







be more efficient in the actual game activities, without demanding extra cognitive load to process them during gameplay.

Another idea to aid the bit selection and usage process is to provide a separate “cheat sheet” with all pieces and their count, next to the actual game boards. Players can cross out any pieces that have been used with a marker in order to keep track of what has been used and what is still available. This cheat sheet can be used during the initial sessions and then progressively removed, letting the users depend on their ability to recognize the physical pieces. This is a common process of scaffolding in instructional design, also called fading, because the additional information (scaffold) is removed (faded) over time [8].

These introductory puzzles can also assist in dealing with some observed instances of under-specification. We suggest that children should have a very clear understanding of the piece properties and the constraints that they introduce. Thus, we should help them form some kind of algorithmic representation including all the properties that bits should have in any given position, and show them how to apply it in similar situations. This can be achieved through guiding questions that will lead children to evaluate the different properties of any missing piece on the board. Questions like “How big should this piece be?”, “How should it attach to adjacent blocks?”, and “What polarity should the magnets have?” will help them construct mental functions of bit and path properties that need to be evaluated at every point.

Social interactions are important in the conversion of the game attributes (i.e., path shape on board, bit properties, remaining bits) to mental functions. Students should be encouraged to question each other’s assumptions while moving from the initial introductory puzzles to more complex game boards, to prevent an adversarial tone. Because the game could become quite difficult, depending on the path and pieces provided, we found it helpful to include a “more knowledgeable other” in the form of a guide, who could intervene before frustration overwhelmed the students. This guide, in conjunction with the students’ interpersonal interactions, keeps the activity in their “zone of proximal development” [16].

While further, rigorous evaluation is necessary, we agree with one of our reviewers that RabBit EscApe “seems novel and engaging, and likely to be of interest to many other researchers, and to spark interesting debates.”

## 5. CONCLUSION

A significant leap must be made to educate our youth as society continues to develop computational systems with which they must interact. Along these lines, we have developed RabBit EscApe to teach CT in a relatively explicit way, intentionally moving the focus of the game away from mathematical concepts, which are predominant in other CT game setups. Having run a study to observe children’s interactions with each other and our game, we believe there is a promising avenue for low-tech, tangible games for teaching CT to children aged 6-10 years in an engaging way. Our next step includes running a formal study to assess the game for its appropriateness in cultivating CT skills, and verify if the designed strategies support these skills in a successful manner.

## 6. ACKNOWLEDGEMENTS

We would like to thank the Institute for Creativity, Arts, and Technology (ICAT, <http://www.icat.vt.edu>) at Virginia Tech for their generous support of this project.

## 7. REFERENCES

- [1] Allan, W., Coulter, B., Denner, J., Erickson, J., Lee, I., Malyn-Smith, J. and Martin, F. Computational thinking for youth. *White Paper for the ITEST Small Working Group on Computational Thinking (CT)*, 2010.
- [2] Barr, V. and Stephenson, C. Bringing computational thinking to k-12: what is involved and what is the role of the computer science education community? *Inroads*, 2(1):48–54, 2011.
- [3] Berland, M and Lee, V.R. Collaborative strategic board games as a site for distributed computational thinking. *International Journal of Game-Based Learning*, 1(2):65, 2011.
- [4] Bruner, J.S. The process of education. *American Journal of Physics*, 31:468–469, 1963.
- [5] National Research Council. Report of a Workshop on the Scope and Nature of Computational Thinking. *National Academies Press*, 2010.
- [6] Denning, P.J. Great principles of computing. *Communications of the ACM*, 46(11):15–20, 2003.
- [7] DiSessa, A.A. *Changing minds: Computers, learning and literacy*. The MIT Press, 2001.
- [8] Driscoll, M.P. *Psychology of Learning for Instruction (3rd Edition)*. Pearson, 2004.
- [9] ISTE. *Operational definition of computational thinking of the international society for technology in education*. <https://www.iste.org/learn/computational-thinking/ct-operational-definition>
- [10] Liebschner, J. *A child’s work: Freedom and play in Froebel’s educational theory and practice*. Lutterworth Press Cambridge, 1992.
- [11] Newell, A., Simon, H.A., et al. *Human problem solving*, volume 14. Prentice-Hall Englewood Cliffs, NJ, 1972.
- [12] Papert, S. *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc., 1980.
- [13] Resnick, M., Martin, F., Berg, R., Borovoy, R., Colella, V., Kramer, K., and Silverman, B. Digital manipulatives: new toys to think with. In *Proceedings of the SIGCHI conference on Human factors in computing systems*, 281–287. ACM Press/Addison-Wesley Publishing Co., 1998.
- [14] Schweikardt, E. and Gross, M.D. Roblocks: a robotic construction kit for mathematics and science education. In *Proceedings of the 8th international conference on Multimodal interfaces*, 72–75. ACM, 2006.
- [15] Picasso Tiles. *Picasso tiles 3d*. <http://www.picassotiles.com/>
- [16] Vygotsky, L. *Mind in society: The development of higher psychological processes*. Harvard University Press, 1978.
- [17] Weller, M.P., Do, E. Y.-L., and Gross, M. D. Escape machine: teaching computational thinking with a tangible state machine game. In *Proceedings of the 7th international conference on Interaction design and children*, 282–289. ACM, 2008.
- [18] Wilensky, U. and Reisman K. Thinking like a wolf, a sheep, or a firefly: Learning biology through constructing and testing computational theories—an embodied modeling approach. *Cognition and instruction*, 24(2):171–209, 2006.
- [19] Wing, J.M. Computational thinking and thinking about computing. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 366(1881):3717–3725, 2008.