“Novel Roboting”: A Playful Learning Approach to Digital Literacy in Early Childhood Education through Story-Tinkering and Computational Play with Robots

Pauline Fredskilde[1][0000-0002-0965-8031] and Lykke Brogaard Bertel[2][0000-0002-1460-2905]

[1, 2] Aalborg Center for PBL in Engineering Science and Sustainability under the auspices of UNESCO, Department of Sustainability and Planning, Aalborg University
paulinef@plan.aau.dk

Abstract. This paper introduces ‘Novel Roboting’ at the intersection between Novel Engineering, Educational Robotics and Computational Thinking and explores its potential as a playful approach to developing digital literacy through story-tinkering and computational play in early childhood education. A novel roboting model was developed based on 4 years of participatory and exploratory research in 40 Danish kindergartens, testing the approach with 80 kindergarten teachers and 600+ children aged 4-6. In this paper we present the novel roboting concept and its theoretical underpinnings with initial findings from case studies on teachers’ and children’s librarians' work with the concept, and propose directions for future research to further develop and test novel roboting approaches in real-world learning environments in collaboration with teachers.

Keywords: novel engineering, educational robotics, computational thinking

1 Introduction

Digital literacy is increasingly considered a key 21st century skill, and receiving increasing attention in early childhood education [1] and teacher education [2]. Studies have shown that educational robots can be used to support different skills, including cognitive abilities such as problem solving and critical thinking in K-12 STEM education [3-4] as well as early childhood education and care (ECEC) [5-7]. ‘Educational robots’ broadly refers to tangible and programmable robotic technologies and/or toys used in educational settings, that leverage embodied cognition (e.g. through movement) and through this become objects-to-think-with [4, 8]. Educational robots often, but not always, take the form of small character-like (social) robots [4, 9]. Thus, while buildable ‘robotic construction kits’ such as LEGO Mindstorms have long been used in education to teach engineering and coding skills [4, 8], the field of educational robotics is increasingly including programmable socially interactive robots e.g. to teach socio-emotional skills such as communication and collaborative problem-solving, thus somewhat “opening up” the black-boxed social robot for pedagogical purposes [9-10].

1.1 Digital Literacy through Computational Play and Story-Telling

Although these educational robots are often designed as 'out-of-the-box' teaching tools, and are considered motivational 'by default' because of their 'cute' appearance, educators often do not feel equipped to use them, or know how to relate, reconfigure and integrate them into everyday practice [2]. Thus, there is a risk that these robots stay 'inside the box', literally and figuratively.

Play and *story-telling* approaches have shown potential to develop digital literacy (for teachers and children alike) by building on well-known and integrated practices in ECEC, thus providing a platform for teachers to integrate new technologies and methods into their everyday practice [11-12]. One approach that utilizes storytelling to introduce new teaching methods is 'Novel Engineering', a fairly new but well-researched concept combining literacy and engineering developed by Tufts University [13]. However, while novel engineering builds engineering capacity, it rarely focuses on technological aspects of engineering or digital literacy, such as computational thinking or coding. Thus, we suggest 'Novel Roboting' as a particular pedagogical approach at the intersection between novel engineering, educational robotics and computational thinking, that highlights the potential of storytelling with educational robots to support digital aspects of literacy through computational play. In this paper, we explore the concept and its applicability within ECEC through case studies with teachers and children's librarians.[1]

2 Novel Engineering

In Novel Engineering (NE), students use literature as the basis for engineering design challenges, drawing information from the text to identify engineering problems and constraints, considering characters as clients with problems, for which they build functional solutions [13]. As such, NE fuses the 3 Rs (reading, writing and arithmetic) with building capacity and agency to engineer solutions to practical problems [13-14]. To do this, the children need to analyze the problem and the story to design appropriate solutions, e.g. building model houses that can in fact resist the *"huffing, puffing and blowing from the big bad wolf"*. Because of the focus on characters as 'clients', some approaches to NE specifically highlight social aspects of the activity, including the ability to observe, understand (emphasize with) and respond to the needs of others and adding to this design thinking and making [15-16]. In some versions of NE, specific aspects of engaging with the storyline are integrated as well, such as 'recall' (story elements or one's own experiences) and 'rewrite the story' [17].

2.1 Novel Roboting

While NE explores the intersection between engineering and literacy, Novel Roboting specifically adds to NE a focus on developing computational thinking and coding

[1] This work is part of the DiCoTe (Digital Competence in early childhood Teacher Education) project (2021-2025), which aims to increase digital competence in early childhood teacher education, with a focus on enriching and supporting children's play with coding toys [18]. The project is led by the University of Stavanger and funded by the Norwegian Research Council.

skills through the integration of educational robots. Novel Roboting (NR) still takes point of departure in a literary work and is centered around an engineering design process, but adds to the engineering aspect a specific focus on *technology* and view *coding* as a particular type of language that involves *pattern recognition*, *deconstruction*, *abstraction* and *algorithmic thinking*, which can be explored through 'unplugged' coding activities (e.g. with LEGO or Centicubes).

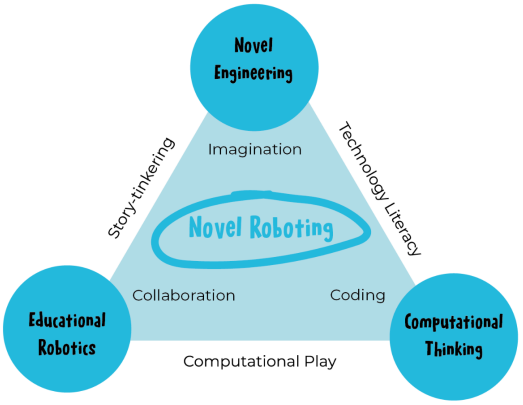

Fig. 1. Conceptual model of Novel Roboting.

Some type of *educational robot* is then introduced, either as a means of playful exploration of hands-on coding and computational play [10-11], or as a 'disruption' to the storyline. Here, the robot can both serve as the character with a problem ('client'), be (part of) the solution (as a tool/friend), or even the source of it (foe), or something else entirely. Depending on the affordances of the robot, socio-emotional themes can be included in the story-telling perspective (*"What would happen if a robot appeared here?"*) or to the computational play perspective (*"How would the robot interact with the character and express [emotion]?"*) Thus, the 'rewriting' in NR is not limited to problem-solving, but can take place throughout the story or change the narrative entirely, here referred to as story-*tinkering*, inviting children's imagination and inherent creativity to come up with ideas and stories themselves [19-20].

Teachers can choose different approaches to NR depending on the context, age group and pedagogical purpose, however NR generally involves three interrelated processes: *Read, Create* and *Play* (Fig. 2). Between Read and Create, teachers can *Intervene*, i.e. introduce unplugged or robot-supported activities, after which they return to the story. At this stage, the children start to tinker with the story; collaborating and co-creating to change or create new storylines, scenarios, and characters.

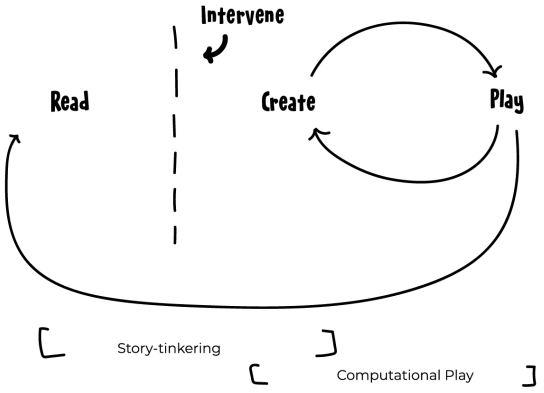

Fig. 2. Instructional model of novel roboting processes in practice.

3 Case studies on Novel Roboting Practices

3.1 Jack, Jansen and Ada Acorn: Examples of Novel Roboting in ECEC

In a 4-week participatory action research project 'Coding Class Toddler' (2020-2021), 80 Danish kindergarten teachers and 600+ children from 40 kindergartens participated [21]. A storyline was designed around "Jack the Penguin", who travels to another planet and meets a robot, Benny.[2] The kindergarten teachers in Coding Class Toddler (CCT) reported that the story-telling element motivated the children, while also scaffolding their own pedagogical exploration of the new technology. Some teachers developed stories of their own, which involved both problem solving methods and coding activities with a Blue-Bot. Later, in another CCT-program in 2022, 60 kindergarten teachers worked with "Jansen the Poodle" and were encouraged to develop their own stories with Jansen to use in their kindergartens, daycares or classrooms. 34 stories were created, in which Jansen met some kind of robot; a friend or a foe, or a means of transportation (a boat, cargo bike, or helicopter) or even a household appliance, such as a vacuum cleaner. In the DiCoTe project, the character Ada Acorn has been designed along with a playful forest-based learning universe for kindergarten teachers across Scandinavia. The 'Ada Acorn' storyline involves nature and the outdoors to a greater extent, as one of the robots used in DiCoTe, 'Rugged Robot', is able to navigate outdoor terrains. More storylines, characters and "universes" have since been developed for different CCT-programs and local municipalities in Denmark, e.g. Tønder and Esbjerg in Southern Denmark.

[2] After the project, 'Jack the Penguin' became an activity-based children's book with educational materials and instructions for teachers: https://guldastronaut.dk/vare/pingvinen-jack-paa-blaabotternes-planet-bogen/

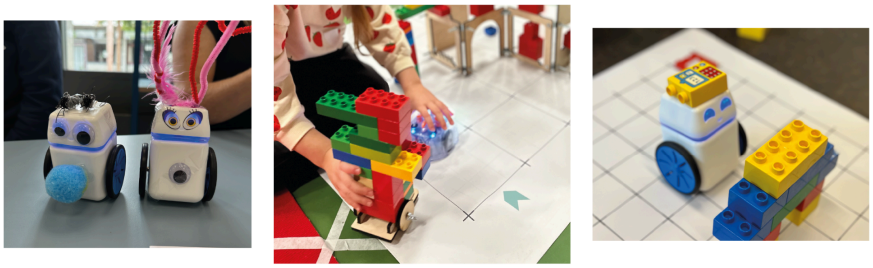

Fig. 3. Examples of novel roboting in Coding Class Toddler.

3.2 Co-constructing New Novel Robotic Practices: Children's Librarians Hack the Story of "The Little Red Robot Hood"

Based on experiences with novel roboting in different specific, tailored "universes", we wanted to explore the application of novel roboting to any existing literature in a co-creation process with the target group. In this case study, children's librarians were chosen due to expertise in disseminating children's literature. 17 children's librarians from across Denmark participated in the course during spring of 2024 with 4 workshop days designed around materials and activities originally developed with Jack the Penguin. The concept of Novel Roboting was introduced, both from a theoretical perspective and with practical examples, templates and feedback to support the librarians' design of their own novel roboting activities. In one example, two librarians co-constructed "Robot Hood", inspired by a "hacked" version of the Little Red Riding Hood story using the robot KUBO.

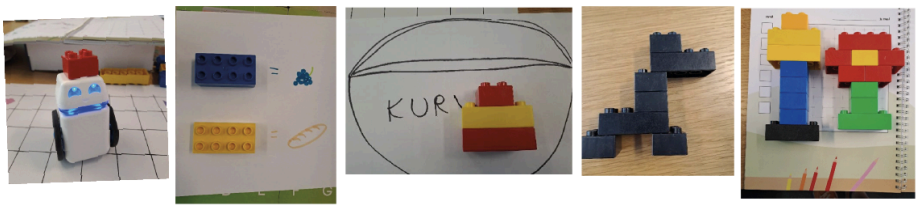

Fig. 4. "Robot Hood": A robot character created by children's librarians through novel roboting and unplugged activities for story tinkering.

The target group for this activity is children aged 6-8, and NR processes include 1) *Reading* the story of The Little Red Riding Hood, 2) *Intervening* with unplugged activities using LEGO Duplo bricks to 3) *Create* representations of characters, foods and flowers for Robot Hood's basket, as well as playful coding activities with KUBO (e.g. coding routes using functions and loops to pick flowers, avoid the Wolf and get safely to Grandma's house). Finally, the children are encouraged to 4) *Play* with the robots in a game of catch, inspired by 'Battleship'.

In between course days, the librarians tested out different formats, and materials are currently being tested with children across libraries. A follow-up meeting is planned for the fall of 2024 to evaluate and plan future research and development.[3]

4 Scaffolding NR Practices: Initial Findings and Next Steps

While participants in the NR-course generally report a high degree of satisfaction (45% and 55% found the course 'highly relevant' or 'relevant', respectively. 73% said it contributed to their creative digital literacy to a 'high degree'), the current study does not provide insights into whether and how this training translates into new NR and computational play practices in Danish kindergartens, schools and libraries, nor what impact it has on children's and teachers' digital literacy. Furthermore, while the process of designing characters and stories is engaging for both teachers and children, it also requires a lot of support and perhaps most importantly: time. Thus, to make NR and computational play practices accessible to novices, ideally teachers should not depend on specific materials to engage in NR, rather they should be able to apply it to any book they wish, with minimal preparation and training. Thus, based on experiences from the case study with children's librarians, a framework for scaffolding NR practices in day-to-day ECEC is to be developed and tested in real-world formal and informal learning environments in Scandinavia in close collaboration with teachers. Furthermore, future studies will continue to employ design-based and participatory action research approaches to explore and co-construct novel roboting and computational play practices with teachers and children outside of Scandinavia, to contribute to local, contextual and culturally-responsive approaches to NR that support digital literacy internationally, for children and teachers alike.

Acknowledgments. This study was partly funded by The Norwegian Research Council, the central libraries in Denmark, and Guldastronaut.

Disclosure of Interests. Author 1 is co-founder of Guldastronaut, which sells Jack the Penguin books and other educational materials, occasionally along with educational robots.

References

1. Louka, K.: Programming Environments for the Development of CT in Preschool Education: A Systematic Literature Review. Advances in Mobile Learning Educational Research **3**(1): 525–540.(2023) https://doi.org/10.25082/AMLER.2023.01.001
2. Undheim, M.: Children and teachers engaging together with digital technology in early childhood education and care institutions: A literature review. European Early Childhood Education Research Journal, **30**(3), 472-489. (2022).
3. Anwar, S., Bascou, N. A., Menekse, M., & Kardgar, A. (2019). A systematic review of studies on educational robotics. Journal of Pre-College Engineering Education Research (J-PEER), 9(2), 2.

[3] Examples of co-created materials and NR-resources from the course can be found here: www.novelroboting.com

4. Alimisis, D. (2013). Educational robotics: Open questions and new challenges. Themes in Science and Technology Education, 6(1), 63-71.
5. Kamola, M., Granone, F., Grøsvik, K., & Reikerås, E. (2024). High-quality strategies for supporting children’s problem-solving skills: a study on coding toy activities in Norwegian ECECs. European Early Childhood Education Research Journal, 1-20.
6. Bertel, L. B., Dau, S., & Brooks, E. (2020). ROSIE: Robot-Supported Inclusive Education - A Play-Based Approach to STEM Education and Inclusion in Early Childhood Transitions. In O. Levrini, & G. Tasquier (Eds.), Electronic Proceedings of the ESERA 2019 Conference. (pp. 1810-1817). Alma Mater. Link
7. Pollarolo, E. et al.: Play with Coding Toys in Early Childhood Education and Care: Teachers’ Pedagogical Strategies, Views and Impact on Children's Development. A Systematic Literature Review. Entertainment Computing, Volume 50, 2024, 100637, ISSN 1875-9521, https://doi.org/10.1016/j.entcom.2024.100637
8. Papert, S. A.: Mindstorms: Children, computers, and powerful ideas. Basic books. (1980).
9. Majgaard, G., & Bertel, L. B. (2014). Initial phases of design-based research into the educational potentials of NAO-robots. I Proceedings of the 2014 ACM/IEEE international conference on Human-robot interaction (s. 238-239). Association for Computing Machinery. https://doi.org/10.1145/2559636.2563690
10. Bertel, L. B., & Fredskilde, P. (2021). Whiteboxing bits’n’bots: How ‘flawed’ and emerging technologies can facilitate computational play and learning. I E. Brooks, S. Dau, & S. Selander (red.), Digital Learning and Collaborative Practices: Lessons from Inclusive and Empowering Participation with Emerging Technologies Routledge. https://doi.org/10.4324/9781003108573-14
11. Brooks, E., Dau, S., Bertel, L.B., Granone, F., Edstrand, E., Reikerås, E.K.L. (2024). Towards Computational Play. In: Brooks, E., Kalsgaard Møller, A., Edstrand, E. (eds) Design, Learning, and Innovation. DLI 2023. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 589. Springer, Cham. https://doi.org/10.1007/978-3-031-67307-8_11
12. Maureen, I. Y., van der Meij, H., & de Jong, T.: Enhancing storytelling activities to support early (digital) literacy development in early childhood education. International Journal of Early Childhood, **52**(1), 55-76. (2020)
13. Novel Engineering (n.d.). What does NE look like?. https://www. Novelengineering.org/.
14. Portsmore, M., Milto, E.: Novel Engineering in Early Elementary Classrooms. In: English, L., Moore, T. (eds) Early Engineering Learning. Early Mathematics Learning and Development. Springer, Singapore. (2018). https://doi.org/10.1007/978-981-10-8621-2_10
15. Milto, E., et al.: Novel engineering, K-8. NSTA Press. (2020).
16. Milto, E., et al.: Elementary school engineering for fictional clients in children’s literature. In Connecting Science & Engineering Education Practices in Meaningful Ways (pp. 263-291). Springer International Publishing. (2016).
17. Kim, J. Y., Chung, H., Jung, E. Y., Kim, J. O., & Lee, T. W. (2020). Development and application of a novel engineering-based maker education course for pre-service teachers. Education Sciences, **10**(5), 126.
18. DiCoTe (n.d.). https://www.uis.no/en/research/dicote-increasing-professional-digital-competence-in-ecte-with-focus-on-enriching-and
19. Resnick, M., & Rosenbaum, E. (2013). Designing for tinkerability. In Design, make, play (pp. 163-181). Routledge.
20. Kaup, C. F., Møller, A. K., & Brooks, E. (2022, November). Bringing computational thinking to life through play. In International Conference on Design, Learning, and Innovation (pp. 95-112). Cham: Springer Nature Switzerland.
21. Coding Class Toddler (n.d.). https://guldastronaut.dk/codingclasstoddler/