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The effectiveness of block-based programming applications in secondary school: meta-thematic analysis complemented with qualitative research

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Programming is becoming increasingly important today and is considered one of the advanced skills that individuals should possess in the 21st century. However, since individuals often struggle when learning programming, block-based programming (BBP) applications have begun to be used to make coding easier to learn. In this study, the effect of BBP applications at the middle school level was investigated using meta-thematic analysis supported by qualitative research. The study consists of two stages. In the first stage of the research, studies were identified through document analysis within the scope of meta-thematic analysis. Two different researchers conducted content analysis on the identified studies to identify themes and codes. A total of 121 codes were identified from 10 studies, and 5 themes were created based on these codes. The study was conducted using an interdisciplinary approach within the scope of the experimental process. Due to the suitability of coding applications for science education and the fact that one of the researchers is a science teacher, the study continued with a 4-week BBP application with 6th-grade students taking science, information technology and software courses. At the end of the process, a semi-structured interview form was administered to the students, and codes were obtained from the participants' responses through content analysis. The results of the study showed that BBP applications contributed to students' affective and academic characteristics, 21st-century skills, personal development, and digital literacy. Therefore, this study not only synthesises the effects of BBP but also presents experimental evidence linking programming education to digital competencies and personal development, offering a rarely explored integrative approach to the literature.

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Introduction

Among the 21st century's digital and cognitive skills, programming is not only a technical skill, it also stands out as a fundamental learning area that supports problem solving, algorithmic thinking and creativity (Montuori et al. 2024). Teaching and learning programming is generally considered a challenging subject for both students and teachers due to its complexity and abstract nature. Traditional teaching approaches fail to significantly contribute to students' development of cognitive models, which can lead to high failure rates in introductory programming activities and even dropout (Papadakis, 2018). In addition, traditional text-based programming languages contain abstract structures (Ou et al. 2023). Therefore, this situation can be challenging, especially for primary and secondary school students. However, another challenge encountered in programming education is the traditional approach, which fails to provide students with environments conducive to exploring concepts and problems in an enjoyable and creative manner (Papadakis and Orfanakis 2017). Although previous studies have documented the benefits of block-based programming (BBP) on motivation and learning, there are still gaps in its integration with artificial intelligence and its combined effect on socio-emotional and digital competencies in secondary education. Especially in recent years, Scratch, Blockly, and mBlock block-based programmes have become more widely used in education (João et al. 2019). With BBP, students learn coding more easily and visually (Yu et al. 2025). This method, supported by Papert's constructivist learning theory, strengthens students' learning by producing digital products (Levin et al. 2025). In addition, in line with Vygotsky's sociocultural theory, students contribute to their individual development with coding activities carried out in groups (Rigopouli et al. 2025). Today, the integration of BBP into STEM courses contributes to students in many ways (Tariq et al. 2025). However, there are still insufficient qualitative and interdisciplinary studies in the literature (Pan et al. 2024). This study investigates the effects of block-based programmes on secondary school students. The study analyses existing qualitative research. In addition, the study examines an applied experimental process with a two-stage approach. In general terms, the study examines the technology dimension of STEM education in depth and reveals its outcomes.

Programming. Technological developments are progressing rapidly in the field of education (Mena-Guacas et al. 2025). This situation leads to the prominence of new concepts in the field of education and informatics (Mukul and Büyüközkcan 2023). One of the basic skills of the digital age is the concept of programming (Eteng et al. 2022). In today's education system, various modelling approaches are developed to solve problems through programming (Çam and Kıyıcı 2022; Ouyang and Xu 2024). Transferring these educational models to the digital environment through software increases the effectiveness of digital solutions in education and makes it possible to produce rapid responses to current needs (Bygstad et al. 2022; Haleem et al. 2022; Mondragon-Estrada et al. 2023). In addition, programming not only gives commands to the computer but also develops systematic thinking skills (Sigayret et al. 2022). In this context, it is seen that individuals improve their ability to develop solutions in different subjects and fields and to choose the most appropriate one (Yu et al. 2015). It is noteworthy that programming teaching has critical importance among the 21st-century skills defined by ISTE (Kuloğlu, 2022). Again, qualitative research and current literature studies reveal that programming skills are one of the basic competencies that individuals need in the digital age (Van Laar et al. 2020). In order to support the development of these

skills, it is recommended to start teaching programming at an early age (Kalelioğlu 2015). *BBP tools* have an important place in programming instruction for early age groups (Totan and Korucu, 2023). The fact that these tools are age-appropriate, interactive and game-based enables students to learn the lesson in a fun and active way (Hu and Razlog, 2023). BBP is based on the principle of combining code blocks by the drag-and-drop method without writing code (Weintrop and Wilensky 2019). In this system, the learning process is made concrete by using visual and colourful blocks instead of abstract structures and complex algorithms encountered in traditional programming languages (Tsai 2019; Çipiloğlu Yıldız and Doğan 2024). Additionally, block-based programming (BBP) environments facilitate the learning of abstract programming concepts such as variables, loops, and conditional statements by enabling students to focus on logical structures rather than complex text-based syntax rules, thereby significantly supporting academic achievement (Sukirman et al. 2022; Weintrop and Wilensky 2017). Beyond technical skills, these visual tools enable students to develop 21st-century skills such as problem solving, algorithmic thinking, and creativity through debugging processes (Hijón Neira et al. 2021), while also increasing classroom interaction, fostering a more "friendly" and collaborative learning culture where students help each other (Weintrop and Wilensky 2017). With the reduction of technical barriers caused by syntax errors, students' anxiety levels regarding programming decrease, positively affecting their interest in the course, their motivation, and their sense of self-efficacy, thus providing a more inclusive learning experience (Sihat and Ocak 2026; Weintrop 2019). In this context, the reduction of cognitive and affective barriers to programming has made it possible to extend the learning process to younger age groups. This situation has lowered the age of learning programming (Kalemkuş and Kalemkuş 2024). Accordingly, platforms such as Scratch, MIT App Inventor, Code.org, Kodu Game Lab, Tynker and Blockly are among the widely used BBP tools developed for early age groups (Yılmaz and Üstün 2021). These tools attract attention by making programming teaching more accessible, fun and interactive (AbdulSamad and Romli 2021). *Scratch*, in particular, draws attention with its *simple* interface and user-friendly structure and is recommended because it is easier and more fun than other BBP tools (Perin et al. 2023). However, although the effectiveness of Scratch has been tested in early education, there is still a need to understand how these tools develop problem-solving and creativity skills in real middle school contexts, which are important elements for meaningful learning.

Purpose, scope and method. The main purpose of this study is to examine the effectiveness of BBP applications at the secondary school level with a qualitative research design supported by a meta-thematic analysis approach. A review of the literature reveals that numerous studies have been conducted on BBP both nationally (Parlar et al. 2024; Yıldırım 2024; Kanmaz and Şahinkaya 2025) and internationally (Wörster and Knobelsdorf 2025; Muhammad et al. 2025; Arruda 2025). Upon examining these studies, it is seen that in order to teach coding skills to middle school students, the learning outcomes of the programming unit in the Information Technology course are attempted to be taught using the Blockly application (Kanzmaz and Şahinkaya 2025). Arduino and Raspberry Pi Pico were compared from physical, technical, and pedagogical perspectives and evaluated in terms of programming instruction (Koç 2025). The interaction between gamification and attitude, academic achievement, self-efficacy perception, and motivation in the programming

education process was examined solely from a quantitative perspective (Karatepe 2025). The effect of the SCRATCH and ALICE programming languages on university students' programming outputs was evaluated (Vinueza-Morales et al. 2025). Studies examining the effect of BBP learning on the development of learning outcomes were reviewed (Sonjaya and Munir 2025). In a study measuring students' programming skills using pre-test–post-test applications and a rubric-based assessment process, it was determined that learning activities integrating unmanned aerial vehicles (UAVs) or drones with BBP were presented to improve students' programming skills (Kanjanasombut et al. 2025). Furthermore, it was understood that the vast majority of studies were conducted with experimental designs and single applications, did not take into account the perceptions/opinions of the study groups (students), and were not supported by qualitative data. A study involving a two-stage mixed method, similar to our current study, has also been found in the literature. In this research, which aims to determine the effect of project-based educational robot activities on middle school students' self-efficacy in computational thinking and programming, a two-stage mixed design was used, but it was understood that the application lesson was the Information and Technology lesson (Doğan and Korkmaz 2025). Therefore, it has been evaluated as a noticeable deficiency and a situation that needs to be investigated, as there are no comprehensive and consistent findings in the literature regarding the effects of BBP at the middle school level and in the context of science courses, and the findings are thematically negligible. In this context, our current study aims to comprehensively reveal the effects of BBP at the middle school level through meta-thematic analysis and thematic analysis, drawing on both the literature and student experiences.

In today's education system, programming is not only considered a technical skill. Programming is also a cognitive process that supports algorithmic thinking, problem solving and creativity. Especially with the widespread use of BBP tools such as Scratch, Blockly and mBlock in education, the effects of these applications on students' cognitive and affective development have become the subject of research. However, existing studies generally focus on single applications and/or limited samples and rely on only one data source. No study in the literature has been found that conducts a comprehensive meta-thematic analysis integrating findings for middle school students. Furthermore, studies supporting the themes obtained from the literature with views on student experience resulting from classroom applications (qualitative data) are also limited.

In this study, a two-stage research design was adopted to address these gaps. In the first stage, a meta-thematic analysis of BBP studies at the middle school level was conducted to generate comprehensive themes and codes. In the second stage, these themes were expanded and supported by qualitative data obtained from a four-week classroom application. Based on both the literature and data obtained from the learning environment, this study presents a unique and dual-source thematic framework for understanding the cognitive, affective, and developmental effects of BBP applications on middle school students. In this context, the study focused on two main questions.

1. What are the effects of BBP applications on affective and cognitive dimensions of middle school students?
2. What are the contributions of these applications to individual development and 21st-century skills?

The study also supports systematic analyses by being prepared from a qualitative, multidimensional and interdisciplinary perspective, which is lacking in the literature.

Methodology

This research was conducted using a two-stage design based on qualitative research methods. In the first stage, qualitative studies on BBP were systematically analysed. The studies examined were interpreted using meta-thematic analysis based on document analysis. Meta-thematic analysis is a way of synthesising qualitative studies on a specific topic. Therefore, meta-thematic analysis is a structured analysis process aiming to identify common themes and codes (Batdı 2021a). In this process, the steps of determining the research problem, selecting the appropriate literature, conducting content analysis and creating code-theme relationships were followed (Büyüköztürk et al. 2019).

In the second stage, an experimental qualitative research process was conducted. In this process, a case study design without a control group was used. Integrating meta-thematic analysis with an experimental process reduces bias by triangulating results and provides a stronger interpretive framework. The application was carried out with 6th-grade students studying in a public secondary school in Gaziantep province. The implementation of the research lasted four weeks. The students participating in the research developed educational games to be integrated with the Science course with the help of tools such as Scratch or mBlock. Throughout the process, students were supported with digital skills such as algorithm building, interaction with artificial intelligence and problem solving. Student opinions were collected through semi-structured interview forms and analysed with MAXQDA software (Yıldırım and Şimşek 2021).

This two-stage approach aims to identify general trends based on a literature review. In addition, it is among the objectives of the study to provide a comprehensive and in-depth analysis of the original data obtained from the implementation processes.

Data collection. During the data collection process, the keywords “block-based programming” and “the effect/effectiveness of block-based programming applications” were used in both Turkish and English. A comprehensive search was conducted for studies published between 2005 and 2025 in the YÖK National Thesis Center, Google Scholar, Web of Science, Taylor & Francis Online, ScienceDirect, and ProQuest Dissertations & Theses Global databases. The content analysis of the studies selected by the document analysis method was carried out using MAXQDA software (Batdı 2021a). In this study, MAXQDA was used to generate meaning beyond coding. Memo notes were added to codes and text segments to record researcher comments; comparative summaries of codes were created using Summary tables. Additionally, Code Relations Browser and MAXMaps were used to examine relationships between codes and ensure the analytical deepening of themes. The study selection process was carried out in four stages, and a total of 10 qualitative studies were included in the meta-thematic analysis. The selection process and the reasons for the excluded studies are detailed in the diagram (Fig. 1).

Coding in the meta-thematic analysis process. Coding in meta-thematic analysis is one of the basic stages of qualitative data analysis (Kurt and Batdı 2022). This process can be carried out with a deductive or inductive approach (Fife and Gossner 2024). In deductive analysis, data suitable for predetermined concepts should be selected (Bingham 2023). In inductive analysis, codes should concretise the relationships between data and derive them directly from the data by transforming them into meaningful categories (Naeem et al. 2023).

In this study, codes were reached by reinterpreting the participants' views with an inductive approach. After coding,

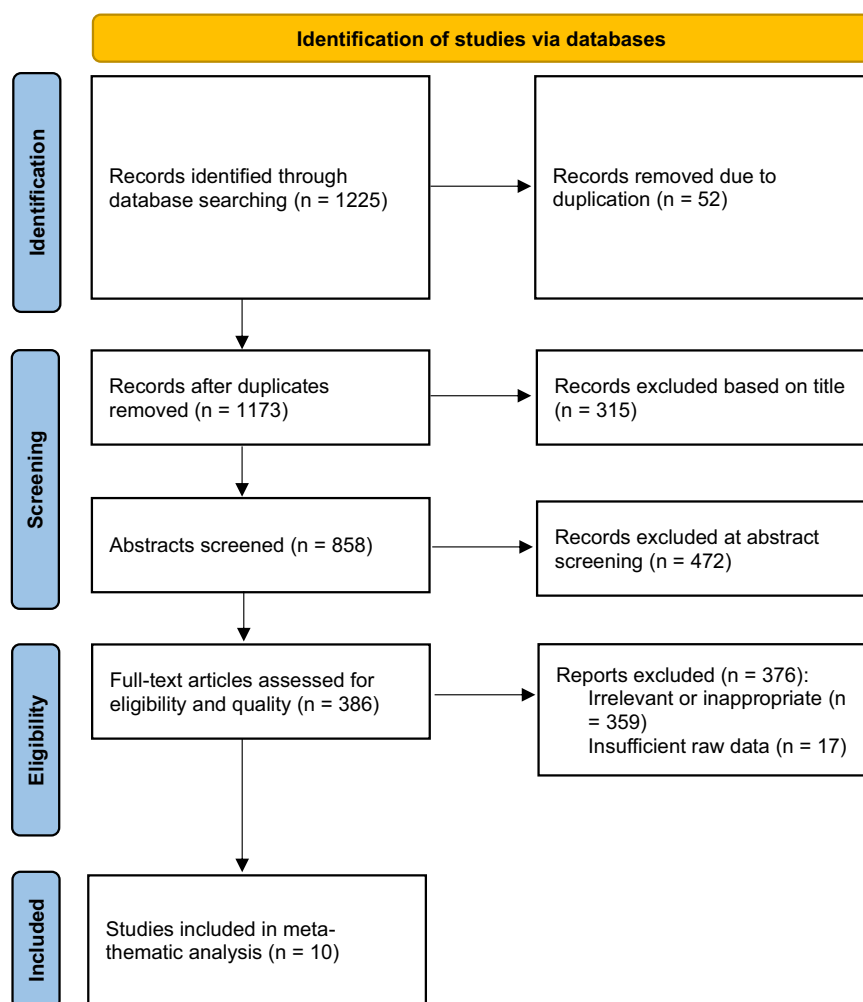


Fig. 1 PRISMA flow diagram of the study selection process.

the codes that overlapped in meaning were grouped under themes and thematic coding was carried out. At this stage, in order to ensure the validity of the themes, the principles of internal consistency (the data under each theme being meaningful and integrated within itself) and external consistency (the power of the themes to explain and represent the general research results) were taken as the basis (Yıldırım and Şimşek 2021; Merriam and Tisdell 2009).

For coder reliability, two researchers analysed the data independently, and a consensus was reached on the codes and themes they created. The reliability of the process was evaluated quantitatively with Cohen's Kappa coefficient (Cole 2024).

Experimental process. This section of the study presents the implementation of an experimental qualitative process. The fundamental rationale for using an experimental qualitative process following the meta-thematic analysis is to enhance the overall validity of the research by validating the meta-thematic findings reached in the literature with data obtained from actual classroom applications. Although meta-thematic analysis systematically identified common themes in existing research, it did not show how these themes corresponded to the BBP application process conducted with middle school students. Therefore, a four-week BBP application was included in the research, and semi-structured interviews were conducted at the end of the process to reveal the students' experiences. This process allowed

the themes identified in the literature to be supported by classroom observations, revealed their missing aspects, and enabled the development of new sub-themes. Thus, the experimental qualitative process took on the function of testing, validating, and expanding the codes and themes obtained in the meta-thematic analysis from a contextual perspective, ensuring that the research results were grounded in both theoretical and practical foundations.

In the qualitative process, the results were determined by content analysis of the studies related to BBP in the literature. In this section, the experimental process was mentioned. The experimental process is the applied research phase carried out to support the results of the qualitative study and to increase its validity. This application, carried out in the experimental phase, was designed for 6th-grade students and was carried out with a holistic approach based on the interaction of different disciplines. As part of the research, a four-week Science and Technology Project (STP) was designed and implemented for 6th-grade students enrolled in Science and Information Technology courses.

Research design. The study is a qualitative research with experimental features. The research design, "*post-test design without control group*", which is among the weak experimental designs, was preferred. In this research design, in which there is no control group, only the intervention for the current group is applied, and measurements related to the dependent variable are

carried out after this intervention (İlhan and Gezer 2021). In selecting the study group, a single group (experimental group) was chosen, necessitating the use of student opinions regarding the effects of BBP. Due to the teacher conducting the application working in an educational environment where it was not possible to administer a pre-test or establish a comparison group, a single-group post-test design was preferred for the current research. Although the absence of a control group limits causal inference, validity has been strengthened through triangulation of sources, independent coding, and calculation of the Kappa coefficient. Additionally, as Shadish et al. (2002) also noted, the pre-test application was not preferred due to the possibility that it could disrupt the natural flow of the learning process and artificially influence the learning process by reminding students of concepts beforehand. Furthermore, Creswell (2009) stated that participants recalling their previous answers while taking the test is a situation that threatens the internal validity of the research. Therefore, the single-group post-test design allows for the collection of data on students' experiences and perceptions after the application, providing qualitatively meaningful information about the effect of BBP. Single-group designs are particularly preferred in application-focused classroom research (Creswell and Creswell 2018). Although causal and comparative inferences are limited, this design provides an important data source that ensures the reliability of the research, as it is supported by qualitative data and the findings of the literature in the meta-thematic analysis.

At the end of the experimental process, participant opinions were sought to increase the credibility of the results and to support the validity of the data. Participant feedback was considered as one of the validity strategies in the qualitative research process. In this direction, the “*case study*” design, one of the qualitative research designs, was preferred in the study. A case study, also called a case study, is a research method in which a group is specified according to a specific place and time and is conducted under special conditions (Büyüköztürk et al. 2019; Çapar and Ceylan 2022; Tran and Nguyen 2024).

Study group. In the study, easily accessible case sampling, one of the sampling methods commonly used in qualitative research, was used. The application, which was carried out in the schools where the researchers were actively working, was carried out with the students in the classes in these schools. The fact that researchers turn to the easiest sampling that they can reach from the universe means the convenience of the sampling method (Priya, 2021). The study group of the research consists of 6th-grade students studying in a secondary school in Gaziantep province. All students participating in the study were male. It was determined that the vast majority of students (98%) had no prior experience with BBP tools. In other words, it was assumed that the students were at an equal starting level. The students' participation in the study was based on the suitability of the school's curriculum and the students' voluntary participation. The applications prepared within the scope of the Science and Technology Project (STP) were applied to forty 6th-grade students determined as the experimental group. During the application process, students were organised to work in groups of two. It was predicted that group work would contribute to the development of students' 21st-century skills. In the literature, interdisciplinary studies in which the outcomes of different courses are combined are frequently encountered. One of the studies conducted in this context analysed the studies conducted between 2013 and 2020 on technology integration in the context of science education and conducted a content analysis of these studies. In this study, which was based on the analysis of a total of 49 scientific studies, it was concluded that the studies examined were largely based on

quantitative research methods (Devran et al. 2021). A study titled *The Effect of Technology Integration Matrix on Students' Academic Achievement in Science Course* states that technology positively affects student achievement. In line with the studies examined and because one of the researchers is both a Science teacher and takes Information Technologies courses, it was decided that the integration of these two courses would be appropriate. Before the application, the subject of the game to be developed was determined by using the brainstorming method with the students. At the beginning of the process, the researcher selected two science subjects with the students and planned the implementation process accordingly. The topics were “*systems in our body*” and “*solar system*”, and the students were expected to design a game that would support the learning of these topics with MBlock or Scratch software. Artificial intelligence support was utilised in the game development process. Students interacted with artificial intelligence to generate questions and integrated these questions into the game content. Details about the implementation process are explained below, and student opinions were taken after the implementation. The experimental process of the research was conducted during the Spring semester of the 2024–2025 academic year.

1st Week (classroom implementation process of the activity supported by BBP). Prior to the research, the teacher gave the students basic information about algorithms, coding, problem solving, data sources, artificial intelligence and digital ethics. The teacher in charge determined the topics they wanted to work with the students first. The solar system and systems were the topics determined. Students were informed about the research process and BBP applications. The students were asked to identify a topic related to the science course. The students were informed that they would design a game within the scope of BBP with the Scratch Web 2.0 tool in line with the topic they determined. At the same time, the students were told about the scientific research process. It was emphasised that the research process should start with problem awareness, and sample problems from daily life were identified through brainstorming. Research processes for these problems were created by the students, and the nature of learning and the contribution of games to learning were discussed in the classroom environment. The images presented in Fig. 2 illustrate the in-class implementation process of the activity.

2nd Week (artificial intelligence-supported game design and question development process). The students were divided into groups and asked to design games containing 20–40 questions on the topic they determined. The developed questions and game ideas were discussed in the classroom environment, and games were developed in line with teacher and peer feedback. Artificial intelligence applications were introduced to the students under the guidance of the teacher; sample studies on the use of ChatGPT and Scratch were carried out. It was observed that the questions produced by the commands given to artificial intelligence were generally superficial, and the importance of limiting the commands for effective guidance was emphasised. The questions were structured by limiting them with expressions such as “*6th-grade level*” and “*single answer*”. The tutorial questions prepared by the students were discussed with ChatGPT and finalised in line with the feedback received from artificial intelligence (Fig. 3).

3rd Week and 4th week (technology and peer feedback in the development process of student products). In line with the determined framework, students started game design by coding on Scratch. The use of code blocks was explained by the teacher;

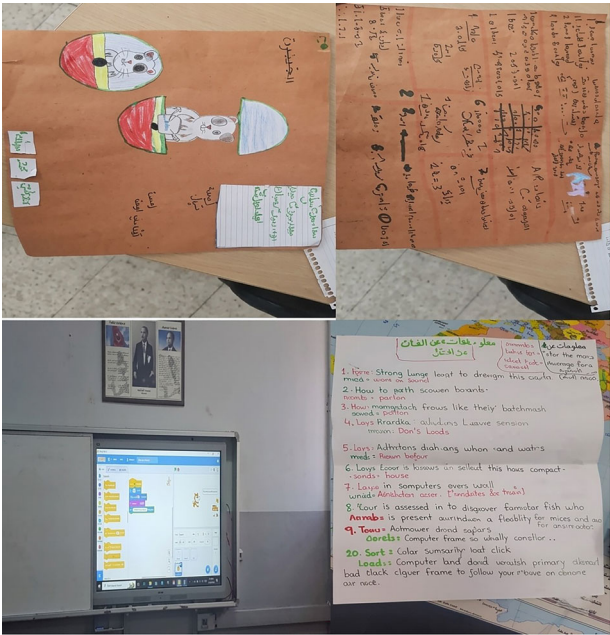


Fig. 2 Classroom implementation process of the activity supported by BBP.

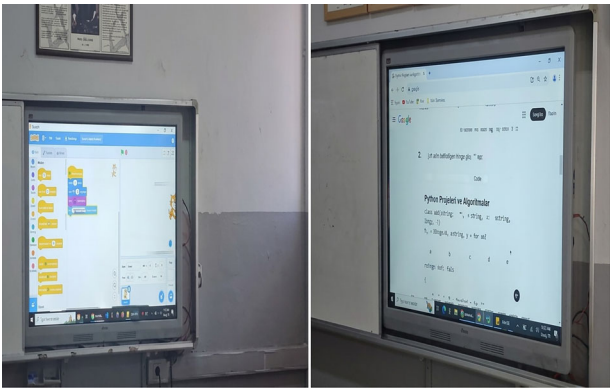


Fig. 3 Artificial intelligence-supported game design and question development process.

students first tried to get support from ChatGPT for the problems they encountered. Since there are many artificial intelligence versions, the students were provided with teacher support on which one to choose. The teacher guided the students on how to ask their questions to the artificial intelligence. The technical problems experienced by the students were solved with the support of the teacher in charge. After the deficiencies were eliminated, the coding was completed, and the developed games were tested by other groups (Fig. 4). The effectiveness of the studies was discussed, and student products were evaluated with a semi-structured interview form.

Data collection tool. An interview is a data collection technique; its purpose is to collect information. Interviews can be conducted in different ways. While the interview is conducted, it can be transcribed, and audio recordings can be taken, and then the audio recordings can be transcribed (Creswell, 2021). In the literature, the interview type is divided into two: structured interview and unstructured interview. If the questions and boundaries are strictly predetermined, this is a structured interview (McIntosh and Morse, 2015). The purpose of a structured interview is to



Fig. 4 Technology and peer feedback in the development process of student products.

identify similarities and differences between the responses given by individuals. In an unstructured interview, however, there are no expectations; interview topics are explored, and more detailed questions can be used to conduct in-depth investigations (Ruslin et al. 2022).

In this study, a semi-structured interview form was used to collect data. “In structured interviews, the researcher prepares the questions in a certain order. This method allows for rapid coding and analysis of the data, ease of measurement and then comparison with the scope of the research” (Adeoye-Olatunde and Olenik 2021). In the interview form, there are questions about BBP practices. These questions were chosen to access data that could not be obtained in the meta-thematic section, and therefore, questions related to themes not included in the meta-thematic section were selected. Since personal development, digital competence, advantages and disadvantages were explored, the questions were designed to obtain them. The interview form was prepared by taking into account the expert opinions on BBP applications and examining the existing studies. After it was prepared, expert opinions were needed again, and the interview form was finalised after the necessary arrangements were made. In the semi-structured interview form, the questions “What do you think about the contribution of BBP applications to your personal development?”, “What do you think about the contribution of BBP applications to your digital skills development?”, “What do you think are the negative aspects of BBP applications?”, “Do you have any suggestions about BBP applications?”, “What are your opinions about BBP?” were included.

Data analysis. While carrying out the coding process, firstly, content analysis was performed for the 10 included studies. Content analysis is a process in which words in a text are coded and divided into smaller categories, and it is also a repeatable process (Serafini and Reid 2023). In this study, the studies included in the meta-thematic analysis process were analysed through detailed interviews. Themes and codes were created as a result of repeated analyses. The codes and themes obtained were compared with other data, and the results were made comprehensive. In order to ensure the validity and reliability of qualitative data, the elements of credibility, transferability, consistency and confirmability were included. In order to ensure the credibility criterion, a diversification strategy was preferred. In qualitative research, diversified data collection methods can make the results of research stronger and more reliable (Berthet et al. 2023). The results of the studies in which data obtained by different methods, such as document analysis, observation and interview,

Table 1 Fit values of the study.

The effect of BBP on the affective dimension					Contribution of BBP to the academic dimension					BBP ... challenges and ... recommendations					21st-century skills in BBP				
K2					K2					K2					K2				
K1	+	−	Σ		K1	+	−	Σ		K1	+	−	Σ		K1	+	−	Σ	
	+	31	2	33		+	30	1	31		+	29	1	30		+	30	2	32
	−	2	18	20		−	3	16	19		−	1	13	14		−	2	11	13
	Σ	33	20	53		Σ	33	17	50		Σ	30	14	44		Σ	32	13	45
Kappa: 0.839 p: 0.000					Kappa: 0.827 p: 0.000					Kappa: 0.895 p: 0.000					Kappa: 0.784 p: 0.000				

were used as triangulation data sources were taken into consideration. The criterion of transferability was ensured by transferring the research results as they are without intervention. In order to ensure the consistency criterion, themes and codes were created separately by two researchers, and their consistency was checked. The fact that the codes created by the researchers are consistent within themselves means that the coding process is reliable (Berthet et al. 2023). Direct quotations were made from the opinions for the confirmability criterion. MAXQDA software was used to analyse the data obtained in the semi-structured interview form after the BBP applications.

Reliability in the qualitative research process. In this study, coder reliability was used to test the reliability of themes and codes. Coding was carried out by two different researchers. The coders independently evaluated the participants' views and extracted codes and themes. After the coding process was completed, the agreement between the coders was examined. It is very important that the coders create similar coding in the same data set they use (O'Connor and Joffe 2020). Inter-coder reliability can be calculated by dividing the codes with which the coders agree by the codes with which they do not agree (O'Connor and Joffe 2020). Inter-coder reliability can be considered reliable if it is eighty per cent or above. One of the equivalents of the concept defined as reliability in quantitative research in qualitative research is credibility. Including quotations from participant views in qualitative research affects the credibility of thematic analysis (O'Connor and Joffe 2020). In the research, it was aimed to increase credibility by including direct quotations. When there was a difference between the codings, discussions continued until the harmony between the codings was achieved. At this stage, Cohen Kappa agreement values, which provide reliability between coders, were calculated. Kappa agreement value is an important tool to ensure reliability in data analysis in qualitative research, and is widely used to evaluate the consistency between coders. The values obtained are between 0.784 and 0.895. Kappa value is between +1 and −1, and as the value approaches 1, the agreement is accepted as very good. 0.81–1.00: Excellent agreement; 0.61–0.80: Good agreement; 0.41–0.60: Moderate agreement; 0.21–0.40: Poor agreement; 0–0.20: Very poor or almost non-existent agreement. (Cohen 1960). It can be said that the Kappa values of the study are in the good to excellent agreement ranges.

This study was approved by the Scientific Research and Publication Ethics Committee of the Faculty of Social Sciences and Humanities at Gaziantep University, as per the decision dated March 03, 2025, numbered E-87841438-302.08.01-624494. Written informed consent was obtained from all participating students and, when necessary, from their parents. Data collection procedures were conducted in accordance with the guidelines of the Helsinki Declaration (2013) and ethical standards. This practice guarantees the protection of participants' rights and privacy and adherence to the principle of voluntariness in the data collection process.

Results

In the findings section of the study, the results of content analysis and participant views on the effectiveness of BBP practices at the secondary school level were presented and interpreted. In the first stage, the results of the meta-thematic analysis and the results of the participants' views in the experimental stage are shown. Also, the fit values of the study are given in Table 1.

In all categories, Cohen's Kappa coefficients are above 0.78, and *p*-values are 0.000. This shows that there is a high level of consistent and significant agreement between the two coders. The reliability of the coding is quite high.

Results obtained within the scope of meta-thematic analysis. In this section of the study, research on the effectiveness of the BBP application at the middle school level was examined using the meta-thematic analysis method. As a result of this analysis, five themes emerged: *"The impact of BBP on the affective dimension"*, *"BBP's contribution to the academic dimension"*, *"challenges encountered in the BBP process"*, *"suggestions for overcoming challenges"*, and *"21st-century skills in BBP"*. The themes and codes were presented in relevant figures, and the students' statements used in the comments in the text were given as direct quotations (Fig. 5 shows the theme and codes related to the effect of BBP on the affective dimension).

The analysis determined that BBP applications were effective in the affective dimension by stimulating students' emotions. Student opinions considered within this theme are presented as direct quotations in the study coded as 594858: *"It was challenging and a good competitive environment."* and *"Because it taught me to achieve different things."* (p. 51); in the study coded M12, the statements *"Because I really liked it, it was a very good application,"* *"When I struggled, I got bored and felt negative,"* *"When I struggled, I got help from my friends,"* (p. 275), *"The lesson seems to end faster,"* and *"If I work hard, I can create my own game"* (p. 276). These opinions show that students enjoyed the application and felt the desire to design. In addition, students collaborated with each other during BBP applications and developed their intra-group communication skills. From the study coded M6, *"It looks like a jigsaw puzzle."* (p. 47), from the study coded 591569, *"For example, I design houses and cars, I design things as I think of them. I like it. It's not like a homework or a task, so it's fun to do."* (p. 74). Again, when examining the relevant student opinions, it can be stated that students taking on different tasks and designing games and projects together provides them with the opportunity to increase their creativity. From the study coded 863542. *"My family helps me when I want, but I don't want help, I prefer to do it myself,"* *"teacher, my favourite part is the support and hint place, it is very nice when we look at the blocks we cannot find from there, that part makes the system fun"* (p. 83), the students stated that they could get help when they needed help in the process and that the applications facilitated their learning. This finding suggests that coding and BBP activities enable students to gain a sense of responsibility and

Joy of Learning	Listening
	Writing
	Reading
	Confidence
	Focus
	Discipline
	Skills
	Knowledge
	Curiosity
	Motivation
	Creativity
	Cultural Awareness
	Autonomy
	Organization
	Evaluation
	Open-mindedness
	Experimentation
	Learning Styles
	Enthusiasm
	Persistence
	Resilience
	Empathy
	Adaptability
	Innovation
	Growth Mindset
	Goal Setting
	Reflection
	Understanding
	Research
	Communication
	Technology
	Time Management
	Collaboration
	Problem Solving
	Critical Thinking
	Speaking

Fig. 5 Effect of BBP on affective dimension.

improve their digital literacy. 742149 coded “Of course it was a lot. I feel better developed in BBP, it helped me learn BBP more easily. There are similarities between each other, since what I learnt in intelligence games is also useful in BBP, they have an effect on each other. Both have step-by-step thinking. Both are problem solving orientated.” (p. 91). These statements demonstrate the relationship between academic activities and problem-solving and digital skill acquisition. Codes related to BBP’s contribution to the academic dimension are presented in Fig. 6. Content analysis revealed that BBP applications increased motivation to learn, developed a sense of responsibility, and supported the retention of learning. The findings regarding academic contributions are also supported by participant statements. Students expressed opinions such as, “We were able to learn by doing and seeing,” “We were able to learn faster,” and “We progressed gradually from easy to difficult” (p. 274). In the study coded M12, students stated that the process contributed to their development, saying, “Both our imagination is developing more and it is becoming easier for us to produce the robot of our dreams... Because we are interested, we see and learn new things; this develops us further” (p. 67).

Students also related BBP applications to other subjects. In the M2 coded study, the view “I can use the sequence if I get confused in math problems. I can use it in sections such as introduction, development, and conclusion in my Turkish homework” (p. 10) was expressed. The analysis of the theme of BBP’s contribution to the academic dimension shows that skills that support students’ active role in the learning process come to the fore. Participants

stated that they encountered various difficulties during the process. Figure 7 also shows suggestions regarding these difficulties. Among the participants’ views are “The displayed codes could have been in Turkish.” (p. 275), in the study coded M12, “I’m having a lot of fun, but sometimes I get a little bored when the codes are long.” (p. 71), in the study coded 591569, “There is too much information, and you are trying to work with it, trying to do the process.” (p. 113), in the study coded 863542, “...time is passing, I’m not trying very hard to get 4 stars, I’m moving on to the next question right away...” (p. 109), and in the study coded 742149, “Consistency and continuity are very important in this job.” (p. 88). These findings show that students struggle particularly with the coding process, which is understandable given that the application is not yet widespread. Furthermore, some students viewing the application merely as a game, with their primary goal being to pass the sections, were considered a factor that could negatively affect the learning process. The theme of suggestions regarding the difficulties encountered in BBP is based on various solutions proposed by the participants. Students suggested, “There could be extra hint videos when we have difficulty passing a level” (p. 275), and in the study coded M12, “The number of lessons could be increased, and two or three activities could be held per week instead of one” (p. 53). (p. 129), and in the study coded 757101, “It would make more sense if it were used in numerical subjects such as science and mathematics.” (p. 53). The codes identified under the theme of 21st-century skills in BBP are presented in Fig. 8. The analysis showed that BBP applications support students’ 21st-century

BBP's Academic Contributions	Creating scenario cards
	Improving experimental skills
	Designing STEM projects
	Increasing academic career awareness
	Enhancing scientific writing
	Enhancing academic achievement
	Developing interdisciplinary skills
	Understanding scientific ethics
	Developing scientific skills
	Improving decision-making
	Increasing persistence
	Improving retention skills
	Developing critical thinking
	Improving digital literacy
	Strengthening self-efficacy
	Explaining cause-effect relations
	Developing cooperation
	Improving scientific communication
	Improving inquiry-based learning
	Interpreting scientific concepts
	Developing problem-solving skills
	Improving data literacy
	Developing hypothesis setup skills
	Analyzing and verifying data
	Using multiple representations
	Improving scientific creativity
	Enhancing technology use
	Developing authentic productions
	Improving scientific research skills
	Developing peer learning
	Improving analytical thinking

Fig. 6 Contribution of BBP to the academic dimension.

skills. In this context, students stated that they “*learned to write and build computer and work systems*” (p. 118), and in the study coded 681680, they stated that “*I want to improve myself with robots... We need to learn about robots or technology, because everything is done with robots now.*” (p. 67). Study code M12 included the opinion, “*We can use computers more.*” (p. 276), while study code 694752 included the statement, “*I learned how to model in the Scratch application. If I remove the code blocks, there is no problem, the codes work... After a few attempts, I managed to draw it.*” (p. 46). In the study coded 863542, students explained their problem-solving processes by saying, “*When I don’t understand the question, I first press the ‘I don’t understand the question’ button... Then I go to the support section and understand the solution path.*” (p. 108). The overall analysis of this theme shows that BBP applications make significant contributions to the development of 21st-century skills such as technology use, problem solving, modelling, and independent learning among students.

Results obtained in the experimental process. In the experimental section of the study, data was collected from 29 students via a semi-structured interview form after a four-week BBP application. Although a total of 40 students participated in the applications, some interview forms were deemed invalid due to the absence of some students on the data collection day and the insufficient Turkish language proficiency of some foreign students. Therefore, 29 usable forms were evaluated in the analysis. Based on the data obtained, two themes were identified: “*BBP’s contribution to personal development*” and “*General characteristics of BBP,*” and 56 codes were determined under these themes. The themes and codes are presented in the relevant figures. The

participant views considered in the creation of the codes are given as direct quotations (Fig. 9), which shows the theme of BBP’s contribution to personal development and the codes belonging to this theme.

The students’ responses to the semi-structured interview form show that BBP applications contribute to their personal development. The opinions reveal that students worked collaboratively and that their friendships strengthened. Participant statements considered in reaching this conclusion include “*Yes, it did, our group work improved*” and “*We are learning; when we place the blocks, we are both designing games and learning. One of us takes the mouse, another takes the keyboard, and another teaches.*” Students also stated that they experienced mental and personal development thanks to the applications. Statements such as “*I think I have improved and can solve problems easily. I didn’t know some things before, but now I can find them easily*” and “*I learned to be good and patient*” support this situation. In addition, BBP contributes to design skills: “*I can design games better now,*” “*I didn’t know anything about computers, but I learned everything over time,*” “*I didn’t know how to make games on the computer before, but now I do,*” “*I didn’t know Scratch on the computer, but I learned it...*” and “*Yes, our skills are improving.*” When this theme is evaluated overall, it is seen that BBP significantly improves students’ digital skills, collaboration abilities, and design processes. Codes related to the general characteristics of BBP are presented in Fig. 10. The analysis of participant views also revealed findings related to the general characteristics of BBP applications. Students stated that BBP supports the process of learning through fun and that the application would also be beneficial for other students. In this context, the following opinion is noteworthy: “*I didn’t know how to do preliminary design, but thanks to this, I showed more progress, and I think*

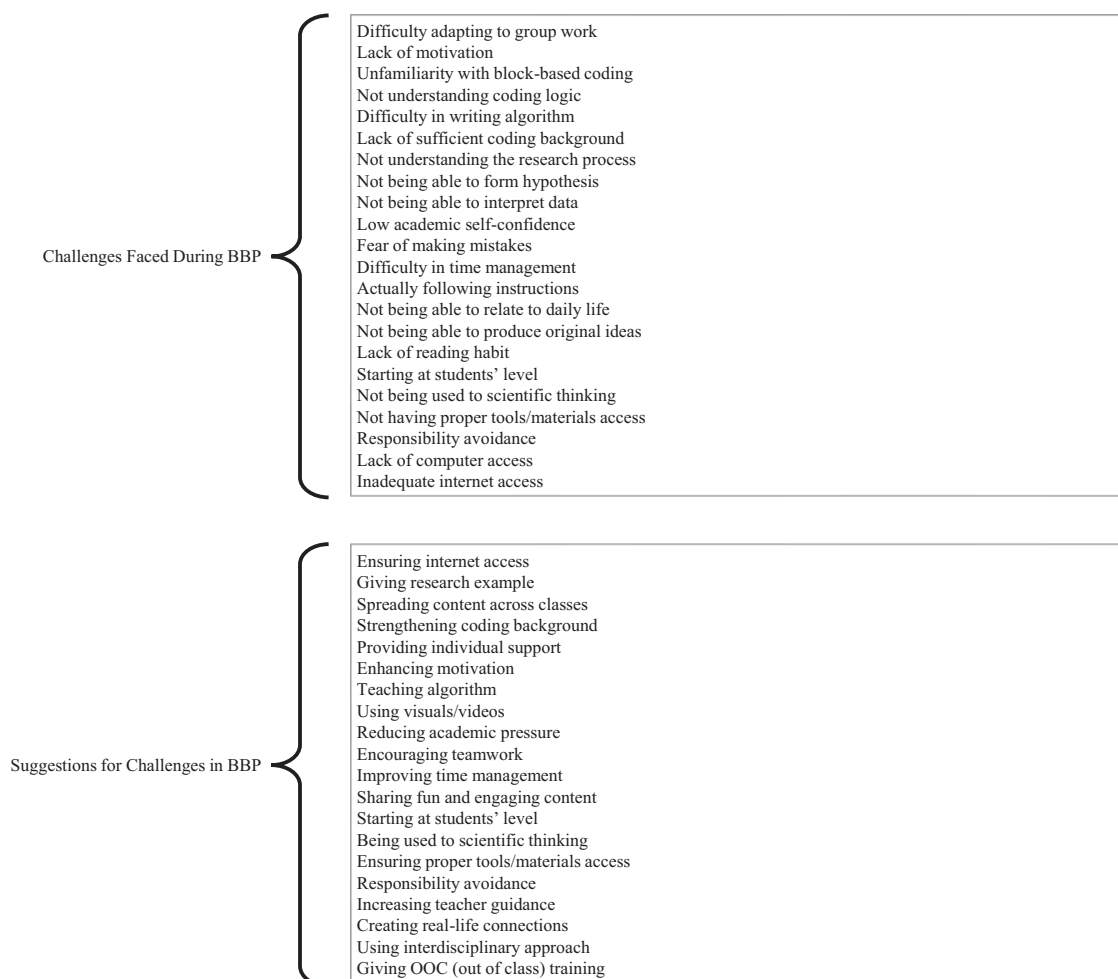


Fig. 7 Difficulties seen in the BBP process and suggestions for difficulties seen in BBP.

other children will progress like me; you have fun and you learn.” The students’ responses show that BBP improves computer and coding skills and facilitates research. Students mentioned that BBP has positive effects as well as some negative aspects. For example, statements such as “The positive effect is that it allows us to learn faster; the negative effect is that our hands go numb if we use the computer too much”, “The positive aspect is gaining knowledge, the negative aspect is that we can’t do it without working” and “Our contribution to the lesson increases, we design games; the negative aspect is that they place too much importance on things like computers and phones” reflect this situation. These views show that the application is generally considered positive, but it is thought that intensive computer use may lead to some negative health effects. Students also highlighted technical issues: “The internet connection is sometimes difficult”, “It would be better if the applications were more reliable” and “It would be much better if there was a button next to the computer to go to the second page”. On the other hand, some students stated that they had no suggestions (“I have no suggestions”). Overall, it is seen that students learn while having fun with BBP applications and develop their knowledge and skills. However, it is understood that students are unable to sufficiently integrate artificial intelligence applications into the BBP process.

Discussion

Within the scope of this study, the effectiveness of BBP practices in secondary schools was analysed. In the study, qualitative

research supported meta-thematic analysis was applied. In this study, which was carried out in two stages, a total of 121 codes and 5 themes were created as a result of the findings obtained from 10 studies examined in the meta-thematic analysis part. In the second stage of the study, an experimental study was conducted, and Scratch teaching with artificial intelligence support was applied to the students for 4 weeks. Then, a semi-structured interview form was applied to the students. At this point, the findings obtained in our current research are consistent with studies on perceptions and adoption of technology-supported learning environments; recent studies have shown that technology-focused applications increase student motivation and participation. It is also stated that artificial intelligence-supported learning applications strengthen interdisciplinary connections and increase digital literacy levels (Noroño Sánchez 2025; Espina-Romero et al. 2023).

Discussion related to the meta-thematic analysis process. The themes obtained as a result of the meta-thematic analysis process are as follows: “The impact of BBP on the affective dimension”, “The contribution of BBP to the academic dimension”, “Challenges observed in the BBP process”, “Recommendations for challenges observed in BBP”, “21st-century skills in BBP”. A comprehensive evaluation of these themes shows that BBP applications have a simultaneous impact on emotional, cognitive, and skill-based development areas. When examining the relationships between the themes, it is seen that emotional experiences (curiosity, self-

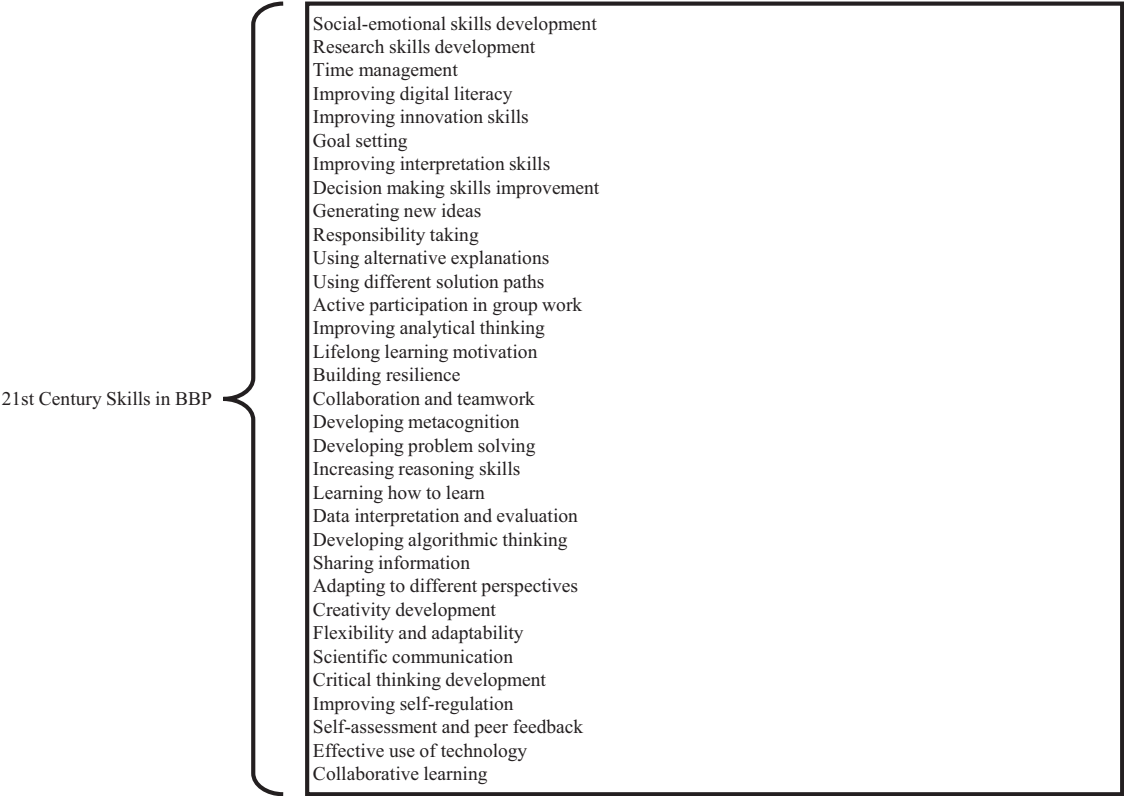


Fig. 8 21st-century skills in BBP.

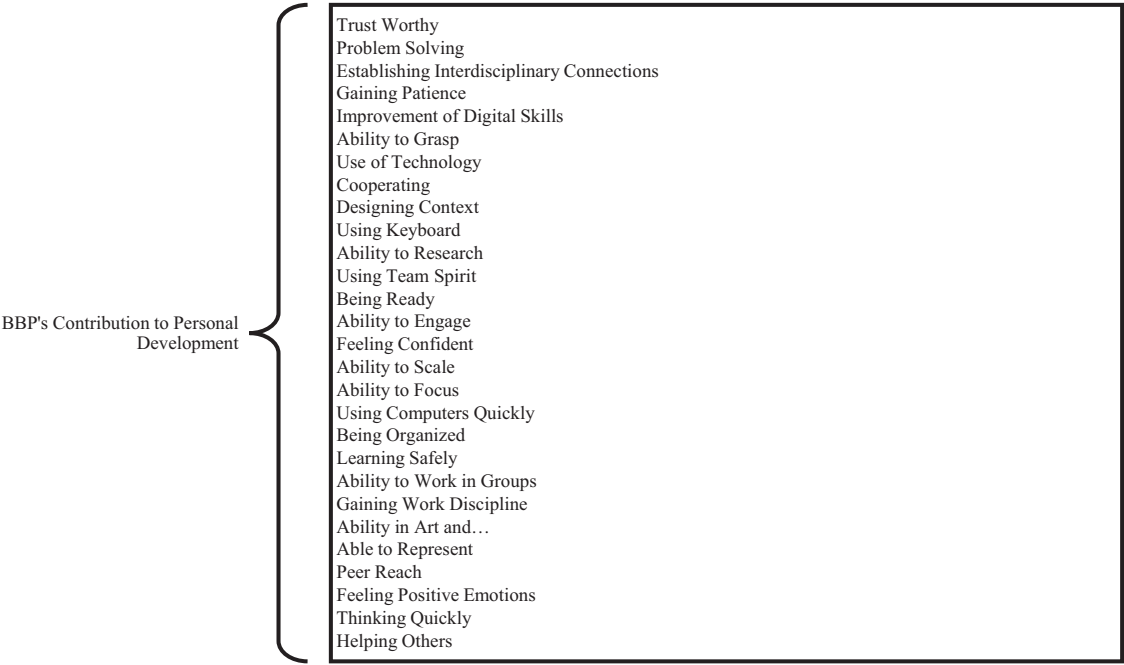


Fig. 9 Contribution of BBP to Personal Development.

confidence, interest) directly pave the way for the development of 21st-century skills, while academic contributions integrate with higher-level digital skills such as computational thinking, thereby enhancing the quality of learning outcomes. Thus, the findings present a model that not only describes the student experience but also frames it conceptually. The descriptive analysis concluded that BBP applications are effective in affective and

academic dimensions and develop 21st-century skills. Furthermore, it was observed that students experienced some difficulties during the BBP process, and solutions to these difficulties were proposed.

When examining the theme of its impact on the emotional dimension, it was seen that BBP applications instilled positive emotions such as happiness, love, and empathy in students and

General Features of BBP

- Teaches research
- Eliminates learning difficulties
- Requires long term practice
- Motivates
- Centers the student
- Supports class participation
- Supports cognitive development
- Needs reaction
- Is informative
- Strengthens friendship relations
- May require language support
- Supports skill development
- Helps fast learning
- Teaches with fun
- May increase technology addiction
- Enhances thinking
- Is attention grabbing
- Encourages
- Supports personal development
- Requires technical support
- Prevents boredom
- Supports group work
- Facilitates technology use
- Helps gain 21st century skills
- May negatively affect health
- Makes remembering easier
- Is practice based

Fig. 10 General Features of BBP.

increased their interest in the course. The increase in students' self-confidence and self-efficacy is also a noteworthy finding. Therefore, it is predicted that individuals with high self-confidence will become more productive. However, it has also been observed that negative emotions such as impatience, competitiveness, and anger are present in the theme. The emergence of a competitive spirit in game-based learning environments is natural, and it is believed that these characteristics can contribute to students' development in the long term. The analysed studies support these findings; students state that BBP applications make lessons less boring and increase their love for the subject (Zhang 2022). This finding shows that when students interact with digital content, they are not merely passive users but actively participate in the process of creating their own learning products, which is consistent with Papert's constructionism approach and Vygotsky's sociocultural learning theory. Furthermore, when students use BBP applications, their use of AI-supported tools and their work on tasks related to different subjects yield results consistent with the technology perception, AI adoption, and interdisciplinary learning processes mentioned by Noroño Sánchez (2025). In this context, it can be said that the structural characteristics of online learning communities are important in terms of increasing the effectiveness of individual reflection processes and supporting the professional development of pre-service teachers. In this context, when the findings are evaluated within the framework of Papert's constructivist approach, it is understood that block-based programming applications take the learning process beyond passive knowledge transfer. This application is consistent with the constructivist understanding that advocates for students to engage in the learning process interactively with digital content and through the products they create themselves. Particularly in game-based and interaction-based learning environments, processes such as competition, trial and error, producing products with creative skills, and activity development increase students' cognitive and affective participation, making learning efficient and meaningful. On the other hand, when the results of the study are considered from the perspective of Vygotsky's sociocultural learning theory, it can be stated that block-based programming environments

provide cultural tools that support the learning process in terms of social interaction and collaboration. Students' collaborative work, receiving feedback from their peers, and working on similar problems demonstrate that the learning action takes place in a social context. This allows for the effective use of students' zone of proximal development and supports cognitive development through social learning. The research findings show that constructivist and sociocultural theories offer a complementary and integrated learning process in digital applications and AI-supported learning environments. Block-based programming applications contribute to the reinterpretation of contemporary learning theories in a digital context by integrating individual production-based learning and social interaction-based learning in the same environment. These findings show that structures based on interaction, collaboration, and co-production in digital learning environments strengthen not only cognitive gains but also reflective thinking and individual learning experiences; in this respect, they coincide with qualitative studies examining community-based digital learning approaches.

Indeed, a qualitative study conducted by Tang and Lam (2014) stated that the community phenomenon plays a decisive role in effective learning in blog-based teaching portfolios. The study emphasises that active participation, mutual support, and shared values deepen collaboration and individual learning experiences and strengthen reflective thinking. This finding is consistent with the results of our current study and reveals that the pedagogical functionality of digital portfolios is shaped by both individual and community-based learning dynamics. Considering the intensity of course content, it is natural for students to become bored with the course; however, BBP applications attract students' interest, facilitating their participation in the course and increasing their curiosity and motivation. In terms of contributing to the academic dimension, it was concluded that BBP applications develop students' problem-solving skills, guide them towards practical thinking, increase their awareness of research, contribute to effective learning, and support their reading skills. Instant feedback, self-monitoring, and personalised step-by-step progress make individuals' learning processes more efficient. Therefore, it is expected that BBP applications will increase academic

achievement (Wang and Chiou 2022). Factors affecting academic achievement include variables such as motivation, interest, self-efficacy, and attitude (Alyahyan and Düşteğör 2020). Supporting these factors with appropriate methods can increase success. Considering the findings obtained within the scope of this study in the context of Cognitive Learning Theory, BBP-based applications have been shown to increase students' academic achievement. Although BBP has various contributions, students also experienced some difficulties related to the process and offered suggestions for solutions. According to the theme of *"Challenges Observed in the BBP Process and Suggestions for Challenges Observed in BBP"*, the difficulties encountered include the inability to keep the process in mind, technical problems, mixing up blocks, feeling negative in case of failure, the inability to notice mistakes, finding the process tiring, and the need for repetition. Some students were observed to give up because they found the process challenging. Loss of motivation and a sense of obligation reduce the efficiency of the learning process (Rahiem 2021). Michailidis et al. (2022) drew attention to the problems that may be encountered in the educational use of blogs, emphasising the lack of complete control and the limited effect of group/peer performance on motivation. However, in some studies, students stated that they would not experience difficulties if BBP were transferred to daily life, linked to other courses, and the number of examples and applications were increased. Linking the process across subjects and strengthening its connections to daily life can facilitate learning (Munna and Kalam 2021). Overall, it is believed that the difficulties arising in the process can be reduced by taking appropriate measures. Medina (2025) states that BBP-supported teaching has the potential to create fundamental transformations in education; however, for this to happen, there are important issues that need to be resolved in structural, pedagogical, and ethical dimensions, and in this context, inclusive, sustainable learning environments need to be designed. Angeli and Giannakos (2020) have indicated that students may experience difficulties in their educational processes. Therefore, it can be said that the results of studies in the literature support the data obtained from this study. In the 21st-century skills theme of BBP, students stated that BBP developed their problem-solving skills, facilitated finding solutions, helped them generate ideas, enabled them to question, and developed their analytical skills. These findings show that BBP applications play an important role in acquiring 21st-century competencies. Langbeheim and Bielik (2025), whose findings support the results obtained, also demonstrated in their studies that BBP develops problem-solving skills. In this regard, it can be said that BBP is an effective method for developing problem-solving skills. The findings from this study show that BBP applications not only provide technical skills but also directly correspond to the problem-solving, digital content production, and data literacy dimensions of the EU Digital Competence Framework. The analysis, questioning, and solution-generating skills expressed by the students indicate that the areas of critical thinking and creativity within the P21 framework are also supported. Therefore, the themes obtained reveal that the BBP process holistically develops both students' computational thinking skills and higher-level 21st-century competencies, as stated in the report (The definition and selection of key competencies) prepared by the OECD (2005).

Discussion related to the experimental process. In this study, the design of classroom activities was directly linked to the findings obtained in the meta-thematic analysis. When examining themes related to affective, academic, and 21st-century skills, it was observed that students particularly needed support in the

areas of motivation, curiosity, self-confidence, problem-solving, and making connections. Therefore, the four-week AI-supported Scratch activities prepared in the experimental phase were structured to increase students' affective participation, reduce technical difficulties, strengthen connections to daily life, and encourage interdisciplinary thinking. Thus, the needs and suggestions that emerged in the meta-thematic phase were reflected in the content of the application activities, task types, feedback system, and step-by-step progression.

In this context, following the implementation of the four-week programme, the themes of "BBP's contribution to personal development" and "BBP's general characteristics" emerged based on the students' responses to the semi-structured interview form. Analysis of participant feedback shows that BBP supports students' personal development and digital literacy, but that some difficulties were encountered during the process. The results obtained show that BBP improved students' digital literacy and problem-solving skills, facilitated easy learning, understanding, and quick thinking, and helped them establish interdisciplinary relationships. In their study, Maş'ula et al. (2021) stated that students who received programming education were more successful in learning because it was suitable for use in learning and produced practical solutions. Similarly, Vidal-Silva et al. (2024) stated in their study that the development and application of programming skills improved students' knowledge and skills regardless of their educational level and status, and in particular increased their motivation to learn. It is seen that BBP supports students' mental development, enables them to acquire 21st-century skills, and eliminates learning difficulties. Similarly, Quadir et al. (2022) also stated in their study that student-student and student-content interactions have a significant impact on objective learning outcomes. Im et al. (2025) and Wang et al. (2025) focused on how block-based artificial intelligence applications teach students how to learn and on their thinking and personal development. The research indicates that blog-based AI applications can increase students' perceptions of learning, improve learning outcomes, and encourage knowledge sharing. At the same time, they state that these applications facilitate learning, teach students how to learn, and ultimately enable students to achieve their educational goals. In another study, Azap (2025), using a mixed-methods methodology, examined the academic language development of teacher candidates studying foreign language education. The study expressed positive views that blog-based applications improve participants' creativity, self-confidence, social interaction, motivation, and academic achievement. Erinc (2022, p. 93) examined the effect of intelligence and mind games activities on the ICT learning of 7th-grade students. The experimental group, which used intelligence games, achieved higher success in BBP skills. When the group's self-efficacy perception was examined, it was found that male students' perception was higher than that of female students. This difference is statistically significant. In their research, Lin et al. (2025) used artificial intelligence tools to develop students' computational thinking skills. They stated that the use of these tools in education resulted in the development of students' computational thinking skills. Again, in a study conducted using a mixed-method approach with a quasi-experimental design investigating the effect of large language model-based programming, perceptions of how programming activities meet students' learning behaviours and basic psychological needs were investigated. As a result, evidence was found that programming activities support students' basic psychological needs, increase autonomous motivation, and develop programming skills (Choi and Kim, 2025). The findings from this study reveal that BBP is effective in many dimensions. It is predicted that BBP applications will become more widespread over time;

considering that individuals will encounter these applications more frequently, the importance of providing students with BBP experiences becomes apparent. Ultimately, it is evident that the process develops students in various ways and contributes to the acquisition of 21st-century competencies. It has been concluded that learning BBP at an early age provides an important advantage in terms of individuals adapting to emerging technologies.

Limitations. Some limitations were encountered while conducting this study. Limitations are thought to reduce the effectiveness of the study. This study was conducted with a group consisting entirely of male students. This situation may limit the generalisability of findings regarding gender differences in BBP participation. Technical problems were experienced due to the physical conditions of the school during the BBP applications. Another limitation is that the process is limited due to the fact that the informatics course hours in which the research is conducted are two hours, and that little time can be allocated to the applications because it takes time to explain artificial intelligence applications. At the same time, the fact that the students in the school where the application was carried out did not have a good command of the programming language is among the limitations. In the meta-thematic analysis part of the study, all the effects of BBP applications could not be reached in the existing studies. At the same time, the limited number of studies with BBP applications and the fact that the existing studies are not carried out with an interdisciplinary approach are among the limitations. Therefore, the results should be interpreted with caution, as the sample was drawn from a single public school; future studies should encompass different educational and cultural contexts.

Suggestions. Some suggestions have been made for future studies.

- Physical planning and connection controls should be carried out before the application in order to minimise technical problems. Implementing applications in an environment where physical planning and connection controls can be performed can make the process of strengthening infrastructure and technical support more efficient in the short term.
- It is thought that more effective results will be obtained by providing language support to the applications for students with language problems.
- BBP can be associated with other courses to enable students to learn faster and more effectively.
- Performing block-based applications over a longer period of time can provide more effective results.
- The applications in this study were prepared in connection with the science course. In future studies, an interdisciplinary approach can be used by associating BBP applications with different courses (mathematics, Turkish, social studies, etc.).
- More studies can be conducted at the secondary school level related to BBP applications.
- Future studies can be carried out with an interdisciplinary approach.

Data availability

During peer review, the materials underpinning this study have been made available to the editors and reviewers as confidential supplementary files. These materials include the PRISMA flow diagram, the Theme–Code Table, the anonymised interview forms, the MAXQDA project files, the search strategy document, and the full set of studies included in the meta-thematic analysis.

Owing to copyright and confidentiality considerations, these materials are provided for confidential peer review only and are not intended for public distribution. Additional information may be made available from the corresponding author upon reasonable request.

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Author contributions

AB and ASY contributed to the design and theoretical framework of the study. VB conducted the qualitative analysis and contributed to the data collection process. ŞK, MK, GA and GB conducted the experimental phase of the study and wrote the manuscript. NB and MK were responsible for the literature review. AB and VB revised the manuscript. All the authors read and approved the final version of the manuscript.

Competing interests

The authors declare no competing interests.

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Ethics approval and consent to participate

This study has been approved by the Scientific Research and Publication Ethics Committee of Gaziantep University Faculty of Social Sciences and Humanities under decision number E-87841438-302.08.01-624494 dated 03 March 2025. Data collection was performed following the guidelines and regulations of the Declaration of Helsinki (2013).

Informed consent

Since all participants in this study were under the age of 18, written informed consent was obtained from participants and their legal guardians between 19 March 2025 and 19 April 2025 at Şehit Cengiz Topel Secondary School in Gaziantep Province / Türkiye. The anonymity and privacy of the participants were strictly maintained, and all collected data were kept in complete confidentiality and used solely for research purposes.

Additional information

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1057/s41599-026-08297-3>.

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