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Studies into interactive didactic approaches for learning software design using UML

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Bibliography

- [1] Ritu Agarwal and AP Sinha. Object-oriented modeling with UML: a study of developers' perceptions. *Communications of the ACM*, 46(9):248–256, 2003. (cited on page 79).
- [2] Seiko Akayama, Marion Brandsteidl, Birgit Demuth, Kenji Hisazumi, Timothy C Lethbridge, Perdita Stevens, and Dave R. Stikkolorum. Tool use in software modelling education: state of the art and research directions. In *the Educators' Symposium co-located with ACM/IEEE 16th International Conference on Model Driven Engineering Languages and Systems (MODELS 2013)*, 2013. (cited on pages 8, 63, 65, 104, 117 and 145).
- [3] Vincent Aleven and Kenneth R Koedinger. Limitations of student control: Do students know when they need help? In *International Conference on Intelligent Tutoring Systems*, pages 292–303. Springer, 2000. (cited on page 170).
- [4] Vincent Aleven, Elmar Stahl, Silke Schworm, Frank Fischer, and Raven Wallace. Help seeking and help design in interactive learning environments. *Review of educational research*, 73(3):277–320, 2003. (cited on page 170).
- [5] Scott W. Ambler. Agile model driven development is good enough. *IEEE Software*, 20(5):71–72, 2003. (cited on pages 110 and 190).
- [6] Helen Anckar. Providing automated feedback on software design for novice designers. BSc thesis, Goteborg University, 2015. (cited on page 153).
- [7] John R Anderson, Frederick G Conrad, and Albert T Corbett. Skill acquisition and the lisp tutor. *Cognitive Science*, 13(4):467–505, 1989. (cited on page 170).
- [8] Cynthia Andres and Kent Beck. Extreme programming explained: Embrace change. *Reading: Addison-Wesley Professional*, 2004. (cited on page 110).

- [9] Nikolaos Avouris, Vassilis Komis, Georgios Fiotakis, Meletis Margaritis, and Eleni Voyiatzaki. Logging of fingertip actions is not enough for analysis of learning activities. In *12th Int. Conf. AI Edu. (AIED 05) Workshop 1: Usage analysis in learning systems*, pages 1–8, 2005. (cited on page 79).
- [10] Nilufar Baghaei and Antonija Mitrovic. COLLECT-UML : Supporting Individual and Collaborative Learning of UML Class Diagrams in a Constraint-Based Intelligent Tutoring System. In R. Khosla, R. Hewlett & L. Jain (Eds.) *Proc. KES*, pages 458–464, 2005. (cited on page 169).
- [11] Nilufar Baghaei, Antonija Mitrovic, and Warwick Irwin. Supporting collaborative learning and problem-solving in a constraint-based CSCL environment for UML class diagrams. *International Journal of Computer-Supported Collaborative Learning*, 2(2-3):159–190, 2007. (cited on page 66).
- [12] Lut Baten. The c-test revisited a freeware package for placing efl students of business english in the new bachelor-master structure. *BELL: Belgian Journal of English Language and Literatures*, 2:301–315, 2004. (cited on page 30).
- [13] Mordechai Ben-Ari. Constructivism in computer science education. *Journal of Computers in Mathematics and Science Teaching*, 20(1):45–74, 2001. (cited on page 108).
- [14] Jens Bennedssen and Michael E. Caspersen. Abstraction ability as an indicator of success for learning computing science? In *Proceedings of the Fourth international Workshop on Computing Education Research, ICER '08*, pages 15–26, New York, NY, USA, 2008. ACM. (cited on page 27).
- [15] Marc Berges, Andreas Mühling, and Peter Hubwieser. The gap between knowledge and ability. In *Proceedings of the 12th Koli Calling international conference on computing education research*, pages 126–134. ACM, 2012. (cited on page 44).
- [16] Gustav Bergström. Using machine learning to evaluate the layout quality of uml class diagrams. M.sc. thesis, Chalmers and Göteborg University, Sweden, April 2021. supervisor: M.R.V. Chaudron. (cited on page 167).
- [17] Weiyi Bian, Omar Alam, and Jörg Kienzle. Automated grading of class diagrams. In *Proceedings of the Educators' Symposium at the 22nd International Conference on Model Driven Engineering Languages and Systems*, 2019. (cited on page 153).
- [18] Paulo Blikstein. Using learning analytics to assess students' behavior in open-ended programming tasks. In *Proc. 1st int. conf. learning analytics and knowledge*, pages 110–116. ACM, 2011. (cited on page 79).
- [19] Narasimha Bolloju and Felix S.K. Leung. Assisting novice analysts in developing quality conceptual models with UML. *Communications of the ACM*, 49(7):108–112, 2006. (cited on page 110).

- [20] Grady Booch. Object-oriented design. *ACM SIGAda Ada Letters*, 1(3):64–76, 1982. (cited on pages 4 and 7).
- [21] Nadia Boudewijn. Automated grading of java assignments. Master’s thesis, Utrecht University, The Netherlands, 2016. (cited on page 154).
- [22] Martin M Broadwell. Teaching for learning (xvi). *The Gospel Guardian*, 20(41):1–3, 1969. (cited on page 214).
- [23] PJ Burton and RE Bruhn. Using UML to facilitate the teaching of object-oriented systems analysis and design. *Journal of Computing Sciences in Colleges*, 19(3):278–290, 2004. (cited on page 41).
- [24] Weiqin Chen, Roger Heggernes Pedersen, and Øystein Pettersen. CoLeMo: A collaborative learning environment for UML modelling. *Interactive Learning Environments*, 14(May 2014):233–249, 2006. (cited on pages 66 and 169).
- [25] S R Chidamber and C F Kemerer. A metrics suite for object oriented design. *IEEE Transactions on Software Engineering*, 20(6):476–493, 1994. (cited on pages 53 and 167).
- [26] Jan Claes, Irene Vanderfeesten, Jakob Pinggera, HajoA. Reijers, Barbara Weber, and Geert Poels. A visual analysis of the process of process modeling. *Information Systems and e-Business Management*, 13(1):147–190, 2015. (cited on page 93).
- [27] Jan Claes, Irene Vanderfeesten, Hajo a Reijers, Jakob Pinggera, Matthias Weidlich, Stefan Zugal, Dirk Fahland, Barbara Weber, and Jan Mendling. Tying Process Model Quality to the Modeling Process : The Impact of Structuring , Movement , and Speed Background on the Process of Process Modeling. *10th International Conference, BPM 2012, Tallinn, Estonia, September 3-6, 2012. Proceedings*, pages 1–16, 2012. (cited on page 79).
- [28] J. Cohen. *Statistical power analysis for the behavioral sciences*. Erlbaum, 1988. (cited on page 32).
- [29] Eric Crahen, Carl Alphonse, and Phil Ventura. QuickUML: a beginner’s UML tool. In *OOPSLA ’02 Companion of the 17th annual ACM SIGPLAN conference on Object-oriented programming, systems, languages, and applications*, OOPSLA ’02, pages 62–63, NY, USA, 2002. ACM New York. (cited on page 66).
- [30] Holger Danielsiek, Jan Vahrenhold, Peter Hubwieser, Johannes Krugel, Johannes Magenheimer, Laura Ohrndorf, Daniel Ossenschmidt, and Niclas Schaper. Undergraduate teaching assistants in computer science: Teaching-related beliefs, tasks, and competences. In *IEEE Global Engineering Education Conference, EDUCON*, pages 718–725, 2017. (cited on pages 128 and 148).

- [31] Oswald de Bruin. The art of software design, creating an educational game teaching software design. Master's thesis, Leiden University, 2012. (cited on page 34).
- [32] Birgit Demuth and Dave R. Stikkolorum, editors. *Proceedings of the MODELS Educators Symposium co-located with the ACM/IEEE 17th International Conference on Model Driven Engineering Languages and Systems (MODELS 2014), Valencia, Spain, September 29, 2014*, volume 1346 of *CEUR Workshop Proceedings*. CEUR-WS.org, 2014. No citations.
- [33] John Dewey. *Experience and education*. Simon and Schuster, 2007. (cited on page 44).
- [34] Serkan Dinçer and Ahmet Doğanay. The effects of multiple-pedagogical agents on learners' academic success, motivation, and cognitive load. *Computers and Education*, 111:74–100, 2017. (cited on page 172).
- [35] Brian Dobing and Jeffrey Parsons. Dimensions of uml diagram use: a survey of practitioners. *Journal of Database Management (JDM)*, 19(1):1–18, 2008. (cited on page 6).
- [36] João M Fernandes and Sónia M Sousa. Playscrum—a card game to learn the scrum agile method. In *Games and Virtual Worlds for Serious Applications (VS-GAMES), 2010 Second International Conference on*, pages 52–59. IEEE, 2010. (cited on page 191).
- [37] Kiko Fernandez-Reyes, Dave Clarke, and Janina Hornbach. The impact of opt-in gamification on students' grades in a software design course. *21st ACM/IEEE International Conference on Model Driven Engineering Languages and Systems: Companion Proceedings, MODELS-Companion 2018*, 3:90–97, 2018. (cited on page 44).
- [38] L Dee Fink. *Creating significant learning experiences: An integrated approach to designing college courses*. John Wiley & Sons, 2013. (cited on page 10).
- [39] Scott Freeman, Sarah L Eddy, Miles McDonough, Michelle K Smith, Nnadozie Okoroafor, Hannah Jordt, and Mary Pat Wenderoth. Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23):8410–8415, 2014. (cited on page 146).
- [40] Fabrice Gibert-Darras, Elisabeth Delozanne, Françoise Le Calvez, Agathe Merceron, Jean-Marc Labat, and Fabrice Vandebrouck. Towards a design pattern language to track students' problem-solving abilities. In *12th Int. Conf. AI Edu. (AIED 05) Workshop 1: Usage analysis in learning systems*, page 33, 2005. (cited on page 79).

- [41] Jos Groenewegen, Stijn Hoppenbrouwers, and Erik Proper. Playing archimate models. In *Enterprise, Business-Process and Information Systems Modeling*, volume 50 of *Lecture Notes in Business Information Processing*, pages 182–194. Springer Berlin Heidelberg, 2010. (cited on page 43).
- [42] Agneta Gulz and Magnus Haake. Design of animated pedagogical agents - A look at their look. *International Journal of Human Computer Studies*, 64(4):322–339, 2006. (cited on page 172).
- [43] Magnus Haake and Agneta Gulz. A look at the roles of look & roles in embodied pedagogical agents - A user preference perspectivenet. *International Journal of Artificial Intelligence in Education*, 19(1):39–71, 2009. (cited on page 172).
- [44] Patricia L. Hardré. Instructional design as a professional development tool-of-choice for graduate teaching assistants. *Innovative Higher Education*, 30(3):163–175, 2005. (cited on page 128).
- [45] Patricia L. Hardré and Alicia O. Burris. What contributes to teaching assistant development: Differential responses to key design features. *Instructional Science*, 40(1):93–118, 2012. (cited on page 128).
- [46] R Harrison, S J Counsell, and R V Nithi. An investigation into the applicability and validity of object-oriented design metrics. *Empirical Software Engineering*, 3(3):255–273, 1998. (cited on pages 60 and 167).
- [47] Robert W Hasker. UMLGrader: an automated class diagram grader. *Journal of Computing Sciences in Colleges*, pages 47–54, 2011. (cited on page 153).
- [48] Robert W Hasker and Mike Rowe. UMLint: Identifying defects in uml diagrams. In *American Society for Engineering Education*. American Society for Engineering Education, 2011. (cited on page 153).
- [49] J. Hattie and H. Timperley. The Power of Feedback. *Review of Educational Research*, 77(1):81–112, mar 2007. (cited on pages 59, 146, 171, 176 and 181).
- [50] Orit Hazzan and Jeff Kramer. Assessing abstraction skills. *Communications of the ACM*, 59(12):43–45, 2016. (cited on pages 12 and 108).
- [51] Peter B. Henderson. Mathematical reasoning in software engineering education. *Commun. ACM*, 46(9):45–50, September 2003. (cited on page 27).
- [52] Peter B. Henderson. Math counts: Mathematical reasoning in computing education. *ACM Inroads*, 1(3):22–23, September 2011. (cited on page 27).
- [53] Peter B. Henderson. Mathematical reasoning in computing education ii. *ACM Inroads*, 2(1):23–24, February 2011. (cited on page 27).

- [54] Alan Hevner and Samir Chatterjee. *Design Science Research in Information Systems*, pages 9–22. Springer US, Boston, MA, 2010. (cited on page 173).
- [55] Shuhei Hiya, Kenji Hisazumi, Akira Fukuda, and Tsuneo Nakanishi. clooca: Web based tool for domain specific modeling. In *Demos/Posters/StudentResearch@MoDELS*, pages 31–35, 2013. (cited on page 67).
- [56] Ting-Chia Hsu, Shao-Chen Chang, and Yu-Ting Hung. How to learn and how to teach computational thinking: Suggestions based on a review of the literature. *Computers & Education*, 126:296–310, 2018. (cited on page 12).
- [57] Jeff Irvine. A framework for comparing theories related to motivation in education. *Research in Higher Education Journal*, 35, 2018. (cited on page 10).
- [58] Ivar Jacobson. *Object-oriented software engineering: a use case driven approach*. Pearson Education India, 1993. (cited on page 4).
- [59] W Lewis Johnson and Jeff W Rickel. Animated Pedagogical Agents: Face-to-Face Interaction in Interactive Learning Environments. *International Journal of Artificial Intelligence in Education*, 11:47–78, 2000. (cited on page 66).
- [60] Rodi Jolak, Boban Vesin, Marcus Isaksson, and Michel R.V. Chaudron. Towards a new generation of software design environments: Supporting the use of informal and formal notations with octouml. In *Second International Workshop on Human Factors in Modeling (HuFaMo 2016)*. CEUR-WS, pages 3–10, 2016. (cited on page 67).
- [61] Goda Jusaite, Pim Sanders, Damani Lawson, Koen van Polanen, Hani Al-Ers, and Dave R. Stikkolorum. Improving the quality of online collaborative learning for software engineering students. In *International Academic Conference on Teaching, Learning and E-learning*, pages 8–15, 2020. No citations.
- [62] Hermann Kaindl. Difficulties in the transition from OO analysis to design. *IEEE Software*, 16(5):94–102, 1999. (cited on pages 12 and 190).
- [63] Slava Kalyuga. Enhancing instructional efficiency of interactive e-learning environments: A cognitive load perspective. *Educational Psychology Review*, 19(3):387–399, 2007. (cited on page 171).
- [64] Bilal Karasneh, Dave R. Stikkolorum, Enrique Larios, and Michel R.V. Chaudron. Quality assessment of UML class diagrams. In *Proc. Educators' Symp at MoDELS*, 2015. No citations.
- [65] Barbara a. Kitchenham, Shari L Pfleeger, Lesley M Pickard, Peter W Jones, David C Hoaglin, Khaled El Emam, and Jarrett Rosenberg. Preliminary guidelines for empirical research in software engineering. *IEEE Transactions on Software Engineering*, 28(8):721–734, 2002. (cited on page 14).

- [66] Andrew J Ko, Brad A Myers, Michael J Coblenz, and Htet Htet Aung. An exploratory study of how developers seek, relate, and collect relevant information during software maintenance tasks. *Software Engineering, IEEE Transactions on*, 32(12):971–987, 2006. (cited on page 79).
- [67] David A Kolb. *Experiential learning: Experience as the source of learning and development*. FT Press, 2014. (cited on pages 78 and 92).
- [68] Michael Kölling. Using bluej to introduce programming. In *Reflections on the Teaching of Programming*, pages 98–115. Springer, 2008. (cited on page 44).
- [69] Jeff Kramer. Is abstraction the key to computing? *Communications of the ACM*, 50(4):36–42, April 2007. (cited on pages 4, 12, 26, 40, 92, 108 and 166).
- [70] David R. Krathwohl. A revision of bloom’s taxonomy: An overview. *Theory Into Practice*, 41(4):212–218, 2002. (cited on pages 10 and 44).
- [71] A. Krivitsky. A multi-team, full-cycle, product-oriented scrum simulation with lego bricks – the small & medium business edition v2.0., jun October 2011. (cited on page 190).
- [72] Han Lai and Wenjuan Xin. An experimental research of the pair programming in java programming course. *Proceeding of the International Conference on eEducation Entertainment and eManagement*, pages 257–260, 2011. (cited on pages 108, 110 and 117).
- [73] Craig Larman. *Applying UML and Patterns: An Introduction to Object Oriented Analysis and Design and Iterative Development*. Pearson Education India, 2012. (cited on page 7).
- [74] Michael J. Lee and Andrew J. Ko. Personifying programming tool feedback improves novice programmers’ learning. In *Proceedings of the seventh international workshop on Computing education research - ICER ’11*, page 109, New York, New York, USA, 2011. ACM Press. (cited on page 43).
- [75] Michael J. Lee and Andrew J. Ko. A demonstration of gadget, a debugging game for computing education. *Proceedings of IEEE Symposium on Visual Languages and Human-Centric Computing, VL/HCC*, pages 211–212, 2014. (cited on pages 43 and 59).
- [76] Lego4scrum. <https://www.lego4scrum.com>. [Online; accessed 20-March-2016]. (cited on pages 189, 190 and 219).
- [77] T.C. Lethbridge. What knowledge is important to a software professional? *Computer*, 33(5):44–50, 2000. (cited on page 27).

- [78] Timothy C Lethbridge. Teaching modeling using Umple: Principles for the development of an effective tool. *Software Engineering Education and Training (CSEE&T), 2014 IEEE 27th Conference on*, pages 23–28, 2014. (cited on page 67).
- [79] F. Leung and N. Bolloju. Analyzing the Quality of Domain Models Developed by Novice Systems Analysts. *Proceedings of the 38th Annual Hawaii International Conference on System Sciences*, 00(C):188b–188b, 2005. (cited on pages 108, 110 and 127).
- [80] Felix Leung and Narasimha Bolloju. Analyzing the quality of domain models developed by novice systems analysts. In *System Sciences, 2005. HICSS'05. Proc. of the 38th Annual Hawaii Int. Conf. on*, pages 188b–188b. IEEE, 2005. (cited on pages 40, 92, 93 and 166).
- [81] C. Lewis. Using the "thinking-aloud" method in cognitive interface design. Technical report, IBM T.J. Watson Research Center, 1982. (cited on pages 15 and 45).
- [82] Clayton Lewis and John Rieman. Task-centered user interface design. *A Practical Introductio*, 1993. (cited on page 94).
- [83] Grischa Liebel, Rogardt Heldal, and Jan Philipp Steghofer. Impact of the use of industrial modelling tools on modelling education. *Proceedings - 2016 IEEE 29th Conference on Software Engineering Education and Training, CSEEandT 2016*, pages 18–27, 2016. (cited on pages 8, 118 and 145).
- [84] Zhiyi Ma, Chih-yi Yeh, Huihong He, and Hongjie Chen. A Web Based UML Modeling Tool with Touch Screens. In *Proceedings of the 29th ACM/IEEE international conference on Automated software engineering*, pages 835–838, 2014. (cited on page 67).
- [85] Ntima Mabanza and Lizette de Wet. Determining the usability effect of pedagogical interface agents on adult computer literacy training. In *E-Learning Paradigms and Applications*, pages 145–183. Springer, 2014. (cited on page 71).
- [86] Philip Machanick. A social construction approach to computer science education. *Computer Science Education*, 17(1):1–20, 2007. (cited on page 11).
- [87] Maíra R Marques, Alcides Quispe, and Sergio F Ochoa. A systematic mapping study on practical approaches to teaching software engineering. In *2014 IEEE Frontiers in Education Conference (FIE) Proceedings*, pages 1–8. IEEE, 2014. (cited on pages 11 and 40).
- [88] Robert C Martin. Design Principles and Design Patterns. *Object Mentor*, pages 1–34, 2000. (cited on pages 7, 29 and 44).

- [89] Ian McChesney. Three Years of Student Pair Programming – Action Research Insights and Outcomes. *Proceedings of the 47th ACM Technical Symposium on Computer Science Education (SIGCSE '16)*, pages 84–89, 2016. (cited on pages [108](#), [110](#) and [117](#)).
- [90] Sabine Moisan and Jean Paul Rigault. Teaching object-oriented modeling and UML to various audiences. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 6002 LNCS:40–54, 2010. (cited on page [108](#)).
- [91] Anders I. Mørch, Silje Jondahl, and Jan A. Dolonen. Supporting conceptual awareness with pedagogical agents. *Information Systems Frontiers*, 7(1):39–53, 2005. (cited on page [172](#)).
- [92] Robert Moser. A fantasy adventure game as a learning environment. why learning to program is so difficult and what can be done about it. *ITiCSE 97 Proceedings of the 2nd conference on Integrating technology into computer science education*, 29(3):114–116, 1997. (cited on page [52](#)).
- [93] Madlen Müller-Wuttke and Nicholas H Müller. Cognitive load levels while learning with or without a pedagogical agent. In *International Conference on Human-Computer Interaction*, pages 266–276. Springer, 2019. (cited on page [173](#)).
- [94] Gunter Mussbacher, Daniel Amyot, Ruth Breu, Jean-Michel Bruel, Betty HC Cheng, Philippe Collet, Benoit Combemale, Robert B France, Rogardt Haldal, James Hill, et al. The relevance of model-driven engineering thirty years from now. In *Model-Driven Engineering Languages and Systems*, pages 183–200. Springer, 2014. (cited on pages [3](#), [13](#) and [188](#)).
- [95] Valbona Muzaka. The niche of graduate teaching assistants (GTAs): Perceptions and reflections. *Teaching in Higher Education*, 14(1):1–12, 2009. (cited on page [126](#)).
- [96] Sharon Nelson-Le Gall. Help-seeking: An understudied problem-solving skill in children. *Developmental review*, 1(3):224–246, 1981. (cited on page [170](#)).
- [97] Hafeez Osman, Arjan van Zadelhoff, Dave R. Stikkolorum, and Michel R.V. Chaudron. UML class diagram simplification: what is in the developer’s mind? In *Proceedings of the Second Edition of the International Workshop on Experiences and Empirical Studies in Software Modelling*, page 5. ACM, 2012. No citations.
- [98] Maria Paasivaara, Ville Heikkilä, Casper Lassenius, and Towo Toivola. Teaching students scrum using lego blocks. In *Companion Proceedings of the 36th International Conference on Software Engineering*, pages 382–391. ACM, 2014. (cited on page [190](#)).

- [99] Chris Park. The graduate teaching assistant (GTA): lessons from North American experience. *Teaching in Higher Education*, 9(3):349–361, 2004. (cited on page 127).
- [100] Óscar Pastor, Sergio España, and Jose Ignacio Panach. Learning Pros and Cons of Model-Driven Development in a Practical Teaching Experience. In *International Conference on Conceptual Modeling*, pages 218–227. Springer, 2016. (cited on page 110).
- [101] Elizabeth Ann Patitsas. A case study of the development of CS teaching assistants and their experiences with team teaching. In *Proceedings of the 13th Koli Calling International Conference on Computing Education Research - Koli Calling '13*, pages 115–124, 2013. (cited on page 128).
- [102] Dewayne E Perry, Adam a Porter, and Lawrence G Votta. Empirical Studies of Software Engineering : A Roadmap. *Proceedings of the conference on The future of Software engineering ICSE 00*, pages 345–355, 2000. (cited on page 14).
- [103] Jakob Pinggera, Pnina Soffer, Stefan Zugal, Barbara Weber, Matthias Weidlich, Dirk Fahland, Hajo a. Reijers, and Jan Mendling. Modeling styles in business process modeling. *Lecture Notes in Business Information Processing*, 113 LNBIP:151–166, 2012. (cited on page 79).
- [104] M Prensky. *Digital game-based learning*. McGraw-Hill & Paragon House, New York, 2001. (cited on page 42).
- [105] Marc Prensky. Digital Game-Based Learning. *Computers in Entertainment (CIE)*, 1(1):1–4, 2003. (cited on page 42).
- [106] Andrew K Przybylski, C Scott Rigby, and Richard M Ryan. A motivational model of video game engagement. *Review of General Psychology*, 14(2):154–166, 2010. (cited on pages 52, 59 and 218).
- [107] Truong Ho Quang. LogViz - visual log analyzer. <https://gitlab.com/truonghoquang/LogVisualizer>, 2015. [Online; accessed 8-March-2015]. (cited on page 71).
- [108] Ebrahim Rahimi and Dave R. Stikkolorum, editors. *CSERC '19: Proceedings of the 8th Computer Science Education Research Conference*, New York, NY, USA, 2019. Association for Computing Machinery. No citations.
- [109] Ervin Ramollari and Dimitris Dranidis. StudentUML: An educational tool supporting object-oriented analysis and design. . . . of the 11th Panhellenic Conference on . . . , pages 363–373, 2007. (cited on page 66).
- [110] John Raven. The raven’s progressive matrices: change and stability over culture and time. *Cognitive psychology*, 41(1):1–48, 2000. (cited on page 31).

- [111] Maryam Razavian, Antony Tang, Rafael Capilla, and Patricia Lago. In two minds: how reflections influence software design thinking. *Journal of Software: Evolution and Process*, 28(6):394–426, 2016. (cited on page 110).
- [112] Arthur J. Riel. *Object-Oriented Design Heuristics*. Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, 1st edition, 1996. (cited on page 29).
- [113] Patricia Roberts. Abstract thinking: a predictor of modelling ability? In *Educators Symposium of the ACM/IEEE 12th International Conference on Model Driven Engineering Languages and Systems*, pages 753–754. Springer, 2009. (cited on pages 27, 40, 92 and 166).
- [114] Anthony Robins, Janet Rountree, and Nathan Rountree. Learning and teaching programming: A review and discussion. *Computer science education*, 13(2):137–172, 2003. (cited on page 44).
- [115] James Rumbaugh, Michael Blaha, William Premerlani, Frederick Eddy, William E. Lorensen, et al. *Object-oriented modeling and design*, volume 199. Prentice-hall Englewood Cliffs, NJ, 1991. (cited on page 4).
- [116] Bernhard Rumpe. Agile Modeling with the UML 1 Portfolio of Software Engineering Techniques. *Radical Innovations of Software and Systems Engineering in the Future. 9th International Workshop*, pages 297–309, 2004. (cited on pages 110 and 190).
- [117] Bernhard Rumpe. *Agile Modellierung mit UML: Codegenerierung, Testfälle, Refactoring*. Springer-Verlag, 2012. (cited on page 190).
- [118] Adrian Rusu, Robert Russell, Remo Cocco, and Spence DiNicolantonio. Introducing object oriented design patterns through a puzzle-based serious computer game. In *2011 Frontiers in Education Conference (FIE)*, pages F1H–1. IEEE, 2011. (cited on page 43).
- [119] Andreas Schroeder, Annabelle Klarl, Philip Mayer, and Christian Kroiss. Teaching agile software development through lab courses. *IEEE Global Engineering Education Conference, EDUCON*, pages 1177–1186, 2012. (cited on page 190).
- [120] Noah L Schroeder. The influence of a pedagogical agent on learners’ cognitive load. *Journal of Educational Technology & Society*, 20(4):138–147, 2017. (cited on pages 172 and 173).
- [121] Swapneel Sheth, Jonathan Bell, and Gail Kaiser. A competitive-collaborative approach for introducing software engineering in a cs2 class. In *2013 26th International Conference on Software Engineering Education and Training (CSEE&T)*, pages 41–50. IEEE, 2013. (cited on page 42).

- [122] Shin-shing Shin. A Study on the Difficulties of Learning Phase Transition in Object-Oriented Analysis and Design From the Viewpoint of Semantic Distance. *IEEE*, 58(2):1–7, 2014. (cited on pages [12](#), [108](#), [121](#) and [190](#)).
- [123] Ricardo Azambuja Silveira, Eduardo Rodrigues Gomes, and Rosa Maria Viccari. Intelligent learning objects: An agent approach to create reusable intelligent learning environments with learning objects. *Advances in Artificial Intelligence - Iberamia-Sbia 2006, Proceedings*, pages pp. 17–26, 2006. (cited on page [71](#)).
- [124] J. Soler, I. Boada, F. Prados, J. Poch, and R. Fabregat. A web-based e-learning tool for UML class diagrams. *2010 IEEE Education Engineering Conference, EDUCON 2010*, pages 973–979, 2010. (cited on page [67](#)).
- [125] Minseok Song and W.M.P. van der Aalst. Supporting process mining by showing events at a glance. In *Proceedings of 17th Annual Workshop on Information Technologies and Systems*, pages 139–147, 2007. (cited on page [93](#)).
- [126] Mauricio Ronny De Almeida Souza, Lucas Furtini Veado, Renata Teles Moreira, Eduardo Magno Lages Figueiredo, and Heitor Augustus Xavier Costa. Games for learning: bridging game-related education methods to software engineering knowledge areas. In *2017 IEEE/ACM 39th International Conference on Software Engineering: Software Engineering Education and Training Track (ICSE-SEET)*, pages 170–179. IEEE, 2017. (cited on pages [42](#) and [44](#)).
- [127] Shashank Srikant and Varun Aggarwal. A system to grade computer programming skills using machine learning. *Proceedings of the 20th ACM SIGKDD international conference on Knowledge discovery and data mining - KDD '14*, pages 1887–1896, 2014. (cited on page [153](#)).
- [128] Thomas Staubitz, Hauke Klement, Jan Renz, Ralf Teusner, and Christoph Meinel. Towards practical programming exercises and automated assessment in massive open online courses. In *Teaching, Assessment, and Learning for Engineering (TALE), 2015 IEEE International Conference on*, pages 23–30. IEEE, 2015. (cited on page [44](#)).
- [129] Christoph Johann Stettina and Werner Heijstek. Necessary and neglected?: An empirical study of internal documentation in agile software development teams. In *Proceedings of the 29th ACM International Conference on Design of Communication, SIGDOC '11*, pages 159–166, New York, NY, USA, 2011. ACM. (cited on page [188](#)).
- [130] Dave R. Stikkolorum. Online Experiment with WebUML : recording difficulties and strategies of students. Technical report, Leiden University, LIACS, 07 2015. (cited on page [94](#)).
- [131] Dave R. Stikkolorum and Michel R.V. Chaudron. A workshop for integrating UML modelling and agile development in the classroom. In *Proceedings of the*

- Computer Science Education Research Conference 2016*, pages 4–11. ACM, 2016. (cited on pages 109, 110 and 116).
- [132] Dave R. Stikkolorum and Michel R.V. Chaudron. Teaching of agile uml modelling: Recommendations from students' reflections. In *Proceedings of the 20th Ibero-American Conference on Software Engineering, Buenos Aires, Argentina, 2017*. (cited on pages 127, 145 and 147).
- [133] Dave R. Stikkolorum, Michel R.V. Chaudron, and Oswald de Bruin. The art of software design, a video game for learning software design principles. In *Gamification Contest MODELS'12 Innsbruck*, 2012. (cited on page 34).
- [134] Dave R. Stikkolorum, F. Gomes de Oliveira Neto, and Michel R.V. Chaudron. Evaluating didactic approaches used by teaching assistants for software analysis and design using uml. In *Proceedings of the 3rd European Conference of Software Engineering Education, ECSEE'18*, pages 122–131, New York, NY, USA, 2018. ACM. No citations.
- [135] Dave R. Stikkolorum, Birgit Demuth, Vadim Zaytsev, Frédéric Boulanger, and Jeff Gray. The MOOC hype: Can we ignore it? In *Reflections on the current use of massive open online courses in software modeling education. MODELS Educators Symposium, EduSymp*, 2014. No citations.
- [136] Dave R. Stikkolorum, Truong Ho-Quang, and Michel R.V. Chaudron. Revealing students' UML class diagram modelling strategies with WebUML and LogViz. In *Software Engineering and Advanced Applications (SEAA), 2015 41st Euromicro Conference on*, pages 275–279. IEEE, 2015. (cited on pages 71, 97, 153, 155 and 189).
- [137] Dave R. Stikkolorum, Truong Ho-Quang, Bilal Karashneh, and Michel R.V. Chaudron. Uncovering students' common difficulties and strategies during a class diagram design process: an online experiment. In *Educators Symposium 2015, co-located with the ACM/IEEE 18th International Conference on Model Driven Engineering Languages and Systems*, 2015. (cited on pages 71, 108, 109, 174 and 189).
- [138] Dave R. Stikkolorum and Ebrahim Rahimi, editors. *CSERC '20: Proceedings of the 9th Computer Science Education Research Conference*, New York, NY, USA, 2020. Association for Computing Machinery. No citations.
- [139] Dave R. Stikkolorum and Ebrahim Rahimi, editors. *CSERC '21: Proceedings of the 10th Computer Science Education Research Conference*, New York, NY, USA, 2021. Association for Computing Machinery. No citations.
- [140] Dave R. Stikkolorum and Ebrahim Rahimi, editors. *CSERC '22: Proceedings of the 11th Computer Science Education Research Conference*, New York, NY, USA, 2022. Association for Computing Machinery. No citations.

- [141] Dave R. Stikkolorum, Claire Stevenson, and Michel R.V. Chaudron. Assessing software design skills and their relation with reasoning skills. In *EduSymp 2013. CEUR, vol. 1134, paper 5*, 2013. (cited on pages 40, 92, 108 and 166).
- [142] Dave R. Stikkolorum, Claire E. Stevenson, and Michel R.V. Chaudron. Technical report 2013-02. https://research.drstikko.nl/files/technical_report_2013-02.pdf, 2013. (cited on page 31).
- [143] Dave R. Stikkolorum, Peter van der Putten, Caroline Sperandio, and Michel R.V. Chaudron. Towards automated grading of uml class diagrams with machine learning. In *BNAIC/BENELEARN*, 2019. No citations.
- [144] Harald Störrle. On the impact of layout quality to understanding UML diagrams: Diagram type and expertise. *Proceedings of IEEE Symposium on Visual Languages and Human-Centric Computing, VL/HCC*, pages 49–56, 2012. (cited on page 94).
- [145] Harald Störrle. On the impact of layout quality to understanding UML diagrams: Size matters. In *Model-Driven Engineering Languages and Systems*, pages 518–534. Springer, 2014. (cited on page 94).
- [146] Michael Striewe and Michael Goedicke. Automated checks on uml diagrams. In *Proceedings of the 16th Annual Joint Conference on Innovation and Technology in Computer Science Education, ITiCSE '11*, pages 38–42, New York, NY, USA, 2011. ACM. (cited on page 153).
- [147] Michael Striewe and Michael Goedicke. Automated assessment of uml activity diagrams. In *ITiCSE*, page 336, 2014. (cited on page 153).
- [148] Antony Tang. Software Designers , Are You Biased ? *Program*, pages 1–8, 2011. (cited on page 110).
- [149] Jennifer Tenzer and Perdita Stevens. GUIDE: Games with UML for interactive design exploration. *Knowledge-Based Systems*, 20(7):652–670, 2007. (cited on page 44).
- [150] Damiano Torre, Yvan Labiche, Marcela Genero, and Maged Elaasar. A systematic identification of consistency rules for uml diagrams. *Journal of Systems and Software*, 144:121–142, 2018. (cited on page 167).
- [151] Kalliopi Tourtoglou and Maria Virvou. User modelling in a collaborative learning environment for uml. In *Fifth International Conference on Information Technology: New Generations (itng 2008)*, pages 1257–1258. IEEE, 2008. (cited on page 169).
- [152] Ian Utting, Stephen Cooper, Michael Kölling, John Maloney, and Mitchel Resnick. Alice, greenfoot, and scratch—a discussion. *ACM Transactions on Computing Education (TOCE)*, 10(4):17, 2010. (cited on page 43).

- [153] Marcella Veldthuis, Matthijs Koning, and Dave R. Stikkolorum. A quest to engage computer science students: using dungeons & dragons for developing soft skills. In *Proceedings of the Computer Science Education Research Conference 2021*. ACM, 2021. No citations.
- [154] JDHM Vermunt. *Leerstijlen en sturen van leerprocessen in het hoger onderwijs - Naar procesgerichte instructie in zelfstandig denken*. Amsterdam: Swets & Zeitlinger, 1992. (cited on pages 78 and 92).
- [155] Boban Vesin, Aleksandra Klačnja-Milićević, Katerina Mangaroska, Mirjana Ivanović, Rodi Jolak, Dave Stikkolorum, and Michel Chaudron. Web-based educational ecosystem for automatization of teaching process and assessment of students. In *Proceedings of the 8th International Conference on Web Intelligence, Mining and Semantics*, pages 1–9, 2018. (cited on page 223).
- [156] Arto Vihavainen, Matti Luukkainen, and Jaakko Kurhila. Multi-faceted support for mooc in programming. In *Proceedings of the 13th annual conference on Information technology education*, pages 171–176. ACM, 2012. (cited on page 44).
- [157] Visual paradigm. <https://www.visual-paradigm.com>. [Online; accessed 20-November-2022]. (cited on page 192).
- [158] Christiane Gresse von Wangenheim, Rafael Savi, and Adriano Ferreti Borgatto. Scrumia—an educational game for teaching scrum in computing courses. *Journal of Systems and Software*, 86(10):2675–2687, 2013. (cited on page 191).
- [159] Lorin W Anderson, David R Krathwohl, Peter W Airasian, Kathleen A Cruikshank, Richard E Mayer, Paul R Pintrich, James Raths, and Merlin C Wittrock. *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives, Abridged Edition*. Allyn & Bacon, 2000. (cited on page 30).
- [160] Wim Westera, Rob Nadolski, and Hans Hummel. Serious Gaming Analytics : What Students Log Files Tell Us about Gaming and Learning. *International Journal of Serious Games*, 1(2):35–50, 2014. (cited on page 79).
- [161] Grant P Wiggins, Grant Wiggins, and Jay McTighe. *Understanding by design*. Ascd, 2005. (cited on page 10).
- [162] Yuefeng Zhang. Agile Development in Practice. *IEEE Software - IEEE Computer Society*, 2011. (cited on pages 110 and 190).
- [163] Chen Zhuoyi, Li Na, and Zhang Hongjie. Exploration of teaching model of the database course based on constructivism learning theory. In *Consumer Electronics, Comm. and Networks (CECNet), 2nd Int. Conf. on*, pages 1808–1811. IEEE, 2012. (cited on page 110).

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