Redefining computational thinking: Synergizing unplugged activities with block-based programming

Published: 19 July 2024

(2024) Cite this article

Education and Information Technologies

Aims and scope →

Submit manuscript →

Badrulimen Batni & Syahrul Nizam Junaini

Abstract

In the dynamic educational context of Malaysia, this study examines the impact of integrating Unplugged Activities (UA) with Block-Based Programming (BBP) on improving the computational thinking (CT) skills of secondary students in full boarding schools in Northern Peninsular Malaysia. Using a quasi-experimental design and mixed-methods analysis, the research evaluates the impact of these teaching methods on students' CT skills and attitudes toward programming. This research compares the results between a group that uses only BBP and another that combines both UA and BBP. The results indicate that CT skills improved in both groups, while students in the UA + BBP group showed more significant gains in confidence and a more positive attitude toward programming. These results provide valuable insights into pedagogical strategies within digital education and highlight the benefits of an integrated approach that combines tactile

Redefining computational thinking: Synergizing unplugged activities with block-based programming

Badruliman Batni and Syahrul Nizam Junaini

Abstract

In the dynamic educational context of Malaysia, this study examines the impact of integrating Unplugged Activities (UA) with Block-Based Programming (BBP) on improving the computational thinking (CT) skills of secondary students in full boarding schools in Northern Peninsular Malaysia. Using a quasi-experimental design and mixed-methods analysis, the research evaluates the impact of these teaching methods on students' CT skills and attitudes toward programming. This research compares the results between a group that uses only BBP and another that combines both UA and BBP. The results indicate that CT skills improved in both groups, while students in the UA + BBP group showed more significant gains in confidence and a more positive attitude toward programming. These results provide valuable insights into pedagogical strategies within digital education and highlight the benefits of an integrated approach that combines tactile learning experiences with digital technologies. By combining hands-on activities with technology-based instruction, this approach not only deepens students' understanding of CT concepts but also positively changes their perception and engagement with programming.

Keywords Computational thinking · Block-based programming · Unplugged activities · Pedagogical strategies · Computer science education

References

Academy of Sciences Malaysia (2018). Science Outlook 2017: Converging towards Progressive Malaysia 2050. In *Ministry of Science, Technology And Innovation*.

Aho, A. V. (2012). Computation and computational thinking. *Computer Journal*, *55*(7), 833–835. https:// doi.org/10.1093/comjnl/bxs074.

Allen, O., Downs, X., Varoy, E., Luxton-Reilly, A., & Giacaman, N. (2022). Block-based object-oriented programming. *IEEE Transactions on Learning Technologies*, *15*(4), 439–453. https://doi. org/10.1109/TLT.2022.3190318.

Amnouychokanant, V., Boonlue, S., Chuathong, S., & Thamwipat, K. (2021). A study of first-year students' attitudes toward Programming in the Innovation in Educational Technology Course. *Education Research International*, *2021*, 9105342. https://doi.org/10.1155/2021/9105342.

Bachman, L. F. (2009). Generalizability and research use arguments. *Generalizing from educational research* (pp. 137–158). Routledge.

Bati, K. (2022). A systematic literature review regarding computational thinking and programming in early childhood education. *Education and Information Technologies*, *27*(2), 2059–2082. https://doi. org/10.1007/s10639-021-10700-2.

Bau, D., Gray, J., Kelleher, C., Sheldon, J., & Turbak, F. (2017). Learnable programming: Blocks and Beyond. *Communications of the Acm*, *60*(6), 72–80. https://doi.org/10.1145/3015455.

Bell, T., & Vahrenhold, J. (2018). CS unplugged—how is it used, and does it work? *Lecture notes in Computer Science (including subseries lecture notes in Artificial Intelligence and Lecture notes in Bioinformatics): Vol. 11011 LNCS*. Springer International Publishing. https://doi. org/10.1007/978-3-319-98355-4_29.

Bell, T., Lambert, L., & Marghitu, D. (2012). CS Unplugged, Outreach and CS Kinesthetic activities. *Proceedings of the 43rd ACM Technical Symposium on Computer Science Education*, *676*. https:// doi.org/10.1145/2157136.2157410.

Brackmann, C. P., Román-González, M., Robles, G., Moreno-León, J., Casali, A., & Barone, D. (2017). Development of Computational Thinking Skills through Unplugged Activities in Primary School. *Proceedings of the 12th Workshop on Primary and Secondary Computing Education*, 65–72. https:// doi.org/10.1145/3137065.3137069.

Brennan, K., & Resnick, M. (2012). New frameworks for studying and assessing the development of computational thinking. *Proceedings of the 2012 Annual Meeting of the American Educational Research Association, Vancouver, Canada*, *1*, 25. https://doi.org/10.1007/978-3-319-64051-8_9.

Bui, G., Sibia, N., Zavaleta Bernuy, A., Liut, M., & Petersen, A. (2023). Prior programming experience: A persistent performance gap in CS1 and CS2. *Proceedings of the 54th ACM Technical Symposium on Computer Science Education V 1*, *889-895*. https://doi.org/10.1145/3545945.3569752.

Caeli, E. N., & Yadav, A. (2020). Unplugged approaches to computational thinking: A historical perspective. *TechTrends*, *64*(1), 29–36. https://doi.org/10.1007/s11528-019-00410-5.

Chen, P., Yang, D., Metwally, A. H. S., Lavonen, J., & Wang, X. (2023). Fostering computational thinking through unplugged activities: A systematic literature review and meta-analysis. *International Journal of STEM Education*, *10*(1), 47. https://doi.org/10.1186/s40594-023-00434-7.

Chen, H. E., Sun, D., Hsu, T. C., Yang, Y., & Sun, J. (2023a). Visualising trends in computational thinking research from 2012 to 2021: A bibliometric analysis. *Thinking Skills and Creativity*, *47*(December 2022), 101224. https://doi.org/10.1016/j.tsc.2022.101224.

Cheng, S., Chauhan, B., & Chintala, S. (2019). The rise of programming and the stalled gender revolution. *Sociological Science*, *6*(13), 321–351. https://doi.org/10.15195/v6.a13.

Cheng, Y. P., Lai, C. F., Chen, Y. T., Wang, W. S., Huang, Y. M., & Wu, T. T. (2023). Enhancing student's computational thinking skills with student-generated questions strategy in a game-based learning platform. *Computers & Education*, *200*, 104794. https://doi.org/10.1016/j.compedu.2023.104794.

Code.org (n.d.). CS Fundamentals Unplugged. *Hour of Code*. https://code.org/curriculum/unplugged.

Coşkunserçe, O. (2023). Comparing the use of block-based and robot programming in introductory programming education: Effects on perceptions of programming self-efficacy. *Computer Applications in Engineering Education*, *31*(5), 1234–1255. https://doi.org/10.1002/cae.22637.

Crawford, C. S., & Gilbert, J. E. (2019). Brains and blocks: Introducing novice programmers to brain-computer interface Application Development. *ACM Trans Comput Educ*, *19*(4). https://doi. org/10.1145/3335815.

Cuddeback, G., Wilson, E., Orme, J. G., & Combs-Orme, T. (2004). Detecting and statistically correcting Sample Selection Bias. *Journal of Social Service Research*, *30*(3), 19–33. https://doi.org/10.1300/ J079v30n03_02.

del Olmo-Muñoz, J., Cózar-Gutiérrez, R., & González-Calero, J. A. (2020). Computational thinking through unplugged activities in early years of primary education. *Computers & Education*, *150*(February), 103832. https://doi.org/10.1016/j.compedu.2020.103832.

del Rey, Y. A., Cawanga Cambinda, I. N., Deco, C., Bender, C., Avello-Martínez, R., & Villalba-Condori, K. O. (2021). Developing computational thinking with a module of solved problems. *Computer Applications in Engineering Education*, *29*(3), 506–516. https://doi.org/10.1002/cae.22214.

Denning, P. J., & Tedre, M. (2021). Computational thinking: A disciplinary perspective. *Informatics in Education*, *20*(3), 361–390. https://doi.org/10.15388/infedu.2021.21.

Domínguez Romero, E., & Bobkina, J. (2021). Exploring the perceived benefits and drawbacks of using multimodal learning objects in pre-service English teacher inverted instruction. *Education and Information Technologies*, *26*(3), 2961–2980. https://doi.org/10.1007/s10639-020-10386-y.

Fanchamps, N., van Gool, E., Slangen, L., & Hennissen, P. (2024). The effect on computational thinking and identified learning aspects: Comparing unplugged smartGames with SRA-Programming with tangible or On-screen output. *Education and Information Technologies*, *29*(3), 2999–3024. https:// doi.org/10.1007/s10639-023-11956-6.

Ferguson-Patrick, K., Ruth, R., & Macqueen, S. (2018). Integrating curriculum: A case study of teaching Global Education. *European Journal of Teacher Education*, *41*(2), 187–201. https://doi.org/10.1080 /02619768.2018.1426565.

Fojcik, M., Fojcik, M. K., Høyland, S. O., & Hoem, J. Ø. (2022). *Challenges in Teaching Programming*. 160–163. https://doi.org/10.36315/2022v1end034.

Gale, J., Alemdar, M., Lingle, J., & Newton, S. (2020). Exploring critical components of an integrated STEM curriculum: An application of the innovation implementation framework. *International Journal of STEM Education*, *7*(1), 5. https://doi.org/10.1186/s40594-020-0204-1.

Gao, H., Hasenbein, L., Bozkir, E., Göllner, R., & Kasneci, E. (2023). Exploring gender differences in computational thinking learning in a VR Classroom: Developing machine learning models using Eye-Tracking Data and explaining the models. *International Journal of*

Artificial Intelligence in Education, *33*(4), 929–954. https://doi.org/10.1007/s40593-022-00316-z.

Geng, Z. (2023). Environmental design as a component of block-based programming. *Computer Applications in Engineering Education*, *31*(2), 408–420. https://doi.org/10.1002/cae.22591.

Grover, S., Jackiw, N., Lundh, P., Shuchi Grover, N. J., & Lundh, P. (2019). Concepts before coding: Non-programming interactives to advance learning of introductory programming concepts in middle school. *Computer Science Education*, *29*(2–3), 106–135. https://doi.org/10.1080/08993408.2019.1 568955.

Grover, S., Jean, D., Broll, B., Cateté, V., Gransbury, I., Ledeczi, A., & Barnes, T. (2024). Design of Tools and Learning environments for Equitable Computer Science + Data Science Education. *Improving equity in Data Science* (pp. 57–91). Routledge.

Hashim, N. H. N., & Husnin, H. (2019). Teacher's perception on computational thinking Concept. *International Journal of Academic Research in Business and Social Sciences*, *9*(11), 1536–1546. https:// doi.org/10.6007/ijarbss/v9-i11/6718.

Hiley, K., Cebolla, H., & Elshehaly, M. (2023). The impact of Non-formal Computer Science Outreach on Computational thinking in Young Women. *Proceedings of the 2023 Conference on Innovation and Technology in Computer Science Education V 2*, *642*. https://doi.org/10.1145/3587103.3594197.

Holmes, S. R., Reinke, W. M., Herman, K. C., & David, K. (2022). An examination of Teacher Engagement in intervention training and sustained intervention implementation. *School Mental Health*, *14*(1), 63–72. https://doi.org/10.1007/s12310-021-09457-3.

Hu, L. (2024). Exploring gender differences in computational thinking among K-12 students: A Meta-analysis investigating influential factors. *Journal of Educational Computing Research*, *63*(4). https:// doi.org/10.1177/07356331241240670.

Huang, W., & Looi, C. K. (2021). A critical review of literature on unplugged pedagogies in K-12 computer science and computational thinking education. *Computer Science Education*, *31*(1), 83–111. https://doi.org/10.1080/08993408.2020.1789411.

Jacobi, D. (2011). On the construction of knowledge and the knowledge of construction. *International Political Sociology*, *5*(1), 94–97. https://doi.org/10.1111/j.1749-5687.2011.00122_4.x.

Jiang, S., & Wong, G. K. W. (2018). Are Children More Motivated with Plugged or Unplugged Approach to Computational Thinking? (Abstract Only). *Proceedings of the 49th ACM Technical Symposium on Computer Science Education*, 1094. https://doi.org/10.1145/3159450.3162270.

Kampylis, P., Dagien\.e, V., Bocconi, S., Chioccariello, A., Engelhardt, K., Stupurien\.e, G., Masiulionyt\.e- Dagien\.e, Jasut\.e, V., ., E., Malagoli, C., & Horvath, M. (2023). & others. Integrating Computational Thinking into Primary and Lower Secondary Education. *Educational Technology \& Society*, *26*(2), 99–117.

Kanika, Chakraverty, S., & Chakraborty, P. (2020). Tools and techniques for Teaching Computer Programming: A review. *Journal of Educational Technology Systems*, *49*(2), 170–198. https://doi. org/10.1177/0047239520926971.

Kemp, P. E. J., Wong, B., & Berry, M. G. (2019). Female performance and participation in Computer Science: A National Picture. *ACM Trans Comput Educ*, *20*(1), 1–28. https://doi.org/10.1145/3366016.

Kim, H. S. A. N. S., Kim, S., Na, W., & Lee, W. J. E. E. (2021). Extending computational thinking into information and Communication Technology Literacy Measurement: Gender and Grade issues. *ACM Trans Comput Educ*, *21*(1(5)), 1–25. https://doi.org/10.1145/3427596.

Kite, V., & Park, S. (2024). Context matters: Secondary science teachers' integration of process-based, unplugged computational thinking into science curriculum. *Journal of Research in Science Teaching*, *61*(1), 203–227. https://doi.org/10.1002/tea.21883.

Kite, V., Park, S., & Wiebe, E. (2019). Recognizing and questioning the CT Education paradigm. *Proceedings of the 50th ACM Technical Symposium on Computer Science Education*, *1286*. https://doi. org/10.1145/3287324.3293765.

Koul, R. B., McLure, F. I., & Fraser, B. J. (2023). Gender differences in classroom emotional climate and attitudes among students undertaking integrated STEM projects: A Rasch analysis. *Research in Science & Technological Education*, *41*(3), 1051–1071. https://doi.org/10.1080/02635143.2021.19 81852.

Leavy, A., Dick, L., Meletiou-Mavrotheris, M., Paparistodemou, E., & Stylianou, E. (2023). The prevalence and use of emerging technologies in STEAM education: A systematic review of the literature. *Journal of Computer Assisted Learning*, *39*(4), 1061–1082. https://doi.org/10.1111/jcal.12806.

Lee, J., & Junoh, J. (2019). Implementing Unplugged Coding activities in early childhood classrooms. *Early Childhood Education Journal*, *47*(6), 709–716. https://doi.org/10.1007/s10643-019-00967-z.

Lefa, B. (2014). THE PIAGET THEORY OF COGNITIVE DEVELOPMENT:AN EDUCATIONAL IMPLICATIONS. *Educational Psychology*, *1*, 9.

Li, W., & Yang, W. (2023). Promoting children's computational thinking: A quasi-experimental study of web-mediated parent education. *Journal of Computer Assisted Learning*, *39*(5), 1564–1575. https:// doi.org/10.1111/jcal.12818.

Li, F., Wang, X., He, X., Cheng, L., & Wang, Y. (2022). The effectiveness of unplugged activities and programming exercises in computational thinking education: A Meta-analysis. *Education and Information Technologies*, *27*, 7993–8013. https://doi.org/10.1007/s10639-022-10915-x.

Li, Q., Jiang, Q., Liang, J. C., Xiong, W., & Zhao, W. (2024). Engagement predicts computational thinking skills in unplugged activity: Analysis of gender differences. *Thinking Skills and Creativity*, *52*, 101537. https://doi.org/10.1016/j.tsc.2024.101537.

Lin, Y., & Weintrop, D. (2021). The landscape of Block-based programming: Characteristics of block-based environments and how they support the transition to text-based programming. *Journal of Computer Languages*, *67*, 101075. https://doi.org/10.1016/j.cola.2021.101075.

Loh, E. K. Y. (2019). What we know about expectancy-value theory, and how it helps to design a sustained motivating learning environment. *System*, *86*, 102119. https://doi.org/10.1016/j.system.2019.102119.

Ma, J. K. H. (2021). The digital divide at school and at home: A comparison between schools by socioeconomic level across 47 countries. *International Journal of Comparative Sociology*, *62*(2), 115–140. https://doi.org/10.1177/00207152211023540.

Malaysia Education Ministry (2013). Malaysia education blueprint 2013–2025. In *Education* (Vol. 27, Issue 1).

Malik, S. I., & Coldwell-Neilson, J. (2018). Gender differences in an introductory programming course: New teaching approach, students' learning outcomes, and perceptions. *Education and Information Technologies*, *23*(6), 2453–2475. https://doi.org/10.1007/s10639-018-9725-3.

Merino-Armero, J. M., González-Calero, J. A., Cózar-Gutiérrez, R., & del Olmo-Muñoz, J. (2022). Unplugged activities in Cross-curricular teaching: Effect on Sixth Graders' computational thinking and learning outcomes. *Multimodal Technologies and Interaction*, *6*(2), 13. https://doi.org/10.3390/ mti6020013.

Metin, S. (2022). Activity-based unplugged coding during the preschool period. *International Journal of Technology and Design Education*, *32*(1), 149–165. https://doi.org/10.1007/s10798-020-09616-8.

Minamide, A., Takemata, K., & Yamada, H. (2020). Development of computational thinking Education System for Elementary School Class. *2020 IEEE 20th International Conference on Advanced Learning Technologies (ICALT)*, *22*(23). https://doi.org/10.1109/ICALT49669.2020.00013.

Ministry of Education Malaysia (2018). Annual Report 2018: Malaysia Education Development Plan 2013–2025. *Kementerian Pendidikan Malaysia*, 1–96.

Niederhauser, D. S., Howard, S. K., Voogt, J., Agyei, D. D., Laferriere, T., Tondeur, J., & Cox, M. J. (2018). Sustainability and scalability in Educational Technology initiatives: Research-informed practice. *Technology Knowledge and Learning*, *23*(3), 507–523. https://doi.org/10.1007/s10758-018-9382-z.

OECD (2023). *PISA 2022 Results factsheets Malaysia (Volume I)* (Issue 2). https://www.oecd.org/publication/pisa-2022-results/country-notes/malaysia-1dbe2061/.https://www.oecd-ilibrary.org/education/ pisa-2022-results-volume-i_53f23881-en

Opsal, T., Wolgemuth, J., Cross, J., Kaanta, T., Dickmann, E., Colomer, S., & Erdil-Moody, Z. (2016). .: Considering the Risk/Benefit Ratio of Qualitative Research. *Qualitative Health Research*, *26*(8), 1137–1150. https://doi.org/10.1177/1049732315580109. There Are No Known Benefits.

Orhan, A., & Çeviker Ay, Ş. (2023). How to teach critical thinking: An experimental study with three different approaches. *Learning Environments Research*, *26*(1), 199–217. https://doi.org/10.1007/ s10984-022-09413-1.

Pappa, C. I., Georgiou, D., & Pittich, D. (2024). Technology education in primary schools: Addressing teachers' perceptions, perceived barriers, and needs. *International Journal of*

Technology and Design Education, *34*(2), 485–503. https://doi.org/10.1007/s10798-023-09828-8.

Paucar-Curasma, R., Cerna-Ruiz, L. P., Acra-Despradel, C., Villalba-Condori, K. O., Massa-Palacios, L. A., Olivera-Chura, A., & Esteban-Robladillo, I. (2023). Development of computational thinking through STEM activities for the Promotion of gender Equality. *Sustainability*, *15*(16). https://doi. org/10.3390/su151612335.

Peel, A., Sadler, T. D., & Friedrichsen, P. (2022). Algorithmic explanations: An Unplugged Instructional Approach to integrate Science and Computational thinking. *Journal of Science Education and Technology*, *31*(4), 428–441. https://doi.org/10.1007/s10956-022-09965-0.

Polat, E., & Yilmaz, R. M. (2022). Unplugged versus plugged-in: Examining basic programming achievement and computational thinking of 6th-grade students. *Education and Information Technologies*, *27*(7), 9145–9179. https://doi.org/10.1007/s10639-022-10992-y.

Rehmat, A. P., Hoda, E., & Cardella, M. E. (2020). Instructional strategies to promote computational thinking for young learners. *Journal of Digital Learning in Teacher Education*, *36*(1), 46–62. https://doi. org/10.1080/21532974.2019.1693942.

Rodriguez, B., Rader, C., & Camp, T. (2016). Using student performance to assess CS Unplugged activities in a Classroom Environment. *Proceedings of the 2016 ACM Conference on Innovation and Technology in Computer Science Education*, 95–100. https://doi.org/10.1145/2899415.2899465.

Rodriguez, B., Kennicutt, S., Rader, C., & Camp, T. (2017). Assessing Computational Thinking in CS Unplugged Activities. *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, 501–506. https://doi.org/10.1145/3017680.3017779.

Román-González, M., Pérez-González, J. C., & Jiménez-Fernández, C. (2017). Which cognitive abilities underlie computational thinking? Criterion validity of the computational thinking test. *Computers in Human Behavior*, *72*, 678–691. https://doi.org/10.1016/j.chb.2016.08.047.

Rosenman, R., Tennekoon, V., & Hill, L. G. (2011). Measuring bias in self-reported data. *International Journal of Behavioural and Healthcare Research*, *2*(4), 320–332. https://doi.org/10.1504/ IJBHR.2011.043414.

Rubio, M. A., Romero-Zaliz, R., Mañoso, C., & de Madrid, A. P. (2015). Closing the gender gap in an introductory programming course. *Computers & Education*, *82*, 409–420. https://doi.org/10.1016/j. compedu.2014.12.003.

Simmonds, J., Diaz, C., & Estay, C. (2023). Introducing Computational Thinking at Vocational High Schools. *Proceedings of the 2023 Conference on Innovation and Technology in Computer Science Education V. 1*, 68–74. https://doi.org/10.1145/3587102.3588818.

Slater, H., Davies, N. M., & Burgess, S. (2012). Do teachers Matter? Measuring the variation in teacher effectiveness in England*. *Oxford Bulletin of Economics and Statistics*, *74*(5), 629–645. https://doi. org/10.1111/j.1468-0084.2011.00666.x.

Smith, N., & Caldwell, H. (2016). Teaching Computing Unplugged in primary schools: Exploring primary computing through practical activities away from the computer. In *Teaching*

Computing Unplugged in primary schools. *Learning Matters*. https://doi.org/10.4135/9781473984332.

Stupurienė, G., Jevsikova, T., & Juškevičienė, A. (2022). Solving ecological problems through Physical Computing to ensure gender balance in STEM Education. *Sustainability*, *14*(9). https://doi. org/10.3390/su14094924.

Sun, L., Hu, L., & Zhou, D. (2021a). Which way of design programming activities is more effective to promote K-12 students' computational thinking skills? A meta-analysis. *Journal of Computer Assisted Learning*, *37*(4), 1048–1062. https://doi.org/10.1111/jcal.12545.

Sun, L., Hu, L., & Zhou, D. (2021b). Improving 7th-graders' computational thinking skills through unplugged programming activities: A study on the influence of multiple factors. *Thinking Skills and Creativity*, *42*, 100926. https://doi.org/10.1016/J.TSC.2021.100926.

Sun, L., Liu, J., & Liu, Y. (2024). Comparative experiment of the effects of unplugged and plugged-in programming on computational thinking in primary school students: A perspective of multiple influential factors. *Thinking Skills and Creativity*, *52*, 101542. https://doi.org/10.1016/j.tsc.2024.101542.

Tiruneh, D. T., De Cock, M., Weldeslassie, A. G., Elen, J., & Janssen, R. (2017). Measuring critical thinking in physics: Development and validation of a critical thinking test in electricity and magnetism. *International Journal of Science and Mathematics Education*, *15*(4), 663–682. https://doi. org/10.1007/s10763-016-9723-0.

Torres-Torres, Y. D., Román-González, M., & Pérez-González, J. C. (2019). Implementation of Unplugged Teaching activities to Foster Computational thinking skills in Primary School from a gender perspective. *Proceedings of the Seventh International Conference on Technological Ecosystems for Enhancing Multiculturality*, *209–215*. https://doi.org/10.1145/3362789.3362813.

Tripon, C. (2022). Supporting Future teachers to promote computational thinking skills in Teaching STEM—A Case Study. *Sustainability*, *14*(19). https://doi.org/10.3390/su141912663.

Tsarava, K., Moeller, K., Pinkwart, N., Butz, M., Trautwein, U., & Ninaus, M. (2017). Training computational thinking: Game-based unplugged and plugged-in activities in primary school. *Proceedings of the 11th European Conference on Games Based Learning, ECGBL 2017*, *October*, 687–695.

Tsarava, K., Moeller, K., & Ninaus, M. (2019). Board games for training computational thinking. *Games and Learning Alliance: 7th International Conference, GALA 2018, Palermo, Italy, December 5–7, 2018, Proceedings 7*, 90–100.

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The Development and Validation of a measure of student attitudes toward Science, Technology, Engineering, and Math (S-STEM). *Journal of Psychoeducational Assessment*, *33*(7), 622–639. https://doi.org/10.1177/0734282915571160.

Ung, L. L., Tammie, C. S., Jane, L., & Norazila, A. A. (2018). Preliminary investigation: Teachers' perception on computational thinking concepts. *Journal of Telecommunication Electronic and Computer Engineering*, *9*(2), 23–29.

Vinnervik, P. (2022). Implementing programming in school mathematics and technology: Teachers' intrinsic and extrinsic challenges. *International Journal of Technology and Design Education*, *32*(1), 213– 242. https://doi.org/10.1007/s10798-020-09602-0.

Waite, J., Curzon, P., Marsh, W., & Sentance, S. (2020). Difficulties with design: The challenges of teaching design in K-5 programming. *Computers & Education*, *150*, 103838. https://doi.org/10.1016/j. compedu.2020.103838.

Walkington, C., & Bernacki, M. L. (2020). Appraising research on personalized learning: Definitions, theoretical alignment, advancements, and future directions. *Journal of Research on Technology in Education*, *52*(3), 235–252. https://doi.org/10.1080/15391523.2020.1747757.

Weintrop, D. (2019). Block-based programming in computer science education. *Communications of the Acm*, *62*(8), 22–25. https://doi.org/10.1145/3341221.

White, R. T., & Arzi, H. J. (2005). Longitudinal studies: Designs, validity, practicality, and Value. *Research in Science Education*, *35*(1), 137–149. https://doi.org/10.1007/s11165-004-3437-y.

Wing, J. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33–35.

Wofford, A. M. (2021). Modeling the pathways to Self-confidence for Graduate School in Computing. *Research in Higher Education*, *62*(3), 359–391. https://doi.org/10.1007/s11162-020-09605-9.

Xu, E., Wang, W., & Wang, Q. (2023). A meta-analysis of the effectiveness of programming teaching in promoting K-12 students' computational thinking. *Education and Information Technologies*, *28*(6), 6619–6644. https://doi.org/10.1007/s10639-022-11445-2.

Yadav, S., & Chakraborty, P. (2023). Introducing schoolchildren to computational thinking using smartphone apps: A way to encourage enrollment in engineering education. *Computer Applications in Engineering Education*, *31*(4), 831–849. https://doi.org/10.1002/cae.22609.

Yadav, A., Hong, H., & Stephenson, C. (2016). Computational thinking for all: Pedagogical approaches to Embedding 21st Century Problem solving in K-12 classrooms. *TechTrends*, *60*(6), 565–568. https:// doi.org/10.1007/s11528-016-0087-7.

Yildiz Durak, H., Saritepeci, M., & Durak, A. (2023). Modeling of relationship of personal and affective variables with computational thinking and programming. *Technology Knowledge and Learning*, *28*(1), 165–184. https://doi.org/10.1007/s10758-021-09565-8.

Zhu, Z., Zhang, Y., Zhu, W., & Ma, J. (2023). Computational Thinking and Academic Achievement: The Mediator Roles of Problem-solving Ability and Learning Anxiety. *2023 International Symposium on Educational Technology (ISET)*, 94–98. https://doi.org/10.1109/ISET58841.2023.00027.