Examining the replicability of contemporary technology education research. *Techne Series: Research in Sloyd Education and Craft Sciences*, *28*(2), 1–9.

Buckley, J., Hyland, T., & Seery, N. (2022). Estimating the replicability of technology education research. *International Journal of Technology and Design Education*. https://doi.org/10.1007/s10798-022-09787-6

Buckley, J., Seery, N., & Kimbell, R. (2022). A review of the valid methodological use of adaptive comparative judgment in technology education research. *Frontiers in Education*, *7*(787926), 1–6. https://doi.org/10.3389/feduc.2022.787926

Chu, W. W., Hafiz, N. R. M., Mohamad, U. A., Ashamuddin, H., & Tho, S. W. (2023). A review of STEM education with the support of visualizing its structure through the CiteSpace software. *International Journal of Technology and Design Education*, *33*(1), 39–61. https://doi.org/10.1007/s10798-022-09728-3

Closa, C. (2021). Planning, implementing and reporting: Increasing transparency, replicability and credibility in qualitative political science research. *European Political Science*. https://doi.org/10.1057/s41304-020-00299-2

De Miranda, M. A. (2004). The grounding of a discipline: Cognition and instruction in technology education. *International Journal of Technology and Design Education*, *14*(1), 61–77. https://doi.org/10.1023/B:ITDE.0000007363.44114.3b

de Vries, M. J. (2003). Editorial. *International Journal of Technology and Design Education*, *13*(3), 199–205. https://doi.org/10.1023/A:1026179627059

de Vries, M. J. (2005). The nature of technological knowledge: Philosophical reflections and educational consequences. *International Journal of Technology and Design Education*, *15*(2), 149–154. https://doi.org/10.1007/s10798-005-8276-2

Eliasson, S., Peterson, L., & Lantz-Andersson, A. (2023). A systematic literature review of empirical research on technology education in early childhood education. *International Journal of Technology and Design Education*, *33*(3), 793–818. https://doi.org/10.1007/s10798-022-09764-z

Garikano, X., Garmendia, M., Manso, A. P., & Solaberrieta, E. (2019). Strategic knowledge-based approach for CAD modelling learning. *International Journal of Technology and Design Education*, *29*(4), 947–959. https://doi.org/10.1007/s10798-018-9472-1

Gómez Puente, S. M., van Eijck, M., & Jochems, W. (2013). A sampled literature review of design-based learning approaches: A search for key characteristics. *International Journal of Technology and Design Education*, *23*(3), 717–732. https://doi.org/10.1007/s10798-012-9212-x

Isager, P. M., Aert, R. C. M. van, Bahník, Š., Brandt, M., DeSoto, K. A., Giner-Sorolla, R., Krueger, J., Perugini, M., Ropovik, I., Veer, A. van 't, Vranka, M. A., & Lakens, D. (2020). Deciding what to replicate: A formal definition of "replication value" and a decision model for replication study selection. In *MetaArXiv*. https://doi.org/10.31222/osf.io/2gurz

Jackson, A., Godwin, A., Bartholomew, S., & Mentzer, N. (2022). Learning from failure: A systematized review. *International Journal of Technology and Design Education*, *32*(3), 1853–1873. https://doi.org/10.1007/s10798-021-09661-x

Kallio, M., & Metsärinne, M. (2017). How do different background variables predict learning outcomes? *International Journal of Technology and Design Education*, *27*(1), 31–50. https://doi.org/10.1007/s10798-015-9339-7

Kimbell, R. (1994). Tasks in technology. *International Journal of Technology and Design Education*, *4*(3), 241–255. https://doi.org/10.1007/BF01212805

Larsson, A., & Stolpe, K. (2023). Hands on programming: Teachers' use of Metaphors in gesture and Speech make Abstract concepts tangible. *International Journal of Technology and Design Education*, *33*(3), 901–919. https://doi.org/10.1007/s10798-022-09755-0

Liu, L., Oh, H., Zhang, L., Fang, T., Huang, M., Hao, Y., Wang, J., Yao, C., & Ying, F. (2023). A study of children's learning and play using an underwater robot construction kit. *International Journal of Technology and Design Education*, *33*(2), 317–336. https://doi.org/10.1007/s10798-021-09720-3

Makel, M. C., Meyer, M. S., Simonsen, M. A., Roberts, A. M., & Plucker, J. A. (2022). Replication is relevant to qualitative research. *Educational Research and Evaluation*, *27*(1–2), 215–219. https://doi.org/10.1080/13803611.2021.2022310

Owen, S., & Heywood, J. (1990). Transition technology in Ireland: An experimental course. *International Journal of Technology and Design Education*, *1*(1), 21–32. https://doi.org/10.1007/BF00420293

Payne, R. N., Bramhall, M. D., Lawson, J. S., Robinson, I., & Short, C. (1993). Portfolio assessment in practice in engineering. *International Journal of Technology and Design Education*, *3*(3), 37–42. https://doi.org/10.1007/BF00183706

Petrina, S. (1998). The politics of research in technology education: A critical content and discourse analysis of the Journal of Technology Education, Volumes 1-8. *Journal of Technology Education*, *10*(1), 27–57. https://doi.org/10.21061/jte.v10i1.a.3

Reed, P., & LaPorta, J. (2015). A content analysis of AIAA/ITEA/ITEEA conference special interest sessions: 1978–2014. *Journal of Technology Education*, *26*(3), 38–72. https://doi.org/10.21061/jte.v26i3.a.2

Schimmack, U. (2022). 2021 Replicability Report for the Psychology Department at the University of Amsterdam. *Replicability-Index*. https://replicationindex.com/2022/03/29/rr22-u-amsterdam/

Seitamaa-Hakkarainen, P., Viilo, M., & Hakkarainen, K. (2010). Learning by collaborative designing: Technology-enhanced knowledge practices. *International Journal of Technology and Design Education*, *20*(2), 109–136. https://doi.org/10.1007/s10798-008-9066-4

Sherman, T. M., Sanders, M., & Kwon, H. (2010). Teaching in middle school Technology Education: A review of recent practices. *International Journal of Technology and Design Education*, *20*(4), 367–379. https://doi.org/10.1007/s10798-009-9090-z

Turnbull, W. (2002). The place of authenticity in technology in the New Zealand curriculum. *International Journal of Technology and Design Education*, *12*(1), 23–40. https://doi.org/10.1023/A:1013056129283

Wells, J. (2015). A century of professional organization influence: Findings from content analyses of MVTTEC annual meetings. *Journal of Technology Education*, *26*(3), 3–37. https://doi.org/10.21061/jte.v26i3.a.1

Williams, P. J. (1993). Technology education in Australia. *International Journal of Technology and Design Education*, *3*(3), 43–54. https://doi.org/10.1007/BF00183707

Williams, P. J. (2013). Research in technology education: Looking back to move forward. *International Journal of Technology and Design Education*, *23*(1), 1–9. https://doi.org/10.1007/s10798-011-9170-8

Williams, P. J. (2016). Research in technology education: Looking back to move forward… again. *International Journal of Technology and Design Education*, *26*(2), 149–157. https://doi.org/10.1007/s10798-015-9316-1

Williams, P. J., Iglesias, J., & Barak, M. (2008). Problem based learning: Application to technology education in three countries. *International Journal of Technology and Design Education*, *18*(4), 319–335.

Williams, P. J., & Kimbell, R. (Eds.). (2012). Special issue on e-scape [Special issue]. *International Journal of Technology and Design Education*, *22*(2).

Xu, M., Williams, P. J., Gu, J., & Zhang, H. (2020). Hotspots and trends of technology education in the International Journal of Technology and Design Education: 2000–2018. *International Journal of Technology and Design Education*, *30*(2), 207–224. https://doi.org/10.1007/s10798-019-09508-6

Ye, L., Yang, S., Zhou, X., & Lin, Y. (2023). Supporting traditional handicrafts teaching through eye movement technology. *International Journal of Technology and Design Education*, *33*(3), 981–1005. https://doi.org/10.1007/s10798-022-09748-z

Zuga, K. F. (1997). An analysis of technology education in the United States based upon an historical overview and review of contemporary curriculum research. *International Journal of Technology and Design Education*, *7*(3), 203–217. https://doi.org/10.1023/A:1008856517112

Zuga, K. F. (2004). Improving technology education research on cognition. *International Journal of Technology and Design Education*, *14*(1), 79–87. https://doi.org/10.1023/B:ITDE.0000007360.33705.94