What Constitutes Effective Step-by-Step Assembly Visualizations? A Systematic Scoping Review and Call for More Empirical Research

Jonas Blattgerste and Thies Pfeiffer

University of Applied Sciences Emden/Leer, Emden, Germany
{jonas.blattgerste,thies.pfeiffer}@hs-emden-leer.de

Abstract. Effective step-by-step assembly instructions depend on visual design characteristics that reduce ambiguity and cognitive load, yet there is no clear consensus on which characteristics contribute to instructional effectiveness. This gap becomes pressing as recent advances in artificial intelligence have increased interest in automatically generating assembly instructions from engineering data and process descriptions. To scope what is already known, we conducted a systematic scoping review of existing research on effective visual assembly instructions. This paper presents our methods and findings, mapping the current state of research, highlighting remaining gaps, and calling for more systematic empirical studies. By scoping existing efforts, we provide a concrete starting point for future work on the visual design of assembly instructions.

Keywords: Assembly · Instructions · Visualizations · Effective · Step · Artificial Intelligence · Manual · Automatic · Authoring · Creation.

1 Introduction

Assembly tasks combine spatial reasoning, sequenced manipulation, and accurate part identification, often under time and quality pressure in industrial settings. Because human vision is central to the interpretation of spatial relations and orientations, visual guidance is particularly well-suited to supporting them.

Effective visual instructions reduce ambiguity and make complex assembly steps easier to interpret. By externalizing intermediate states and required actions, they reduce the cognitive transfer process needed to translate descriptions into concrete actions, or at least make that transfer substantially less demanding [1, 23]. This can lower task completion time and error rates, reduce cognitive load and operator frustration, and improve efficiency and user satisfaction [1]. Their user-sensitive visual design is therefore critical, as effective instructions must make the current action explicit [1, 30], preserve an interpretable view of the task [26], and provide enough information to resolve ambiguity without unnecessary overload [2]. The quality of instructions is especially important because users do not always read procedural instructions beforehand and may skip them entirely when a task appears simple, increasing the risk of errors when instructions are mistimed in use or fail to capture attention altogether [8].

Despite this evident suitability of visual representations for assembly tasks, industrial practice is still often characterized by static and paper-based assembly instructions [28]. Creating effective visual instructions manually is labor-intensive and costly, especially as product variability continuously increases and batch sizes decrease [1]. Consequently, recent advances in artificial intelligence (AI), including generative AI (GenAI), have increased industrial interest in automatically generating assembly instructions from engineering data such as CAD models in combination with formalized work process descriptions [22].

While AI shows promise in supporting this process, generating effective visual assembly instructions is substantially more challenging than improving or generating textual instructions. Several challenges must be addressed before visual assembly instructions can be generated automatically from engineering data: **(1)** the available source data often lacks the semantic connections and task-specific information required; **(2)** there is a fundamental interdependence between the goal and the means of generation—before AI systems can generate effective instructions, we must first define what actually constitutes "effective" assembly instructions, not in terms of desired outcomes such as reduced ambiguity or fewer errors, but in terms of how instructions are visually designed so that these outcomes are achieved (e.g., how a step is segmented, from which viewpoint it is shown, how much detail is displayed, and which visual cues are used); and **(3)** once that goal is defined, we must determine which specific visual design characteristics have to be controlled by the AI to achieve it.

Recent work on automated generation has focused mainly on sequencing assembly steps or simulating part motions, whereas the question of how individual instruction steps should be visually designed has received less systematic attention. At the same time, a broader, non-AI-specific research area has, for decades, examined the visual form of instructions and its effects on human performance. Despite this, there is still no consensus on what constitutes best practices for assembly instructions [18]. This paper focuses on clarifying the second challenge and providing a starting point for the third. We therefore conducted a systematic scoping review to map what is already known about the visual design characteristics of step-by-step assembly instructions and how these characteristics are discussed in the literature in relation to instructional effectiveness. Rather than prescribing specific values for individual characteristics, we aim to map the range of visual design decisions examined in the literature while also indicating where empirical knowledge already exists and where it remains missing. By thinking backwards from the desired results of effective instructions to the visual design characteristics associated with them, we aim to provide a concrete starting point for future research on the visual design of assembly instructions.

2 Methodology

Because this field is interdisciplinary and lacks standardized terminology, we employed a bidirectional snowballing search strategy according to Wohlin et al. [33] rather than a keyword-based database search.

We identified a seed set through a non-representative search (Google Scholar, Google Scholar Labs, and Perplexity), combined with our knowledge of key publications, and selected [1, 14, 16, 17] as the initial seed papers. Forward snowballing relied on citations indexed in Google Scholar [12]; backward snowballing used the Google Scholar PDF Viewer plugin for ad hoc screening of references.

Publications were screened and reviewed by the first author against these inclusion criteria: *Must be written in English*; *Must be a peer-reviewed publication*; *Must be published before 2026*; *Must explicitly investigate, propose, discuss, or evaluate specific visual design parameters contributing to the effectiveness of step-by-step assembly instruction steps*; *Must explicitly address adults as the target audience of the instructions*; and *Must focus on instructions for non-immersive media, excluding works focused on projector-based approaches, AR, or VR.*

2.1 Search Process

Starting from the seed papers, we conducted 2 iterations of bi-directional snowballing. Iteration 1 screened 82 references and 614 citations, yielding 19 and 13 relevant publications, respectively; iteration 2 screened 1115 references and 1543 citations, yielding 13 and 19 additional publications. Across both iterations, we identified 68 publications from 1977 to 2025 that satisfied all eligibility criteria. Figure 1 provides an annual overview of the publications identified.

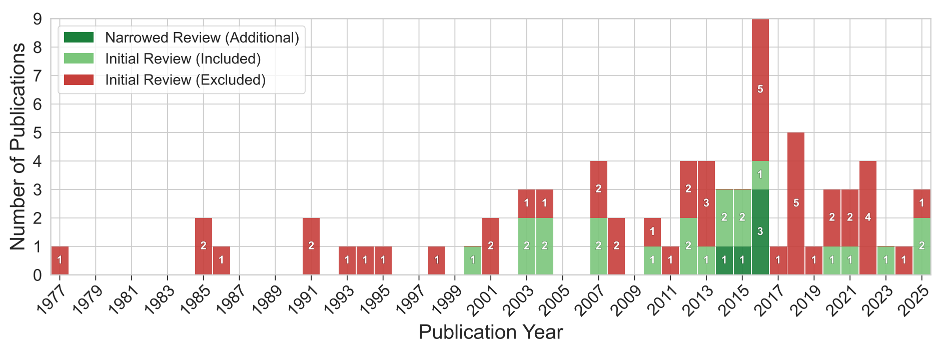

Fig. 1. Publications per year, distinguishing retained and excluded studies from the initial snowballing iterations and empirical studies added after refining the scope.

2.2 Refinement of Scope & Exclusion Criteria

Given the volume of literature identified, which would have exceeded the scope and length limitations of this paper, and the fact that we did not aim for an exhaustive comprehensive review but wanted to scope the state of the literature, we refined our criteria. During the review of the initial set, it appeared that a substantial portion of the publications discuss visual design parameters only tangentially or ground design decisions on citations of prior work or fundamental cognitive principles, effectively propagating existing knowledge without providing new empirical evidence or systematic evaluations for their applications.

To ensure the review focused on new, empirically grounded findings regarding visual effectiveness, we refined our scope and introduced the additional inclusion criterion: *Must empirically investigate or compare specific visual instruction design parameters of a single step and their effects, qualitatively or quantitatively.*

We re-evaluated all 68 publications and found that 21 from the first two snowballing iterations also satisfied this criterion; the complete initial dataset up to this stage is available on GitHub for transparency [4]. Additional bi-directional snowballing then continued until no new eligible studies were identified: iteration 3 screened 332 references and 390 citations, yielding 0 and 2 studies, respectively; iteration 4 screened 73 references and 27 citations, yielding 1 and 0 studies; iteration 5 screened 60 references and 94 citations, yielding 0 and 2 studies; and iteration 6 screened 76 references and 173 citations, yielding no further studies and concluding the search. This resulted in a final corpus of 26 studies.

3 Results

The 26 studies cluster into four recurring themes. Eight studies focused on step structure and action representation, four on viewpoint, perspective, and view control, seven on static, dynamic, and interactive delivery, and seven on information level, detail, and cueing. Across the corpus, the clearest evidence concerns explicit stepwise action depiction and viewpoint alignment, whereas findings on delivery format and information level are more mixed and conditional.

3.1 Step Structure and Action Representation

Multiple studies consistently found that step-by-step, action-oriented diagrams outperform final-state-only, more inferential alternatives in both accuracy and efficiency. Novick and Morse [23] (n=180) showed that step-by-step diagrams improved accuracy and efficiency over less explicit alternatives, with final-state diagrams performing comparably only when the required actions were few and easy to infer. Heiser et al. [15] (n=108) found that participants preferred action-oriented, stepwise 3D depictions featuring arrows and guidelines, and that in the evaluation study, highly rated instructions particularly benefited participants with low spatial ability. These principles were formalized by Agrawala et al. [1] and validated by Heiser et al. [14] in a 30-participant system comparison, who reported roughly 35% faster performance and 50% fewer errors with computer-generated instructions based on them, a finding reiterated by Tversky et al. [31].

Beyond the consistent advantage of stepwise presentation, the literature also addressed how explicitly actions should be externalized and how granularly steps should be segmented. Teeravarunyou and Kitirojpan [30] (n=24) found that step-by-step instructions combined with labels placed directly on the product parts yielded the best time and error performance, while a single exploded-view diagram combining final-state and action information was difficult for novices to interpret. Söderberg et al. [27] (n=41) reported a 10% performance increase after redesigning instructions with better segmentation, separate subassembly views, and visual cues, though multiple simultaneous changes prevent attributing isolated effects. Conversely, Gugolya et al. [10] (n=8) found that the shortened merged-step version was faster in the first session, but participants who began with the semi-detailed instructions improved more and were slightly faster when all participants later used the shortened version, indicating that simplification may be most beneficial after initial familiarization.

3.2 Viewpoint, Perspective, and View Control

The literature consistently indicates that closer alignment between the instructional view and the physical task reduces interpretation effort and improves performance. Schumacher [26] (n=6) observed that stable viewpoints supported backtracking and error correction, whereas compromised views caused confusion. Zimmerman [34] (n=18) found fewer errors and shorter times when users could freely rotate a 3D model rather than viewing a fixed perspective, especially for complex or asymmetric assemblies. Gupta et al. [11] (n=16) reported roughly 14% faster completion times and fewer errors when the instructional view was automatically pose-matched to the physical workspace. Fiorella et al. [9] (n=105 and n=120, across experiments) compared first- and third-person instructional videos and found that first-person perspective improved accuracy and reduced perspective errors, with the strongest advantage on high-complexity tasks.

3.3 Static, Dynamic, and Interactive Delivery

Studies comparing static, dynamic, and interactive formats repeatedly showed that the benefit of dynamic presentation depends on task demands and user characteristics. Animation and video generally improved initial performance: Carroll and Wiebe [5] (n=24) found faster performance and fewer errors for video on easier origami tasks but no advantage on the hardest task; Watson et al. [32] (n=30) found that animation was roughly 56% faster than text in the first build, though static diagrams and animation did not differ significantly overall; and Lušić et al. [20] (n=44) found that dynamic 3D worker information reduced working time and additional instruction lookups compared to static instructions.

However, the animation advantage appears moderated by spatial ability and task complexity. Lee and Shin [19] (n=72) found that animation reduced time and errors specifically for participants with low spatial ability, while static motion cues alone did not improve performance. Castro-Alonso et al. [6] (n=170) found an animation advantage on first-attempt accuracy in one experiment, but the effect was limited in a second, and accuracy was higher when hands were not shown. Chirumalla et al. [7] (n=12) found that video and picture-series instructions were rated best for understanding, with text-only taking about three times longer. In industrial settings, Hartman and Ropp [13] (n=95 across four studies) reported that 2D produced roughly twice as many errors as 3D but found no significant differences for level of detail or delivery mode and that the iPad produced more errors than a computer despite somewhat faster times.

3.4 Information Level, Detail, and Cueing

The literature on information level suggests an inverted-U relationship: both too little and too much detail can hinder performance. Alexander et al. [2] (n=42) found that a designer-curated, intermediate level of detail in line drawings led to significantly faster execution than versions with more or less detail, while Rohe [25] (n=12) found no significant differences across high-, medium-, and low-detail 3D models with 100%, 42%, and 17% of the original mesh faces. Regarding information quantity, Stockinger et al. [28] (n=83) found that high-information conditions significantly reduced documented assembly errors without increasing assembly times, while Stockinger et al. [29] (n=10) found that a less detailed expert mode was over 37% faster for experienced workers on a simple product.

Results for specific visual enhancements were mixed. McAlinden et al. [21] (n=10) reported that pictogram-enhanced instructions lowered build time by roughly 20% and error-correction time by roughly 80%. Ameen et al. [3] (n=40) found only small, non-significant effects of color manipulations on completion time, errors, workload, and frustration, despite a subjective preference for the color-plus-text condition. Park et al. [24] (n=33) reported only marginal support for anticipatory and trajectory cueing on accuracy, with no significant differences for time or cognitive load.

4 Discussion

Across themes, three findings stand out. First, the clearest support exists for stepwise action depiction and viewpoint choices that reduce inference and mental transformation. Step-by-step, action-oriented depictions repeatedly outperformed more inferential alternatives [14, 15, 23, 30], while stable, pose-compatible, freely adjustable, or first-person viewpoints improved orientation and reduced errors [9, 11, 26, 34]. Second, delivery format matters less consistently than how well the chosen medium externalizes motion and spatial relations: dynamic and interactive formats helped in some settings, especially for initial use or specific user groups, but did not uniformly outperform well-designed static alternatives [5, 6, 19, 20, 32]. Third, several intuitive parameters, including color, isolated cueing, and level of detail, remain weakly supported or clearly context-dependent [2, 3, 21, 24, 25, 28, 29]. A practical reading of this is therefore that assembly instructions should first make the current action explicit, preserve a cognitively compatible view, and provide enough information to resolve ambiguity before additional refinements are considered. All this is in line with expectations.

The conditionality is a substantive finding of the review, though, and it is also a clear weakness of the research area as it currently stands. Across studies, recurring moderators such as task complexity, user expertise, spatial ability, familiarization, and properties of the assembly itself shape the observed effects substantially [9, 10, 19, 29, 34]. Yet these moderators were studied piecemeal, across heterogeneous tasks, outcome measures, and analytical approaches, often with small samples and, in several cases, mainly descriptively. This makes it difficult to judge which effects generalize and under what conditions. This fragmentation is also visible bibliographically in Figure 2: the empirical corpus forms only a sparse internal citation network, with many studies linking back to a few earlier anchors rather than building cumulatively on one another, and the cluster of findings around 2014–2016 was followed by literally no direct empirical consolidation. Useful synthesis efforts such as Schumacher [26] and Söderberg et al. [27] help structure the design space and provide some guidance but remain starting points rather than substantiating a stronger shared evidence base.

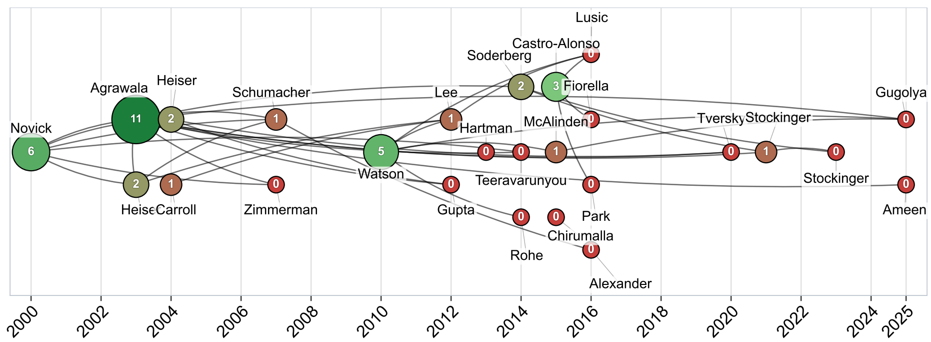

Fig. 2. Internal citation network of the 26 included studies. Bubble size, color, and numbers inside each bubble indicate how often a study is cited by subsequent studies.

This matters especially for endeavors towards AI-based generation of assembly instructions from engineering data. For each step, a system must make concrete choices across many visual parameters—viewpoint, scene composition and occlusion management, rendering style, color and highlighting, action and tool depiction, animation, and annotations—while also responding to contextual factors, such as task complexity, user expertise, or the geometric properties of the parts involved. These parameters exist and must be set whether the literature has studied them or not. Yet for most, the current evidence does not provide robust rules but only scattered indications derived from small studies, bundled comparisons, and task-specific setups. Furthermore, this is also a scholarly inconvenience, which is amplified by AI search engines: once ad hoc or weakly justified design choices are discussed and propagated through published research, they can acquire the appearance of settled knowledge without being sufficiently empirically agreed upon. We therefore see a need for **(1)** more systematic, parameter-level empirical research; **(2)** common evaluation setups and benchmark tasks that allow comparison across studies; and **(3)** controlled variation of the moderators that already appear to matter most in prior work.

5 Conclusion

This scoping review shows that empirical research on effective step-by-step assembly visualizations exists but remains sparse and fragmented. The clearest support concerns explicit stepwise action depiction and viewpoint choices that reduce mental transformation, whereas findings for other design parameters are mixed and appear to depend on moderating factors such as task complexity, user expertise, and spatial ability. Overall, the literature is not yet conclusive enough to provide robust guidance across the many visual parameters of assembly instructions, highlighting a need for more systematic empirical research.

Acknowledgments. This research was partially funded by the German Federal Ministry for Economic Affairs and Energy as part of the TwinMaP project (13IK028K) and is associated with the ArtWork project (ITEA4). It was also partially funded by zukunft. niedersachsen, the joint science funding program of the Lower Saxony Ministry of Science and Culture and the Volkswagen Foundation.

Disclosure of Interests. The authors have no competing interests to declare.

References

1. Agrawala, M., Phan, D., Heiser, J., Haymaker, J., Klingner, J., Hanrahan, P., Tversky, B.: Designing effective step-by-step assembly instructions. ACM Transactions on Graphics **22**(3), 828–837 (2003). https://doi.org/10.1145/882262.882352
2. Alexander, K., Schubert, A., Meng, M.: Does detail matter? the effect of visual detail in line drawings on task execution. Information Design Journal **22**(1), 49–61 (2016). https://doi.org/10.1075/idj.22.1.05ale
3. Ameen, W., Ghaleb, A.M., Mushtaha, R., Aburahma, A., Al-Ahmari, A.: Evaluating instructional formats and performance metrics in manual assembly task. WORK: A Journal of Prevention, Assessment & Rehabilitation **83**(2), 359–373 (2025). https://doi.org/10.1177/10519815251367225
4. Blattgerste, J., Pfeiffer, T.: Effective Assembly Visualizations SLR. https://github.com/jblattgerste/Effective-Assembly-Visualizations-SLR (2026), GitHub repository containing the review dataset and methodology materials.
5. Carroll, L., Wiebe, E.N.: Static versus dynamic presentation of procedural instruction: Investigating the efficacy of video-based delivery. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting. vol. 48, pp. 1059–1063. SAGE Publications (2004). https://doi.org/10.1177/154193120404800712
6. Castro-Alonso, J.C., Ayres, P., Paas, F.: Animations showing lego manipulative tasks: Three potential moderators of effectiveness. Computers & Education **85**, 1–13 (2015). https://doi.org/10.1016/j.compedu.2014.12.022
7. Chirumalla, K., Eriksson, Y., Eriksson, P.: The influence of different media instructions on solving a procedural task. In: Proceedings of the 20th International Conference on Engineering Design (ICED 15). DS 80-11, vol. 11, pp. 173–182 (2015)
8. Eiriksdottir, E., Catrambone, R.: How do people use instructions in procedural tasks? In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting. vol. 52, pp. 673–677. SAGE Publications (2008). https://doi.org/10.1177/154193120805200814

9. Fiorella, L., van Gog, T., Hoogerheide, V., Mayer, R.E.: It's all a matter of perspective: Viewing first-person video modeling examples promotes learning of an assembly task. Journal of Educational Psychology **109**(5), 653–665 (2017). https://doi.org/10.1037/edu0000161
10. Gugolya, M., Varga, V., Medvegy, T., Ruppert, T.: The impact of work instruction simplification on operator performance and learning curve efficiency. In: Advances in Production Management Systems. Cyber-Physical-Human Production Systems: Human-AI Collaboration and Beyond, pp. 148–162. IFIP Advances in Information and Communication Technology, Springer Nature Switzerland (2025). https://doi.org/10.1007/978-3-032-03515-8_11
11. Gupta, A., Fox, D., Curless, B., Cohen, M.: Duplotrack: a real-time system for authoring and guiding duplo block assembly. In: Proceedings of the 25th annual ACM symposium on User interface software and technology. pp. 389–402. ACM (2012). https://doi.org/10.1145/2380116.2380167
12. Gusenbauer, M.: Google scholar to overshadow them all? comparing the sizes of 12 academic search engines and bibliographic databases. Scientometrics **118**(1), 177–214 (2019). https://doi.org/10.1007/s11192-018-2958-5
13. Hartman, N.W., Ropp, T.D.: Examining the use of model-based work instructions in the aviation maintenance environment. In: IFIP International Conference on Product Lifecycle Management. pp. 78–89. Springer (2013). https://doi.org/10.1007/978-3-642-41501-2_9
14. Heiser, J., Phan, D., Agrawala, M., Tversky, B., Hanrahan, P.: Identification and validation of cognitive design principles for automated generation of assembly instructions. In: Proceedings of the working conference on Advanced Visual Interfaces. pp. 311–319. ACM (2004). https://doi.org/10.1145/989863.989917
15. Heiser, J., Tversky, B., Agrawala, M., Hanrahan, P.: Cognitive design principles for visualizations: Revealing and instantiating. In: Proceedings of the Annual Meeting of the Cognitive Science Society. vol. 25, pp. 545–550 (2003)
16. Hinrichsen, S., Bläsing, D.: How to design assembly instructions. In: Human Interaction & Emerging Technologies (IHIET-AI 2022): Artificial Intelligence & Future Applications. IHIET-AI 2022, vol. 23. AHFE International (2022). https://doi.org/10.54941/ahfe100838
17. Kaipa, K., Morato, C., Zhao, B., Gupta, S.K.: Instruction generation for assembly operations performed by humans. In: International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. vol. 45011, pp. 1121–1130. ASME (2012). https://doi.org/10.1115/DETC2012-71266
18. Kuipers, N., Kolbeinsson, A., Thorvald, P.: Appropriate assembly instruction modes: Factors to consider. In: Advances in Manufacturing Technology XXXIV. vol. 15, pp. 27–32. IOS Press (2021). https://doi.org/10.3233/ATDE210007
19. Lee, D.Y., Shin, D.H.: An empirical evaluation of multi-media based learning of a procedural task. Computers in Human Behavior **28**(3), 1072–1081 (2012). https://doi.org/10.1016/j.chb.2012.01.014
20. Lušić, M., Fischer, C., Braz, K.S., Alam, M., Hornfeck, R., Franke, J.: Static versus dynamic provision of worker information in manual assembly: a comparative study using eye tracking to investigate the impact on productivity and added value based on industrial case examples. Procedia CIRP **57**, 504–509 (2016). https://doi.org/10.1016/j.procir.2016.11.087
21. McAlinden, C., Butterfield, J., Cole, J., Burke, R.: Methods for optimal work instruction delivery: pictograms v images. In: 32nd International Manufacturing Conference (IMC 32) (2015)

22. Meyer, F., Freitag, L., Hinrichsen, S., Niggemann, O.: Potentials of large language models for generating assembly instructions. In: 2024 IEEE 29th International Conference on Emerging Technologies and Factory Automation (ETFA). pp. 1–8. IEEE (2024). https://doi.org/10.1109/ETFA61755.2024.10710806
23. Novick, L.R., Morse, D.L.: Folding a fish, making a mushroom: The role of diagrams in executing assembly procedures. Memory & Cognition **28**(7), 1242–1256 (2000). https://doi.org/10.3758/BF03211824
24. Park, S., Lee, J.G., Kim, S.J., Shin, D.H.: The effect of visual cueing in 3d animations for learning procedural-manipulative tasks: From the perspective of cognitive load theory. In: Proceedings of the International Conference on Internet of Things and Cloud Computing. pp. 1–4. ICC '16, ACM (2016). https://doi.org/10.1145/2896387.2896419
25. Rohe, N.: Evaluating optimum levels of detail for 3D interactive aviation maintenance instructions. Master's thesis, Purdue University (2014), Open Access Theses 374. https://docs.lib.purdue.edu/open_access_theses/374
26. Schumacher, P.: Creating effective illustrations for pictorial assembly instructions. Information Design Journal **15**(2), 97–109 (2007). https://doi.org/10.1075/idj.15.2.01sch
27. Söderberg, C., Johansson, A., Mattsson, S.: Development of simple guidelines to improve assembly instructions and operator performance. In: Proceedings of the Sixth Swedish Production Symposium (2014)
28. Stockinger, C., Polanski-Schräder, L., Subtil, I.: The effect of information level of digital worker guidance systems on assembly performance, user experience and strain. Applied Ergonomics **106**, 103896 (2023). https://doi.org/10.1016/j.apergo.2022.103896
29. Stockinger, C., Stuke, F., Subtil, I.: User-centered development of a worker guidance system for a flexible production line. Human Factors and Ergonomics in Manufacturing & Service Industries **31**(5), 532–545 (2021). https://doi.org/10.1002/hfm.20901
30. Teeravarunyou, S., Kitirojpan, P.: Usability of assembly instructions: A case study of portable toilet cardboard. In: Proceedings of the 3rd South East Asian Network of Ergonomics Societies International Conference (2014), Singapore
31. Tversky, B., Agrawala, M., Heiser, J., Lee, P., Hanrahan, P., Phan, D., Stolte, C., Daniel, M.P.: Cognitive design principles for automated generation of visualizations. In: Applied Spatial Cognition, pp. 53–74. Psychology Press (2020). https://doi.org/10.4324/9781003064350-3
32. Watson, G., Butterfield, J., Curran, R., Craig, C.: Do dynamic work instructions provide an advantage over static instructions in a small scale assembly task? Learning and Instruction **20**(1), 84–93 (2010). https://doi.org/10.1016/j.learninstruc.2009.05.001
33. Wohlin, C.: Guidelines for snowballing in systematic literature studies and a replication in software engineering. In: Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering. pp. 1–10. EASE '14, ACM (2014). https://doi.org/10.1145/2601248.2601268
34. Zimmerman, G.W.: Some assembly required-effectiveness of interactive 3d graphics on mobile devices for object assembly. In: International Conference on Computer Graphics Theory and Applications. vol. 1, pp. 191–196. SCITEPRESS (2007). https://doi.org/10.5220/0002084301910196