EMBRY-RIDDLE Aeronautical University
SCHOLARLY COMMONS

Journal of Aviation/Aerospace Education & Research

Volume 30
Number 2 *JAAER 2021*

Article 4

2021

Design Science Research – Alternative Pathway for Aviation Training-Related Studies

Guilherme A. da Silveira
Pontifícia Universidade Católica do Rio Grande do Sul, guilherme.silveira@pucrs.br

Éder Henriqson
Pontifícia Universidade Católica do Rio Grande do Sul, ehenriqson@pucrs.br

Introduction

Of the many reasons why developing knowledge is an important attribute of science, two are particularly important -- rigor and criteria (Corley & Gioia, 2011; Van Aken, 2005). Recognizing such as a permanent requirement of academic research is one of the fundamental steps governing the choice of the methodological approach for any given research. This is not at all a distortion of the scientific method – rather, if a research problem is relevant to the community, then scholars should be concerned from day one with which method best suits their needs, i.e., community needs. In this sense, if one looks at aviation/pilot training literature, where the value of systems development is readily apparent (da Silva & Nunes, 2019; Goldsmith & Johnson, 2009; Salas et al., 1998; Shuffler et al., 2010), it is worth discussing which method or paradigm provides the most useful outcomes while maintaining rigor and criteria at a high level.

Flight training is an interesting field spread across a multidisciplinary set of courses, each with a vast array of challenges and research opportunities (International Civil Aviation Organization [ICAO], 2018; Oster et al., 2013). Current discussions aim to improve cost-effectiveness, reduce training duration, and identify best training practices for both the military and civil aviation branches (Pope, 2019; Valenta, 2018; Vance et al., 2021). Such a class of problems, albeit relevant, demands pragmatic solutions that are not always conspicuous from traditional qualitative or quantitative methods akin to the natural sciences. Something else is needed, for aviation requires more than simply understanding the properties, behaviors and interactions amongst artificial objects or natural phenomena.

The purpose of this essay is to review design science research (DSR) methodology in order to consider its applicability to flight training problems. We suggest that DSR might be a precious tool to aid in the development of artifacts that will eventually enable a meeting point between the artificial substance – e.g., a training program, an artifact – and the surroundings in which such artifact is meant to operate. To this end, we have conducted a literature review based on the roadmap provided by Deng and Ji (2018), who identified seminal studies on DSR (Hevner et al., 2004; March & Smith, 1995; Simon, 1996) and further derived the technique in four distinct areas – (1) concept; (2) processes; (3) outcomes; and (4) evaluation. Consecutive to Deng and Ji (2018), we build on the aforementioned areas and provide a discussion of the potential situations where aviation-related training studies could integrate valid and effective artifacts, eventually increasing rigor and criteria of forthcoming research.

Concept

DSR and other similar terms emerged through the need to make design a more "scientific" task. After some decades of controversy regarding the use of analogous expressions such as design science and design research, it is a valid assumption that today's design methodology can be seen as a mature academic field (Cross, 2001). DSR is a problem-solving paradigm that works through the analysis, design, implementation, management and use of information systems (IS) tools. It is enabled via the creation of innovations, practices, technical capabilities, and products, i.e., artifacts that draw on existing kernel theories (Fischer et al., 2010; Hevner et al., 2004). In fact, the word research in "DSR" has a fundamental meaning: it implies the possibility to generalize DSR solutions, further approximating the method from what is required by science and dissociating it from what is merely routine design.

Besides reaching a consensus on concept, it is equally important to position the DSR paradigm within the fundamental worldviews that underly its efforts (Purao, 2013). After all, unless the researcher's premises and philosophical foundations are clearly stated and conscientiously exercised throughout the research process, chances are that its audience will not

DOI: https://doi.org/10.15394/jaaer.2021.1902

be able to appreciate the work effort. As researchers, we must not only offer a robust study, but also provide our recipients with enough information to consider our work and its built-in propositions against its alleged worldview. The philosophical grounding of DSR is unique for two reasons: (1) it is not possible to derive ontology, epistemology or axiology from one another; and (2) as DSR projects go on, there is an anticipated shift of the epistemological and ontological viewpoints while the researcher exercises his own pragmatism (Vaishnavi & Kuechler, 2015).

Applied Processes

Peffers et al. (2007) used a consensus-building approach to effectively build the design, further establishing the creative process on well-accepted elements instead of focusing on nuanced differences in views amongst various researchers. The result of this approach is a six-step process – which the authors called “activities” – starting with the problem identification and concluding with communication considerations (Peffers et al., 2007).

Activity 1 deals with the problem identification and motivation and is the first step towards a successful application of DSR. If we consider that the result of DSR is an artifact that can effectively solve a problem, it may be useful to split the problem into smaller sections, so that it is easier to appreciate how the artifact captures the problem’s complexity. Furthermore, while clarifying the researcher’s reasoning on understanding the problem, the justification of the value of a solution motivates the audience to accept the study’s results. Also, the starting problem (or class of problems) in the research cycle is a discrepancy between the facts and an existing set of truth-statements concerning these facts. In this perspective, the purpose of the process is adaption of our knowledge to the facts (Eekels & Roozenburg, 1991).

The identification of a problem on *Activity 1* may lead the researcher to the analysis of meta-requirements, i.e., the class of goals to which the solution applies (Walls et al., 1992).

Hence, when *Activity 1* is concluded, the researcher shall infer the objectives for a solution with reference to the problem definition and knowledge of what is possible and feasible – this is *Activity 2*. For training-related problems, such objectives can be both quantitative and qualitative. Quantitative, if the idea is to explain in which terms a desirable solution is more advantageous than current ones; and qualitative if the class of problems demands a description of how the proposed artifact is expected to support solutions not formerly addressed. Logical inferences between the problem specification and the objectives should be established.

Activity 3 is the conception of the article per se, which can be a set of vocabulary and symbols, abstracts and representations, algorithms and practices, or implemented and prototyped systems (Hevner et al., 2004). In other words, *Activity 3* is concerned with new properties of artificial resources. A design research artifact can be distinguished from industry design in that the academia version is associated with the production of interesting new and true knowledge – usually, the research contribution is embedded in the design. This activity includes determining the artifact's desired functionality and its architecture and then creating the actual artifact. This is the realm of systems development life cycle, and Nunamaker et al. (1990) observed that it usually involves the construction of a prototype system. The development of an artifact is essentially an engineering activity, an evolutionary systematic process, and researchers must be alert to new insights that may result from accumulated experience throughout the (cyclical) development phase.

Activity 4 is focused on demonstrating that one or more instances of the problem can be solved via the artifact. Therefore, once the system is built, its performance and usability can be verified in reference to the stated requirements. This demands a set of additional activities such as experimentation, simulation, or case studies. Effective knowledge of how to use the artifact is one of the resources required at this point. Moreover, the conceptual framework and systems requirements that were developed at the early stages of the study should be used to interpret the test results. Eventually, this exercise may lead to the discovery of a new theory to explain a newly observed phenomena or at least further expand the development of the system.

Researchers must be meticulous in the selection of support methods to carry on artifact experimentation. Internal and external validity may be compromised if *Activity 4* is executed carelessly. Therefore, it is a good routine to think of *Activities 1-6* as a collection of subsystems each with their own life cycles, particularly when artifacts are designed for social sciences applications, where usability may be subject to individual interpretation. This is the case, for instance, with instructional design methods administered by a significant number of distinct instructors, each with its own bias.

The purpose of *Activity 5* is to observe and measure how well the problem is supported by the artifact. Hence, it is centered on comparing the gap between intended objectives and actual results obtained from use of the artifact. Knowledge of relevant analysis techniques and metrics is required. This evaluation process can take many forms depending on the nature of the artifact and the problem venue. Researchers could focus on comparing the artifact's functionality with the solution objectives from *Activity 2*, or quantitative measures, such as items produced and budgets, statistical analysis of surveys, user feedback, and even simulations. Evaluation could include system performance, such as response time or any other quantifiable metric. In essence it could include any appropriate empirical evidence or logical proof. Since DSR process is systematic, researchers can always consider going back to *Activity 3* and try to improve the artifact's effectiveness or continue to *Activity 6* and disregard further improvements. It is the researcher's call whether such iteration is feasible or not.

Activity 6 refers to the communication of the artifact's utility, novelty, design requisites, and its effectiveness to other scholars and practitioners. The structure adopted in this section is a good example to be followed when reporting to scholarly research publications. When discussing how difficult it may be to describe the intricacies of an artifact using nothing but words, figures and tables in a journal article, Gregor and Hevner (2013) suggest that researchers be aware of the domain and the audience to which the presentation is made.

Viable Outcomes

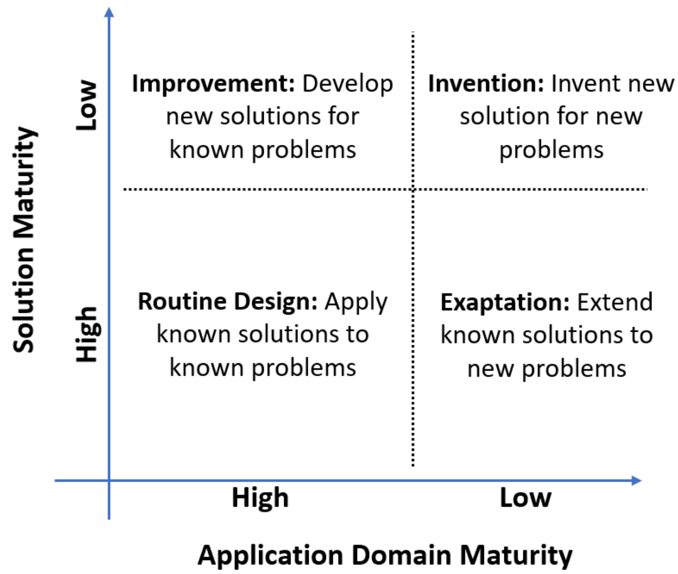
Before pointing out which outcomes best suit aviation training-related studies, we shall discuss what is generally accepted as design science knowledge. According to Baskerville et al. (2018), such contribution may take the form of a design artifact – when the artificial world evolves driven by utilities and sustainability – or a design theory – when (natural) science evolves via a deeper understanding and generalization. Either way, both forms are recognized as design science knowledge.

Figure 1 locates knowledge contribution according to solution maturity and application domain maturity. The reader could argue that ideally researchers should aim at invention. However, as long as scholars are capable of exercising perspicacity and curiosity in order to satisfy the needs of at least one low level maturity cell, then contribution can be considered to be significant (Vaishnavi & Kuechler, 2015).

DOI: https://doi.org/10.15394/jaaer.2021.1902

Figure 1

Knowledge Contribution Framework



Note. Adapted from "Positioning and Presenting Design Science Research for Maximum Impact," by S. Gregor and A. Hevner, 2013, *Management Information Systems Quarterly*, *37*(2), 337-355 (https://doi.org/10.25300/MISQ/2013/37.2.01).

We stress "exercise perspicacity," for researchers must be rigorous when developing new solutions for known problems (improvement); similarly, we emphasize "exercise curiosity," for researchers must be resourceful when extending known solutions to new problems (exaptation). While this is far from being the only attributes necessary for a good researcher, it is a valid thought for consideration. Routine design – when both solution maturity and application domain maturity are both high – should be avoided at all costs if the project manager has any expectation regarding relevant scientific contribution.

Specifically, the output of DSR can be any one amongst the following eight artifacts: (1) constructs, (2) models, (3) frameworks, (4) architectures, (5) design principles, (6) methods, (7) instantiations, or (8) design theories, and the reader is invited to reason whether aviation training-related studies could benefit from such outcomes or not – a discussion that will be later developed on Table 1. Baskerville et al. (2018) suggest that design theorizing is an expected norm for DSR *in addition to* artifact design – there should always exist some reflection on how design knowledge advanced as a result of research work. In other words, what is implicitly observed in the descriptions of the artifact, what nascent design principles exist, or even what new design theory is proposed. The problem with design theorizing is that it is not always recognized as actual theory (Baskerville et al., 2018; Corley & Gioia, 2011; Gregor & Hevner, 2013; Gregor & Jones, 2007), which only reinstates the importance of "design" in "design theorizing" – after all, DSR is not interested in contributions to other forms of non-design theory. Design theorizing is particularly important for aviation training-related studies, for it is an easy, transparent way of communicating the properties and design foundations of an artifact (Piirainen & Briggs, 2011) – much like a framework that helps to create the link between a learning theory and an instructional method.

Evaluating Design Science Research

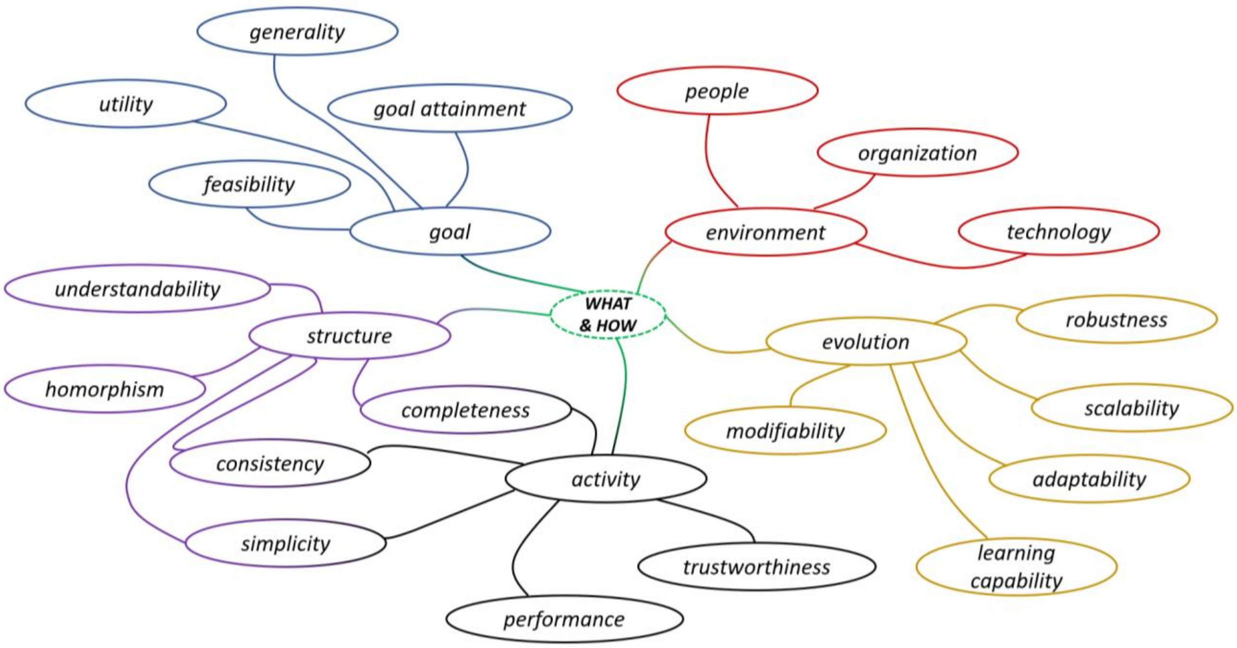
The importance of evaluation for DSR is situated in the paradigm of *what* and *how* to evaluate. In this sense, Venable et al. (2016) argue that artifact evaluation should be both naturalistic and artificial. This is where DSR meets case studies, field studies, field experiments, surveys, ethnography, phenomenology, hermeneutic methods, and action research. In a hypothetical scenario, for instance, a conceived training method (the artifact) could be evaluated with a case study or a field experiment. Moreover, evaluation of artifacts should not be restricted to naturalistic empiricism but may include artificial experimentation where technology (or its representation) can be studied under specific conditions. Hence, like other research methods, an artifact can be evaluated in terms of validity, utility, quality, and efficacy. For DSR, validity means that the artifact works and does what it is meant to do – that in operational terms, it is reliable in providing steady results; utility determines the accumulated value of achieving the artifact's goal, i.e., the difference between the worth of achieving this goal and the price paid for achieving it; quality can be described in terms of more-or-less measurable variables, where differences in quality reflect differences in the quantity or state of some product attribute; and finally, efficacy measures the degree to which the artifact achieves its goal without having to address situational concerns (Pries-Heje et al., 2008).

While academia has observed a continuous effort towards objectifying and/or systematizing evaluation criteria (Gibbert & Ruigrok, 2010) – particularly in positivist research (Straub et al., 2004) – Gregor and Hevner (2013) argue that some amount of flexibility is welcomed when judging the degree of evaluation required by the introduction of novel artifacts. Therefore, to aid researchers on the task of evaluating artifacts, Prat et al. (2015) created a taxonomy of artifact evaluation methods, specifying the "what" and "how" of evaluation. Figure 2 is a concept map that captures the essence of connections between constructs in their final revised hierarchy of evaluation criteria. First level connections – goal, environment, evolution, activity, and structure – should be understood as "what" needs to be evaluated while second/third level connections consist of a set of constructs by means of which the researcher will know "how" to understand *what* needs to be evaluated.

In the "concept" section, we relied on Vaishnavi and Kuechler (2015) to argue that as DSR projects go on, the researcher might exercise their own pragmatism and welcome eventual shifts from epistemological and ontological points of view. In this sense, evaluation is that part of a study where a pairing is expected between the natural and the artificial. Design science researchers must acknowledge this possibility and combine efforts to perform evaluation with as much rigor and criteria as the development of the artifact itself.

Figure 2

Hierarchy of Evaluation Criteria



Discussion

It is not wrong *not* to employ DSR in qualitative studies associated with aviation training, for aviation training itself has evolved to its actual status without DSR. It is our contention, though, that further development requires an additional (perhaps different) effort in order to be effective. In fact, some existing course curriculums are indeed designed with a systems approach and thus share some of the advantages offered by DSR (see Federal Aviation Administration's [FAA] Advanced Qualification Program[1] [AQP] and ICAO's Training Development Guide

[1] AQP is an alternative training method first offered to airline companies in the United States.

[TDG][2], both founded on Instructional System Design [ISD] principles). However, the remainder of academic production in the field focuses on other types of qualitative or quantitative research. Although ISD has proved successful, its methodological assumptions are confined to training *development* scenarios (Rothwell & Kazanas, 2008) – a restriction which, in comparison, does not apply to DSR. We argue that an artifact could be not only a training program, per se, but also the directions to devise such training program, for instance.

If we think of an output in the form of a construct, such as the expression *airmanship,*[3] we might be able to appreciate how having a rich collection of abstract concepts is desirable in order to help achieve a thorough general and specific communication – something highly valuable in academic contexts (Bhattacherjee, 2012). Conceiving new constructs, however, is not an elementary task, but the systematic approach of DSR can facilitate the creation process with added rigor and criteria. The same principle applies to any other type of artifact. Because both aviation *and* training are converging points to many disciplines – from both natural and artificial sciences – it is not difficult to devise multiple scenarios consistent and/or in demand of abstract and/or material artifacts. Table 1 expands on the eight outcomes proposed on the "viable outcomes" section and applies such knowledge to aviation training-related studies. While none of the present catalogued examples have been a direct result of DSR, we hold that future progress with consequences alike could materialize via DSR. In fact, because DSR outputs can take the form of virtually anything, we suggest that the researcher's strategic decision for one method or other shifts from a result-dependent to a process-dependent orientation. In other

[2] TDG is an ICAO document which provides the aviation industry with a competency-based methodology for the development of high-level aviation training courses.

[3] Airmanship is the consistent use of good judgement and well-developed skills to accomplish flight objectives. This consistency is founded on a cornerstone of uncompromising flight discipline and is developed through systematic skill acquisition and proficiency. A high state of situational awareness completes the airmanship picture and is obtained through knowledge of oneself, aircraft, environment, team and risk (Kern, 1997).

words, the added scientific contribution may be found in strong *processes* and not only (but also) in useful *results*. We emphasize that at no moment DSR claims to provide solutions that could not be envisioned by other methodological approaches and/or that have not already been adopted in our industry – DSR distinction, on the other hand, is asserted via thoroughness and robustness. Especially in a world where inventions (see Figure 1) are increasingly scarce, we support emphasis on the process in extension to the result itself. This is precisely the “meeting point” suggested earlier in this essay – the coupling between the natural and the artificial is facilitated via the adoption of a rigorous method.

The need to bridge the gap between industry and academia cannot be underestimated. Hence, it is important to point out that DSR research process is flexible and supports commencement at almost any level (Peffers et al., 2007), which fits both inductive, deductive, and abductive theorizing (Lee et al., 2011). Also, the systematic tone of DSR allows for some back-and-forth movement in the research process, a “wild card” characteristic that may be better appreciated outside the laboratory, further increasing DSR applicability beyond the academic world. Ideally, the design science researcher working in an aviation training environment recognizes how changes in industry might require expeditious adaptation, and finds DSR methodological support to comply with the most rigorous demands.

Table 1

Artifacts Applied to Aviation Training-related Studies

Constructs	Any conceptual vocabulary that may be necessary to elucidate the aviation training domain, such as “competency”, “behavioral indicator”, “transfer of training”, “summative/formative evaluation”, or “non-technical skills”, for instance.
Models	Any set of propositions or statements expressing relationships between constructs, such as the “model for assessing pilots’ performance”, the “SHELL model”, or the “Kirkpatrick four-level evaluation model”, for instance.
Frameworks	Any real or conceptual guide that serve as support or guide, such as a “competency framework”, or a “learning design framework”, for instance.
Architectures	Any high-level structure of systems such as the set of knowledge and skills that enable human mind to yield intelligent behavior in a diversity of complex environments – cognitive architecture, for instance.
Design Principles	Any principles and concepts to guide artifact design, such as “andragogy”, “systems thinking”, and “instructional design”, for instance.
Methods	Any set of steps used to perform tasks – the “how to” knowledge, such as the “instructional system design”, for instance.
Instantiations	Any situated implementations that do or do not operationalize abstract artifacts, such as “job aids”, “video materials”, “training modules”, or “training software”, for instance.
Design Theories	Any prescriptive theory which integrates normative and descriptive theories into design paths intended to produce more effective systems, such as a learning theory, for instance.

Note. Adapted from “The Anatomy of a Design Theory,” by S. Gregor and D. Jones, 2007, *Journal of the Association for Information Systems, 8*(5), 312-335 (https://doi.org/10.17705/1jais.00129).

Conclusion

Take an interesting subject (aviation), add a relevant field of study (training), and combine it with an adequate method/paradigm (DSR); this ought to be the formula for both scientific and practical contribution, something so esteemed in today's research agenda. With this theoretical essay, we hope to provide the reader with an adequate review of DSR methodology considering its applicability to aviation training-related problems. During this process, we structured our work in four distinct domains: concept, process, outcomes and evaluation, and provided a final abstract examination in benefit of the acceptance of DSR by our community.

We argue that DSR possesses the characteristics to build relevant solutions to prominent problems. In this sense, DSR might be a plausible choice whenever an artifact (in any of its forms) is deemed necessary. In retrospect, if one thinks about DSR's concept, not only is it clear about what it is but also about what it is not. Moreover, the method/paradigm is supported by a systematic process that is rigorous and flexible at the same time. The potential outputs/outcomes suit different classes of problems and are receptive to a significant number of different evaluation methods. All that has been stated satisfies design science knowledge criteria.

In closing this essay, we hope that aviation training researchers begin to develop an interest for DSR and consider adding DSR to their portfolio of methods and paradigms. To stimulate work in this direction, we believe that future research should examine and replicate existing aviation training-related studies to assess *what* and *how* results would differ had they been conducted with DSR.

DOI: https://doi.org/10.15394/jaaer.2021.1902

References

Baskerville, R., Baiyere, A., Gregor, S., Hevner, A., & Rossi, M. (2018). Design science research contributions: Finding a balance between artifact and theory. *Journal of the Association for Information Systems, 19*(5), 358-376. https://doi.org/10.17705/1jais.00495

Bhattacherjee, A. (2012). *Social science research: Principles, methods, and practices* (2nd ed.). University of South Florida Scholar Commons. https://digitalcommons.usf.edu/cgi/viewcontent.cgi?article=1002&context=oa_textbooks

Corley, K. G., & Gioia, D. A. (2011). Building theory about theory building: What constitutes a theoretical contribution? *Academy of Management Review, 36*(1), 12–32. https://doi.org/10.5465/amr.2009.0486

Cross, N. (2001). Designerly ways of knowing: Design discipline versus design science. *Design Issues, 17*(3), 49-55. https://doi.org/10.1162/074793601750357196

da Silva, L., & Nunes, R. (2019). Heading towards adaptive behavior in aviation training. *Gestão & Produção, 26*(2), 1-9.

Deng, Q., & Ji, S. (2018). A review of design science research in information systems: Concept, process, outcome, and evaluation. *Pacific Asia Journal of the Association for Information Systems, 10*(1), 1-36. https://doi.org/10.17705/1pais.10101

Eekels, J., & Roozenburg, N. (1991). A methodological comparison of the structures of scientific research and engineering design: Their similarities and differences. *Design Studies, 12*(4), 197–203. https://doi.org/10.1016/0142-694X(91)90031-Q

Fischer, C., Winter, R., & Wortmann, F. (2010). Design theory. *Business & Information Systems Engineering, 2*(6), 387–390. https://doi.org/10.1007/s12599-010-0128-2

Gibbert, M., & Ruigrok, W. (2010). The "what" and "how" of case study rigor: Three strategies based on published work. *Organizational Research Methods, 13*(4), 710-737. https://doi.org/10.1177/1094428109351319

Goldsmith, T., & Johnson, P. (2009). Assessing and improving evaluation of aircrew performance. *The International Journal of Aviation Psychology, 12*(3), 223-240. https://doi.org/10.1207/S15327108IJAP1203_3

Gregor, S., & Hevner, A. (2013). Positioning and presenting design science research for maximum impact. *Management Information Systems Quarterly, 37*(2), 337-355. https://doi.org/10.25300/MISQ/2013/37.2.01

Gregor, S., & Jones, D. (2007). The anatomy of a design theory. *Journal of the Association for Information Systems, 8*(5), 312-335. https://doi.org/10.17705/1jais.00129

Hevner, A., March, S., Park, J., & Ram, S. (2004). Design science in information systems research. *Management Information Systems Quarterly, 28*(1), 75-105. https://doi.org/10.2307/25148625

International Civil Aviation Organization (ICAO). (2018). *ICAO Training Report* (No. 1). Retrieved September 28, 2020, from https://www.icao.int/publications/Pages/training-report.aspx?year=2018

Lee, J., Pries-Heje, J., & Baskerville, R. (2011). Theorizing in design science research. In H. Jain, A.P. Sinha, & P. Vitharana (Eds.), *Service-Oriented Perspectives in Design Science Research* (pp. 1-16). Springer-Verlag.

March, S., & Smith, G. (1995). Design and natural science research on information technology. *Decision Support Systems*, *15*(4), 251-266. https://doi.org/10.1016/0167-9236(94)00041-2

Nunamaker, J. F., Jr., Chen, M., & Purdin, T. (1990). Systems development in information systems research. *Journal of Management Information Systems, 7*(3), 89-106. https://doi.org/10.1080/07421222.1990.11517898

Oster, C., Jr., Strong, J., & Zorn, C. (2013). Analyzing aviation safety: Problems, challenges, opportunities. *Research in Transportation Economics, 43*(1), 148-164. https://doi.org/10.1016/j.retrec.2012.12.001

Peffers, K. Tuunanen, T., Rothenberger, M., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of Management Information Systems, 24*(3), 45-77. https://doi.org/10.2753/MIS0742-1222240302

Piirainen, K. & Briggs, R. (2011). Design theory in practice – Making design science research more transparent. In H. Jain, A.P. Sinha, & P. Vitharana (Eds.), *Service-Oriented Perspectives in Design Science Research* (pp. 47-61). Springer-Verlag. https://doi.org/10.1007/978-3-642-20633-7_4

Pope, T. M. (2019). A cost-benefit analysis of pilot training next [Master's thesis, Air Force Institute of Technology]. AFIT Scholar. https://scholar.afit.edu/etd/2314/

Prat, N., Comyn-Wattiau, I., & Akoka, J. (2015). A taxonomy of evaluation methods for information systems artifacts. *Journal of Management Information Systems, 32*(3), 229-267. https://doi.org/10.1080/07421222.2015.1099390

Pries-Heje, J., Baskerville, R., & Venable, J. (2008). Strategies for design science research evaluation. *European Conference on Information Systems 2008 Proceedings.* AIS Electronic Library.

Purao, S. (2013). Truth or dare: The ontology question in design science research. *Journal of Database Management, 24*(3), 51-66. https://doi.org/10.4018/jdm.2013070104

Rothwell, W. J., & Kazanas, H. C. (2008). *Mastering the instructional design process: A systematic approach* (4th ed.). Pfeiffer.

Salas, E., Bowers, C., & Rhodenizer, L. (1998). It is not how much you have but how you use it: Toward a rational use of simulation to support aviation training. *The International Journal of Aviation Psychology, 8*(3), 197-208. https://doi.org/10.1207/s15327108ijap0803_2

Simon, H. (1996). *The sciences of the artificial* (3rd ed.). MIT Press.

Shuffler, M., Salas, E., & Xavier, L. (2010). The design, delivery and evaluation of crew resource management training. In B. Kanki, R. Helmreich, & J. Anca (Eds.), *Crew resource management* (2nd ed., pp. 205-232). Academic Press. https://doi.org/10.1016/B978-0-12-374946-8.10007-X

Straub, D., Boudreau, M.C., & Gefen, D. (2004). Validation guidelines for IS positivist research. *Communications of the Association for Information Systems, 13*(24), 380-427. https://doi.org/10.17705/1CAIS.01324

Vaishnavi, V., & Kuechler, W. (2015). *Design science research methods and patterns: Innovating information and communication technology* (2nd ed.). CRC Press. https://doi.org/10.1201/b18448

Valenta, V. (2018). Effects of airline industry growth on pilot training. *Magazine of Aviation Development 6*(4), 52-56. https://doi.org/10.14311/MAD.2018.04.06

Van Aken, J. (2005). Management research as a design science: Articulating the research products of mode 2 knowledge production in management. *British Journal of Management, 16*(1), 19-36. https://doi.org/10.1111/j.1467-8551.2005.00437.x

Vance, S. M., Gardner-Vandy, K., & Freihoefer, J. A. (2021). Can backward-chained, ab-initio pilot training decrease time to first solo? *Journal of Aviation/Aerospace Education & Research, 30*(1). https://doi.org/10.15394/jaaer.2021.1839

Venable, J., Pries-Heje, J., & Baskerville, R. (2016). FEDS: A framework for evaluation in design science research. *European Journal of Information Systems, 25*(1), 77-89. https://doi.org/10.1057/ejis.2014.36

Walls, J., Widmeyer, G., & El Sawy, O. (1992). Building an information system design theory for vigilant EIS. *Information Systems Research*, *3*(1), 36-59. https://doi.org/10.1287/isre.3.1.36