A systematic review of the use of BBC Micro:bit in K-12 Education

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Abstract. *The technologies as BBC Micro.Bit open up new opportunities for designers to create innovative forms of interaction based on gestures, body movements or physical manipulation of real objects. This paper is a systematic review of the literature (SLR) on the use of BBC Micro:bit in context of K-12 Education. This review included ten studies published from 2019 – 2023. For such, was adopted the Goal, Question, Metrics (GQM) approach as it represents a systematic approach for defining and evaluating a set of operational goals using a measurement in three phases: Planning, Conducting, Reporting. The results showed that the circuit can be used in different contexts and that students and teachers present difficulties in programming and in understanding the hardware suggesting an effective preparation and training on the part of teachers.*

Keywords*: BBB Micro.bit, Tangible User Interfaces, Computational Thinking.*

Uma revisão sistemática do uso do BBC Micro:bit na Educação Básica

Abstract. *As tecnologias como BBC Micro.Bit abrem novas oportunidades para designers criarem formas inovadoras de interação baseadas em gestos, movimentos corporais ou manipulação física de objetos reais. Este artigo é uma revisão sistemática da literatura (RSL) sobre o uso do BBC Micro:bit no contexto da Educação Básica. Esta revisão incluiu dez estudos publicados de 2019 a 2023. Para tanto, foi adotada a abordagem Objetivo, Pergunta, Métricas (GQM), que representa uma abordagem sistemática para definir e avaliar um conjunto de metas operacionais usando uma medição em três fases: Planejamento, Condução, Reportagem. Os resultados mostraram que o circuito pode ser utilizado em diversos contextos e que alunos e professores apresentam dificuldades na programação e no entendimento do hardware sugerindo uma efetiva preparação e treinamento por parte dos professores.*

Palavras-Chaves*: BBB Micro.bit, Interfaces Tangíveis de Usuário, Pensamento Computacional.*

1. Introduction

Many physical devices supporting the learning of programming and digital making are now available which have the potential to make learning fun, accessible and creative for children and young adults.

The BBC Micro:bit is a pocket-sized computer that introduces to how software and hardware work together. It has an LED light display, buttons, sensors and many input/output features that, when programmed, let it interact with the people and world. The Micro:bit can be programmed to do a number of different things: a digital watch, a fitness tracker or a games console. The device features 25 LED lights and two programmable buttons, which can be used in game-play or to skip through tracks in a playlist (BBC Micro.Bit, 2023).

The BBC Micro:bit is too one of the recently-developed physical devices that can be used to teach programming skills to students. This codeable hardware has some features that will support the skills children need for writing programs, and in addition may help

to improve their science, technology and engineering learning (Kalelioglu & Sentence, 2019). The technology encourages kids to learn basic coding and programming skills. For programming, different programming languages or Integrated development environment (IDEs[1]) can be used: Microsoft's MakeCode, Python, Mobile and tablet apps, Scratch, Swift Playgrounds, Other editors: EduBlocks (Python), Mu (Python) and Strype (Frame Based Python).

The advent of this new technology necessitates research to inform pedagogical approaches that work in the classroom. In this sense, this paper presents a literature review in the form of a research process that sought to identify, select, evaluate and synthesize the materials produced on this topic. The aim is to answer well-defined questions regarding the potential and application of BBB Micro.bit in K-12 education context. To this end, all major studies into BBB Micro.bit since 2019 were considered. The goals were defined by the Goal-Question-Metric (GQM) protocol, a measurement and evaluation instrument designed to provide a better understanding of processes for comparing activities.

The article is structured as follows: Section 2 presents the methodological approach. Section 3 shows and discusses the results obtained and finally, Section 4 includes some conclusions and ideas for future work.

2. Methodology

This literature review was based on research method based on the Goal, Question, Metrics (GQM) approach proposed by (Basili, 1992) because it provide a framework for transitioning from a research objective to research questions, metrics, and the presentation of results.

First a research objective (conceptual level), after was defined a set of research questions (operational level) was then drawn up, and, finally, the metrics to answer the research questions (quantitative level) were described. The steps for structuring the SLR are described below.

2.1. Objectives

The goals of this research were those defined in the GQM protocol (Basili, 1992). Table 1 shows the objectives of the literature review.

Table 1. Objective according to the GQM paradigm

Object of analysis	Scientific publications
Method	Characterization and analysis
Purpose	Investigate the state-of-the-art in the use of BBC Micro.Bit and the pedagogical perspectives using this technology
Perspective	Researchers
Context	Academic

[1] Microsoft's MakeCode: https://makecode.microbit.org/
Python: https://python.microbit.org/v/3
Scratch: https://scratch.mit.edu/microbit
Mobile and tablet apps: https://microbit.org/get-started/user-guide/mobile/
Swift Playgrounds: https://support.microbit.org/support/solutions/articles/19000134117-swift-playgrounds
Other editors: https://microbit.org/code/#other-editors

2.2. Research questions

Research Questions (RQ) are a mechanism that makes it possible to focus any systematic review on specific topics. The objective is to improve scientific knowledge after analyzing research papers related to that topic. Based on the aforementioned objectives, the following research questions were established:

1. What experiences have been recorded regarding the use of the Micro:bit by **students**?
2. What experiences have been recorded regarding the use of Micro:bit by **teachers**?
3. What obstacles have been observed during its implementation in practice?

2.3. Search for relevant studies

This systematic review includes three stages: planning, conducting, reporting (Kitchenham & Charters 2007). The research field mapping began with searching for necessary information about the BBC Micro:bit from the official website on its features and capabilities. The research questions were then identified, and the following search string according to the Boolean system was derived: “micro:bit OR microbit”, applied to the metadata (titles, keywords, and abstracts) of articles published in three different digital repositories: ERIC, CAPES and Web of Science spanning the period from 2019 to 2023. Furthermore, the research concerns sources written in English.

2.4. Inclusion and exclusion criteria

Specific inclusion and exclusion criteria were established, and the PRISMA Statement was applied to collect, identify and analyze source data (Moher et al. 2009). The GQM approach was adopted to define and evaluate research objectives systematically and using measurement (Basili, 1992). The relevant data are grouped into four categories. Firstly, studies that present both students' and teachers' experiences, secondly studies that describe the possibilities or any barriers that may result, thirdly studies related to the effects on skill development and its possible connection with increasing motivation for programming.

The inclusion criteria used were: 1) The study focuses on the keyword that have been entered, 2) The study is scientifically acceptable and has been used as a source by other researchers, 3) The article was published in an international peer-reviewed journal or conference; 4) The article was published after 2019; 5) The article is written in English.

The exclusion criteria were: 1) Repeated articles; 2) The article is not accessible through university services or memberships; 3) The article is only accessible behind a paywall; 4) The Micro.bit is only mentioned as an example, but was not used in the methodology or as a resource.

After performing the searches, a total of 10 articles has been qualified. Figure 1. Flow diagram of study search and selection process based on the PRISMA Statement (Moher et al. 2009).

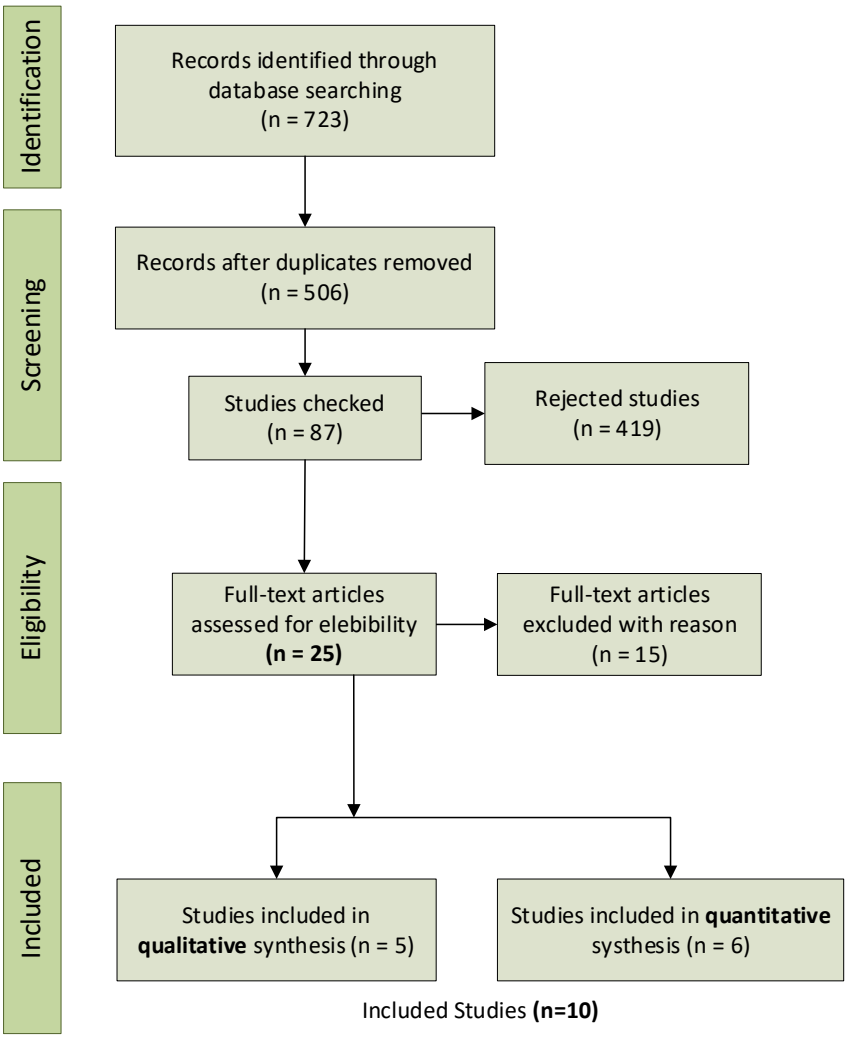

Fig. 1. Flow diagram of study search and selection process based on the PRISMA Statement (Moher et al., 2009).

With regard to threats to validity, one potential threat was the coverage of the literature. In our case, the search string was simple, and so would not cause the omission of any articles. There may have been some studies that we did not find in our literature search, but we believed that by searching CAPES, ERIC and Web of Science, the coverage would be satisfactory. Another possible threat to validity was the filtering of the articles found in the initial search to check if the articles described a study. Articles with studies were then checked for relevance (scope), rigor, and credibility. To our knowledge, all of the rejected articles failed to meet these requirements, either because they lacked descriptions of the research context, the results, or the data analysis.

2.5. Selected studies

Information from the selected studies was extracted to answer the research questions in our study. This allowed us to better classify the articles and analyze their importance in different application contexts. Table 2 shows the summarized results considering the authors and year, the method, the target audience, number of participants of the study and the research approach – QL (qualitative studies) and QT (quantitative studies).

Table 2. Selected Studies

ID:	Authors / Year:	Title:	Method:	Target:	Participants:	QL:	QT:
A1	Morado et al., 2021	Learning by making: A framework to revisit practices in a constructionist learning environment	Case study	Elementary School students (11-year-old boys)	2	X	
A2	Brandhofer, 2021	The micro:bit and computational thinking. Evaluation results of a computational project	Experimental was conducted with pre-testing, a treatment and a post-intervention test	Elementary School students: K5 – K8	1341		X
A3	Cheng et al., 2021	Micro:bit Robotics Course: Infusing Logical Reasoning and Problem-Solving Ability in Fifth Grade Students Through an Online Group Study System	Experimental was conducted with pre-testing and a post-intervention test	Elementary School students: K5	22		X
A4	Tan et al., 2021	A Case Study: Using a Neuro-Physiological Measure to Monitor Students' Interest and Learning during a Micro:Bit Activity	Case study based in Design-based research including a pre- and post-survey	High School Students (13-year-old boys)	2		X
A5	Cederqvist, 2019	Pupils' ways of understanding programmed technological solutions when analysing structure and function	Phenomenographic approach with semi-structured interviews	Elementary School students (11 and 12-year-old): K5 – K6	23	X	
A6	Kaleliogl u & Sentence, 2019	Teaching with physical computing in school: the case of the micro:bit	Survey research (quantitative) and interviews (qualitative)	K-12 teachers with experience of teaching programming and micro.bit	50	X	X
A7	Cederqvist, 2021	Designing and coding with BBC micro:bit to solve a real-world task – a challenging movement between contexts	Phenomenographic approach with semi-structured interviews	Elementary School students: K-4 and K-8	12	X	
A8	Lu et al., 2021	Project-based learning-oriented STEAM: the case of micro–bit paper-cutting lamp	Case study based in Design-based research including a pre- and post-survey	Elementary School students – K5	21		X
A9	Wu et al., 2022	The exploration of continuous learning intention in STEAM education through attitude, motivation, and cognitive load	Survey research questionnaire	University student and elementary school student: K5 – K6	145		X
A10	Teiermay	Improving students'	Descriptive	Physics and	---	X	

	er, 2019	skills in physics and computer science using BBC Micro:bit	research	computer science K-12 teachers			

Reading the articles was of fundamental importance to be able to answer the research questions and also to be able to estimate possible applications in the educational context.

3. Results and Discussions

This section describes the results of the systematic literature review. They were organized in accordance with the research questions presented in the previous section. Some indicators classified as general results are also presented.

3.1. General results

Regarding general results, the Figure 2 presents statistics on the number of articles published per year included in the review. A significant concentration of studies (60% of the sample) can be seen in the period 2021. The absence of studies in the year 2020 is possibly due to may be a consequence of the pandemic period caused by the COVID-19 crisis.

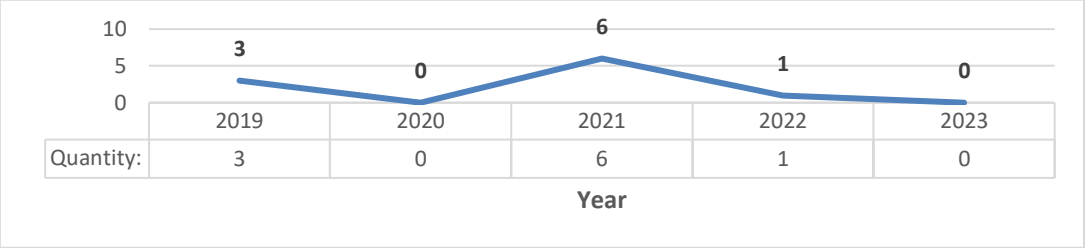

Fig. 2. Flow diagram of study search and selection process based on the PRISMA Statement [Moher et al., 2009].

With the data systematized in Table 2 – Selected Studies made it possible to answer research questions RQ1 and RQ2 (column 'Target'). In this way, we identify 8 studies provided elements with which to answer question RQ1 (Student's experience) – [A1, A2, A3, A4, A5, A7, A8, A9] and 2 studies provided information relevant to question RQ2 (Teacher's experience) – [A6 and A10]. These results show that, in the studies analyzed, we have much more record of the experiences of students than teachers, signaling a lack of data collection in this last area.

In terms of the methodological approach of the researches, 6 studies were classified as quantitative (QT) – [A2, A3, A4, A6, A8, A9], 5 as qualitative (QL) – [A1, A5, A6, A7, A10] and 1 mixed (QT and QL) – A6, this way we have a balanced scenario. This result goes in the opposite direction to that reported by the study by (Papavlasopoulou et al., 2017) – a SLR on the maker movement, where the number of quantitative studies compared to qualitative ones was significantly smaller. In addition, the author points out that few studies focus on gender issues.

On gender issues, only 2 articles deal with this topic. In article A2, the results show that when the pre-test and post-test results are added together, the girls´ overall performance was significantly better than the boys´. This finding is in line with the study of (Yenilmez et al., 2005) the author noted that male students tended to perform better on probabilistic reasoning than did female students. However, in terms of learning achievement, the results were the opposite. In article A3, the results revealed a gender difference in the association between students' logical reasoning and problem-solving

ability. In this context, female students reported a higher level of proportional reasoning, combinatorial reasoning, and correlational reasoning in both the pre-test and post-test.

About target, regarding the educational segment, it is noticed that most studies refer to the Elementary School - represents 70% of the sample, with a predominance for activities carried out with the K-5 through K-8 [A1, A2, A3, A5, A7, A8 and A9]. In addition, we had only one study with the High School Students (A4) and one with of university students (A9).

Lastly, the number of studies participants was reasonably varied. The smallest studies had 2 participants (A1 and A4), while the largest study (A2) involved 1341 participants. One study (A10) did not report the numbers of participants and the average number of participants was 180.

3.2. Student's experience

Regarding student's experience, in study A1, the authors present a framework with eight dimensions and 65 indicators that help tag important aspects of learning in makerspaces: 1) Cognitive domain, 2) Problem solving, 3) Critical thinking, 4) Use of tools and materials, 5) Psychomotor development, 6) Creativity, 7) Intrapersonal domain and 8) Interpersonal domain. To contextualize the framework, a case study was carried out with the objective of to find a technological solution to a problem related to health and well-being. As a result, the creation of a wearable device called the 'Cubik Shaker', which activated different alarms for sedentary. The students designed a case in 3D. With the project, they developed computational thinking. Have learned that microprocessors must be programmed to function, and began to code, empirically learning about algorithms, events, conditionals, loops and variables (Morado et al., 2021).

In study A2, the authors investigated two aspects in a project about computational thinking in school. The results showed that in 80.5 % of the cases the BBC Micro:bits were used in computer science class. In addition, was also used in math, physics, works, music, Education in arts and crafts, movement and sport, religion, descriptive geometry as well as in project teaching or in social learning and the students were very satisfied with the use of this topic in class (Brandhofer, 2021).

In study A3, the authors showed the results of a Micro:bit robotics course with an online group study. A t test performed before and after the course showed a positive increase in students' proportional reasoning, probabilistic reasoning, and ability to analyze a problem (Cheng et al., 2021). In study A4, showed the use of neuro-physiological markers. An Empathic E4 wristband was used to collect electrodermal activity (EDA). The study found that EDA is a possible measure for recording and tracing interest development in students, providing a more nuanced and objective measure of interest development (Tan et al., 2021).

In study A8, has been presents a course is based on the PBL (Project-Based Learning) with the teaching activities combining with "Chinese Paper-cutting" and "BBC Micro: bit". The teaching process used the strategy of creative thinking instruction. The students learned how to apply program logic to connect the sensor, bull, and loudspeaker, they started to combine and design light art functions and created their program design for Micro:bit paper-cutting light lamp. Through this, they learned about mathematics, algebra and function. This study has shown yet that STEAM PBL enables primary school students to improve deduction and induction and such logical reasoning ability in the software programing (Lu et al., 2021).

3.3. Teacher's experience

Regarding teacher's experience, the study A6 explored the pedagogy around the use of the physical devices for programming drawing on teachers' experiences of teaching and assessment using Micro.bit. The study revealed that the most commonly used teaching methods with this physical computing device were live coding demonstrations, pair programming, discussion, collaborative work and tinkering. Additionally, some teachers reported that they introduced concepts as students discovered them (Kalelioglu & Sentence, 2019).

In Study A10, is present some examples of how the Micro:bit can help improve students' skills in Physics and Computer Science. This examples helps students with less experience in more formal text-based programming languages to make them successful with activities related to Physics and Computing (Teiermayer, 2019).

3.4. Difficulties – barriers

Considering that students often have difficulties with coding when using text - based programming languages. The Block-based programming languages, as in Micro:bit, tend to reduce writing problems and difficulties (Milić et al., 2018). However, teachers mention practical difficulties to promote activities along on this theme this being a difficult domain for k-12 Education teachers to navigate (Gibson & Bradley, 2017). In this sense, we understand how relevant it is to show the difficulties and barriers identified in the evaluated studies.

In the view of teachers: according to study A2, it has been shown that computational thinking as a metacognitive ability is in itself difficult to teach or promote and must always be embedded in contexts (Brandhofer, 2021). In study A3, it was reported that, throughout the course, students encountered many difficulties, such as the robot not being able to move as expected due to incorrect programming, hardware problems, or human factors [Cheng et al. 2021]. In study A9, that proposes a learning cycle using Micro.bit. The findings revealed that critical factors affect students' learning attitudes and intentions regarding STEAM education may cause demotivation by the theme (Wu et al., 2022).

In the view of students: The study A5 shows the result of interviews with students after they performed activities with Micro.bit. The results showed that pupils have different approaches to programmed technological solutions based on what parts are discerned in the prepared contexts. As the activities were carried out, it was identified that the parts that are critical to discern in both of the contexts are the physical structure of components in the technological solution, how the components work and what their function is in the solution, as well as the logic in the code and how it controls the components and the flow of information that determines the function of the solution creating barriers to finalizing the project (Cederqvist, 2019).

In a similar way, the study A7 provides in-depth insight into pupils' process of designing and coding with the BBC Micro:bit to solve a real-world task. The results showed that the movements involving the real-world context, the dual nature of the PTS, and the BBC Micro:bit context are challenging, and that pupils' ability to move between the contexts has an effect on how the process unfolds. This situation can make the completion of projects unfeasible (Cederqvist, 2021).

3.5. Under-researched Domains

Finally, it was possible to identify domains that were relatively under-researched in the analyzed sample. These are listed in Table 3 as possible subjects for future studies.

Table 3. Under-researched Domains using BBC Micro.Bit

Under-researched domains	Quantity / Percentage:
Studies that seek to promote gender equality	2 – 20%
Activities with Preschool students	0 – 0%
Activities with High School students	1 – 10%
Studies that report the view and difficulties of teachers	3 – 30%

4. Final Considerations

The use of Micro:bit favors the positive attitude of students who find it fun and easy and are more likely to increase their involvement with it. Despite the limited sample, the findings provide a clear picture of the experience in the use of BBC Micro:bit (Carlborg & Tyrén, 2017). The objective of this study was to carry out a survey of works reporting experiences with BBC Micro.bit in order to identify the contexts in which the technology has been used, how it has been used, and how it can potentially be used in the future. To this end, a search was conducted for articles published in the digital repositories of CAPES, ERIC and Web of Science portals.

The results of the review showed that BBC Micro.bit has been used in a wide variety if contexts. In that regard, we identify the creation **tangible user interfaces (TUI)**: a wearable device called the 'Cubik Shaker' (Morado et al., 2021) and the Empathic E4 wristband was used to collect electrodermal activity (EDA) as a neuro-physiological markers (Tan et al., 2021). The of **areas of knowledge** where Micro.bit was used, going beyond computer science to math, physics, works, music, Education in arts and crafts, movement and sport, religion, descriptive geometry as well as in project teaching or in social learning (Brandhofer, 2021). It was also identified the realization of **robotics courses**, focused on the development of **computational thinking** and coding (Morado et al., 2021; Cheng et al., 2021; Lu et al., 2021).

Besides, the students were very satisfied with the use of BBB Micro.bit in classroom and it is noticed an improvement such logical reasoning ability in the software programing. Finally, it was identified the difficulties and barriers in the evaluated studies. Most important points: Computational thinking as a metacognitive ability is in itself difficult to teach or promote (Brandhofer, 2021). The physical structure of components in the technological solution, how the components work and what their function is in the solution, as well as the logic in the code and how it controls the components it's hard to understand. (Cederqvist, 2019; Cheng et al., 2021).

With regard to future work, it is our intention to create and test activities to students explore Micro:bit Piano module as for the resource to promote music education with a focus on the development computational thinking skills.

References

BASILI, V. R. (1992). **Software modeling and measurement: The goal/question/metric paradigm**. University of Maryland for advanced computer studies.

BBC Micro.Bit (2023). https://www.microbit.org/. Access in: may/2023.

BRANDHOFER, G. **The micro:bit and computational thinking. Evaluation results of a computational project**. International Conferences Mobile Learning 2021 (ML 2021) and Educational Technologies 2021 (ICEduTech 2021).

CARLBORG, N., & TYRÉN, M. (2017). **Introducing micro:bit in Swedish primary schools - An empirical design research on developing teaching material for training**

computational thinking in Swedish primary schools. Available in: https://hdl.handle.net/20.500.12380/252630.

CEDERQVIST, A. M. (2021). **Designing and coding with BBC micro:bit to solve a real-world task – a challenging movement between contexts**. Education and Information Technologies (2022) 27:5917–5951. doi: https://doi.org/10.1007/s10639-021-10865-w.

_____. (2019). **Pupils' ways of understanding programmed technological solutions when analysing structure and function**. Education and Information Technologies (2020) 25:1039–1065. doi: https://doi.org/10.1007/s10639-019-10006-4.

CHENG, P.; LIAO, Y.; YU, P. (2021). **Micro:bit Robotics Course: Infusing Logical Reasoning and Problem-Solving Ability in Fifth Grade Students Through an Online Group Study System**. International Review of Research in Open and Distributed Learning, V. 22, N. 1. doi: https://doi.org/10.19173/irrodl.v22i1.4844.

GIBSON, S., BRADLEY, P., **A study of northern Ireland key stage 2 pupils' perceptions of using the BBC micro:bit in stem education**. The STeP Journal, 4(1), 2017, pp.15-41. Available in: https://ojs.cumbria.ac.uk/index.php/step/article/view/374/495.

KALELIOGLU, F.; SENTANCE, S. (2019). **Teaching with physical computing in school: the case of the micro:bit**. Education and Information Technologies (2020) 25:2577–2603. doi: https://doi.org/10.1007/s10639-019-10080-8.

KITCHENHAM, B., & CHARTERS, S. **Guidelines for performing systematic literature reviews in software engineering**. Keele University and Durham University, Joint Report, 2007.

LU, S.; LO, C.; SYU, J. (2021). **Project-based learning oriented STEAM: the case of micro–bit paper-cutting lamp**. International Journal of Technology and Design Education (2022) 32:2553–2575. doi: https://doi.org/10.1007/s10798-021-09714-1.

MILIĆ, M., KUKULJAN, D. & KRELJA, KURELOVIĆ, E. **Micro:Bit Implementation in ICT Education**. International Conference on Science and Education, 2018, Antalya, pp. 128-133.

MOHER, D., LIBERATI, A., TETZLAFF, J. & ALTMAN, D. **Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement**. Journal of Chinese Integrative Medicine 7(9), 2009, pp. 889-896.

MORADO, M. F.; MEL, E. A.; JARMAN, A. (2021). **Learning by making: A framework to revisit practices in a constructionist learning environment**. Br J Educ Technol. 2021. 52:1093–1115. doi: https://doi.org/10.1111/bjet.13083.

PAPAVLASOPOULOU, S., GIANNAKOS, M. N., JACCHERI, L. (2017). **Empirical studies on the Maker Movement, a promising approach to learning: A literature review**. Entertainment Computing 18 (2017) 57–78. http://dx.doi.org/10.1016/j.entcom.2016.09.002.

TAN, A.L.; GILLIES, R.; JAMALUDIN, A. **A Case Study: Using a Neuro-Physiological Measure to Monitor Students' Interest and Learning during a Micro:Bit Activity**. Educ. Sci. 2021, 11, 379. doi: https://doi.org/10.3390/educsci11080379.

TEIERMAYER, A. (2019). **Improving students' skills in physics and computer science using BBC Micro:bit**. Phys. Educ. 54 (2019) 065021 (8pp). doi: https://doi.org/10.1088/1361-6552/ab4561.

WU, C.; LIU, C.; HUANG, Y. (2022). **The exploration of continuous learning intention in STEAM education through attitude, motivation, and cognitive load**. International Journal of STEM Education (2022) 9:35. doi: https://doi.org/10.1186/s40594-022-00346-y.

YENILMEZ, A., SUNGUR, S., & TEKKAYA, C. (2005). **Investigating students' logical thinking abilities: The effects of gender and grade level**. Hacettepe University Journal of Education, 28, 219–225. Available in: http://efdergi.hacettepe.edu.tr/yonetim/icerik/makaleler/910-published.pdf.