Management of Mathematics Learning Based on Interactive Digital Worksheets to Improve Students' Critical Thinking Ability

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Received: October 12, 2023 Accepted: February 4, 2024 Online Published: February 13, 2024

doi:10.5430/jct.v13n1p159 URL: https://doi.org/10.5430/jct.v13n1p159

Abstract

The use of interactive digital technology in learning is an alternative strategy to create joyful learning activities. Therefore, interactive digital worksheet requires development by considering the critical thinking skills of elementary school students. This research determined the interactive digital media worksheet necessity based on critical thinking skills, compiling design, feasibility identification, and effectiveness test of the interactive digital media worksheet based on critical thinking skills for elementary school students. This research and development applied seven steps: (1) potential and problem identification; (2) data collection; (3) product design; (4) design validation; (5) design revision; (6) product test; and (7) product revision. The researchers collected the data with interviews, observations, questionnaires, and tests. The research results found the necessity of interactive digital student worksheets in managing mathematics learning to improve students' critical thinking skills. The interactive digital LKS design was based on critical thinking skills. The development considered the three components, such as (1) Planning; (2) implementing; and (3) evaluating. Planning consists of (1) the analysis of student characteristics; (2) the analysis of learning achievements (CP); (3) the determination of the learning objectives (TP) and the learning objective flow (ATP) and the assessment; (4) the selections of media, learning methods, and teaching materials. The implementation of the interactive digital student worksheets in learning was based on the problem-based learning model and formative and summative tests for the evaluation. The expert validation found the interactive digital worksheet was valid and reliable. The teacher responses reached the percentage of 87.5% while the student with 90%. The product test obtained an average of N-gain for the control group was 0.31 while the experimental group was 0.50, indicating an increment of students' critical thinking skills in mathematics. Thus, interactive digital worksheet implementation is useful in managing learning. The implementation was also useful for further development to manage various challenging activities and to realize meaningful learning.

Keywords: management learning, interactive digital worksheets, critical thinking skills

1. Introduction

Interactive digital technology is a learning alternative to create joyful learning activities. This implementation facilitates educators to convey information to students. The learning media implementation has a psychological effect on children, such as improved learning interest, eagerness to participate, information acquisition, skill mastery, cognitive load reduction, improved cognition, improved problem-solving skills, and improved critical thinking skills. The effective use of digital media can improve the quality of learning, particularly students' literacy skills.

Schools encounter problems while implementing digital technology, such as the illiteracy of the teachers to use technology. Rahim et al. (2019) and Supandi et al. (2020) found that teachers have less creativity in implementing digital media in learning. Teachers tend to use printed books, blackboards, and printed pictures adapting them to students' conditions and abilities. Most teachers also have poor capability to design the learning media. The observations and interview results at Mangunjiwan 1 Public Elementary School, Demak, Central Java Province found the teachers applied conventional media, such as printed materials due to the lack of digital material development capabilities. Thus, the teachers could not develop teaching aids, animated videos, or interactive multimedia which made the learning process not optimal. Besides that, the teachers also applied inaccurate media to the student's learning development. This problem made the students could not master the mathematics subjects. The reports also found students had low numeracy skills, lower than 50% of the minimum mastery standard. The findings,

based on the educational report analysis at the school, found the numeracy skill of the learners reached a score of 1.63, lower than the minimum competence.

The interview results found that the students encountered difficulties in comprehending various mathematics problems, analyses, and problem-solving. This matter indicates the critical thinking level of the students that must receive further development to realize excellent 21st-century skills. The skill provides the students to encounter the dynamics of global competition. These skills include; (1) communication (communication); (2) collaboration (cooperation); (3) creativity and innovation (creativity and innovation); and (4) critical thinking (critical thinking). Students must receive the training to realize excellent human resources with readiness to compete in the real world, technological development, and artificial intelligence (AI).

Critical thinking skill is an important matter of human maturity. The skill is useful to obtain, manage, and utilize the received information. Students need critical thinking skills to implement various methods of solving problems (Syawaludin et al., 2019; Lestari et al., 2023). Therefore, critical thinking skills are important to apply in learning activities at every level of education. The results of the research found a significant difference between the critical thinking skills of the experimental group and the control group taught with the inquiry-discovery model. The result showed the experimental group had higher critical thinking skills than the conventional learning class (Wartono et al., 2018). Inaccurate media implementation or less attractive media toward the understanding levels of the students lowers the learning outcomes of mathematics. Therefore, teachers must master digital technology and improve their creativity to create excellent and attractive learning content.

Mahardika Arsa Putra & Tri Agustiana (2021) examine the development of online-based worksheet media for mathematics lessons on fractional operations. The results showed that the developed worksheet media was applicable for learning in the fifth grade of elementary schools. The current research and the previous research share a common matter, developing the interactive digital worksheet to improve critical thinking skills. Puspita & Dewi (2021) found that the mathematical critical thinking skills of students taught with E-worksheets based on an integrative approach were higher than those taught with conventional methods. The results showed the applied worksheet for the students could support the learning process implementation (Hayati et al., 2022).

Less and boring learning processes make the students lack a learning experience. This situation lowers the critical thinking skills of the students to deal with various daily life problems. Therefore, the development of electronic, attractive, and practical worksheets is important to help and motivate students to learn (Ladamay et al., 2021). A classroom learning must provide various tasks and encouraging strategies to empower critical thinking skills and detect the encountered challenges by the students particularly in the context of learning mathematics. (Martins & Martinho, 2021). Based on the problems, the researchers offered a solution to improve the student's critical thinking skills by developing mathematics learning management with the assistance of interactive digital student worksheets. The objectives of this research are 1) to describe the necessity for interactive digital media Worksheets based on critical thinking skills, and 2) to develop a design, identify feasibility, and test the effectiveness of managing mathematics learning with the assistance of interactive digital worksheet media based on critical thinking skills for fourth-grade elementary school students.

2. Method

This Research and Development approach consisted of seven steps, such as (1) potential and problem identification; (2) data collection; (3) product design; (4) design validation; (5) design revision; (6) product test; and (7) product revision. The researchers conducted a preliminary research and product trial at the public elementary schools in Demak Regency, Central Java. The research subjects were the teachers and students.

Table 1. Media Expert Validation Questionnaire Grid

No	Indicator	Indicator	Number of Criteria
1	Presentation Design	1-14	14
2	Interaction Usability	15-19	5
3	Accessibility	20-23	4
4	Reusability	24-28	5
	Total		**28**

In this research, the experts in materials, media, and language validated the developed product design, the student interactive digital worksheet. The researchers used closed questionnaires with pre-determined questions. Then, the respondents had to select their responses on the Likert scale model. Table 1 shows the applied validation sheet by the media expert.

Table 2. Material Expert Validation Questionnaire Grid

No	Indicator	Indicator	Number of Criteria
1	Content Quality	1, 2, 3, 4	4
2	Alignment of learning objectives	5, 6, 7, 8	4
3	Feedback and adaptation	9	1
4	Motivation	10	1
	Total		**10**

Table 3. Language Expert Validation Questionnaire Grid

No	Indicator	Indicator	Number of Criteria
1	Straightforward	1, 2, 3	3
2	Communicative	4	1
3	Dialogic and interactive	5, 6	2
4	Suitability to student development	7, 8	2
5	Conformity to language rules	9, 10	2
6	Use of terms, symbols, or icons	11, 12	2
	Total		**12**

The applied eligibility criteria are based on Arikunto (2010: 319). Table 4 shows the eligibility criteria.

Table 4. Media Eligibility Criteria

Percentages	Eligibility Category
< 21%	Extremely not eligible
21% - 40%	Not eligible
41% - 60%	Average
61% - 80%	Eligible
81% - 100%	Very eligible

The researchers involved 16 students in the small-scale product trial and 30 students in the large-scale product trial. The researchers collected the data with interviews, observations, questionnaires, and tests. The researchers analyzed the data qualitatively and quantitatively. The applied analysis technique was the N-gain test. The researchers determined the effectiveness of critical thinking skills in managing learning with interactive digital worksheets and used the independent t-test. The researchers determined the mathematics critical thinking skill levels of learners with the following categories.

Table 5. Mathematical Critical Thinking Ability Level Categories

Scores	Criteria
76 – 100	An observed decline
51 – 75	Excellent
26 – 50	Average
0 – 25	Under average

3. Results

3.1 Results

The researchers changed the developmental steps of the interactive digital worksheet media based on critical thinking skills from 7 to 3, starting from planning, implementing, and evaluating. In the planning stage, the researchers analyzed the necessity by asking the student some questions. The researchers analyzed the necessity based on the questionnaire that provided indicators of the students' necessity for digital-based interactive learning media. The indicators consisted of 8 question items about learning media and activities that students experienced. Table 5 shows the results of the questionnaire on students' necessities for learning media.

Table 5. Results of the Student Needs Questionnaire

No	Questions	Answer Options	Percentage
1	Is mathematics a difficult subject?	Yes	87.5%
		No	12.5%
2	Are your math scores always above the MMS?	Yes	12.5%
		No	87.5%
3	Have you ever studied fractional numbers using a cellphone?	Yes	93.75%
		No	6.25%
4	Is the teacher's explanation clear for you to understand the material on fractions?	Yes	12.5%
		No	87.5%
5	Does the applied media by the teacher in explaining fractional number material help you understand the material?	Yes	18.75%
		No	81.25%
6	Has the teacher ever applied digital media in the learning process?	Yes	75%
		No	25%
7	Do teachers need to apply digital learning media in the learning process?	Yes	81.25%
		No	18.75%
8	Do you agree with the teachers applying digital-based interactive learning media on fractional number material?	Yes	87.5%
		No	12.5%

The questionnaire results show the students' necessity for digital-based interactive learning media on fractional number material. A percentage of 87.5% of students agree with the notion that teachers apply digital-based interactive learning media. The students could use the cell phones to learn. The school also had some facilities, such as the Wifi or Internet access to support the development of the learning media. However, the questionnaire results showed the learning media and the teacher's explanations did not make the students understand the material. The learning activities applied teacher-centered learning with the lecturing method.

The development of interactive digital media design included the critical-thinking skill-based worksheet. The researchers applied the management functions of planning, implementing, and evaluating. Utaminingsih (2011) found that management function implementation facilitated learning goal achievement efficiently and effectively. The planning stage includes (1) the analysis of student characteristics, (2) the analysis of learning outcomes (CP) for class IV Phase B students in Mathematics; (3) the learning objective setting (TP) and the learning objective flow (ATP) based on CP analysis results in the previous stage; (4) the assessment determination; and (5) the learning activity determination. The researcher analyzed the students' characteristics. The students had low learning outcomes in mathematics subject because the presented learning material was abstract. Thus, the students had difficulty understanding and were lack of interactive digital technology implementation.

The analysis of learning achievements (CP). Rational mathematics subject according to (BSKAP Decree No. 033/H/KR/2022, 2022) perceives mathematics as a learning material to understand comprehensively along with the conceptual tool to construct and reconstruct the material, such as processing and training the thinking skills to solve problems in everyday life. The learning outcomes of this research were in Mathematics subjects in phase B. Table 6 shows the excerpt of phase B of CP mathematics.

Table 6. The Snapshot of Phase B Mathematics Learning Achievements

Elements	Learning Outcomes
Numbers	Students compare and order fractions with one numerator (for example,) and between fractions with the same denominator (for example, $\frac{1}{2}, \frac{1}{3}, \frac{1}{4}\frac{2}{8}, \frac{4}{8}, \frac{7}{8}$). They can recognize equivalent fractions using pictures and mathematical symbols.

Table 6 shows the mathematics learning media development based on the fraction by considering the material of the sub-chapter, the learning objective, and the learning objective flow.

The Learning Objective Setting (TP), Learning Objective Flow (ATP), and the Assessment. The researchers prepared and developed the learning objectives based on the achievements of phase B in mathematics learning. The learning objectives for fractional number material were: (1) identifying (read, number, and write) the fraction symbols for objects divided by different divisions; (2) explaining the meaning of equivalent fractions using pictures of objects divided into several parts and fraction tables; (3) comparing the fraction values based on the part of an object on the number line; (4) comparing the values of fractions with the same numerator or the same denominator; (5) understanding the fraction values and the fraction order; (6) simplifying the fractions; and (7) understanding the form of adding and subtracting fractions.

In the next step, the researchers developed the learning objective flow based on the learning objectives. After compiling the ATP, the researchers determined the learning assessment based on the TP. The researchers prepared the adjusted assessment based on the indicators of critical thinking skills and the learning activities with the implementation of the developed learning media. This phase was useful to improve the learning outcomes of the students. The researchers developed the student activities based on indicators and assessments of critical thinking skills in fractional number material. Table 7 shows the description of student assessment activities.

Selecting Media, Learning Methods, and Teaching Materials. The researchers developed the interactive digital worksheet based on critical thinking skills with the implementation of problem-solving learning by the teacher. The problem-based learning could improve students' critical thinking skills (Dewi, 2021). An individual critical thinking skill is observable in the capabilities of interpreting, analyzing, evaluating, and concluding based on the presented problems.

In this stage, the researchers applied five planning steps, starting from (1) the analysis of student characteristics, (2) the CP analysis, (3) the learning objective setting and flow, (4) the activity definition, and (5) the media selection. The analysis of student characteristics dealt with the learning outcome of mathematics due to the applied teacher method. The researchers found the learners could not understand and failed to apply interactive digital technology. The second step dealt with the applied CP for the fourth grader with Phase B. The learning objective setting dealt with developed TP and ATP based on the CP analysis of the previous step. The activity definition dealt with the adapted learning activity to realize the learning outcomes. Then, the media selection dealt with learning methods and teaching materials (select methods, media, and materials). In this research, the researchers developed an interactive digital worksheet based on critical thinking skills in mathematics subjects specifically fractions. This material consisted of seven sub-chapters, such as the concept of fractions, simple fractions, equivalent fractions, fraction comparison, fraction order, fraction addition, and fraction subtraction.

The researchers promoted the learning activity with the implementation of a problem-based learning model to improve students' critical thinking skills. The researchers applied this model with interactive questions and materials. Then, the researchers evaluated the results with a summative assessment after applying the interactive digital worksheet to determine the effectiveness of media in improving the critical thinking skills of fourth-grade students. Figure 1 shows the design.

Table 7. Activities in Fractional Number Learning Activities

Learning objectives	Critical Thinking Indicators	Indicator Description	Learning Activities
Identifying (Read, count, and write) the fraction symbol for an object with different divisions.	Explaining (clarification)	Stating the information asked for in the question correctly.	The students identify fraction values based on the images presented.
Explaining the meaning of equivalent fractions using pictures of objects divided into several parts and fraction tables.	Explaining (clarification)	Stating the requested information and the question correctly.	The students analyze the form of equivalent fractions using pictures of objects divided into several parts
	Concluding (assessment)	Sorting out the information to solve the problem.	The students determine fraction equivalents using a fraction table
	Developing strategies and tactics (strategies)	Concluding the final answer correctly	The students arrange fraction equivalents based on the information provided
Comparing the value of fractions based on the part of an object on a number line	Developing strategies and tactics (strategies)	Concluding the final answer correctly	The students compare fraction values based on pictures of parts of an object
	Concluding (assessment)	Sorting out the information to solve the problem.	The students compare fraction values with the help of a fraction table
Comparing the values of fractions with the same numerator or the same denominator	Inferencing	Explaining the correlation between given or requested information based on the screened information to solve the problem	The students solve problems in everyday life related to fraction comparisons
Understanding the fraction values and order	Concluding (assessment)	Sorting out the information to solve the problem.	The students order the fraction values using a fraction table
	Developing strategies and tactics (strategies)	Concluding the final answer correctly	The students solve problems related to ordering fractions
Simplifying fractions	*Inference*	Explaining the correlation between information known or asked about with the information selected to solve the problem	The students analyze the simplest form of fractions
Understanding the form of adding and subtracting fractions	Developing strategies and tactics (strategies)	Concluding the final answer correctly	The students determine the results of the operation of adding fractions
	Developing strategies and tactics (strategies)	Concluding the final answer correctly	The students determine the results of fraction subtraction operations
	Inference	Explaining the correlation between given and requested information based on the screened information to solve the problem	The students solve problems related to adding and subtracting fractions in everyday life.

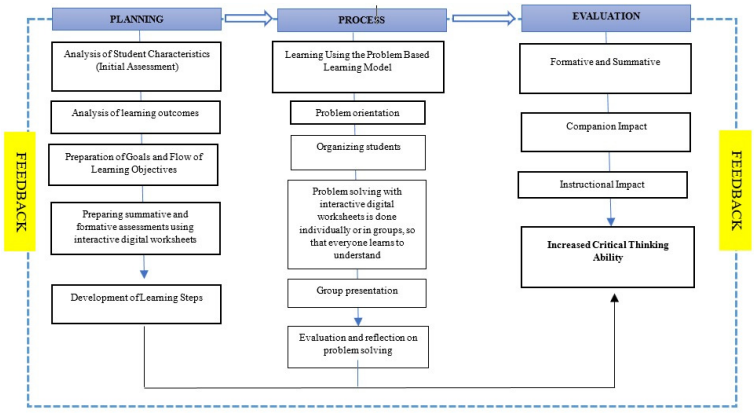

Figure 1. Design for Developing Mathematics Learning Management Based on Interactive Digital Worksheets

Table 8 shows the content of the developed interactive digital worksheet for mathematics learning, starting from the cover, table of contents, exercise, and competency test material.

Table 8. Interactive Digital Worksheet Contents

No	Component	Information
1	Cover	Consisting of product identity, subject identity, media information *barcode* with usage instructions, learning objective, teaching modules, and summative assessment grids.
2	List of contents	The developed i*nteractive digital worksheet* media content
3	Material	Consisting of Fractional Number learning material with a systematic arrangement based on the learning outcomes.
4	Exercises	Consisting of exercise for each learning material based on the indicator development to train participants' critical thinking skills
5	Competence test	Developing the materials based on the learning objectives and integrating them with students' critical thinking abilities

The validation stage was useful to validate the quality of the developed interactive digital worksheet media. The applied instrument to validate was a questionnaire. In this research, the researchers involved the teachers as educational practitioners to validate the developed worksheet. The researchers also involved the master's degree graduate of education to validate the developed worksheet. Table 9 shows the recapitulation of the validations.

Table 9. The Recap of Media Validation Test Results

Validation Type	Validity Results (%)	Qualifications
Media Validation	88.45	Very valid
Material Validation	93.15	Very valid
Language Validation	86.34	Very valid

Table 1 shows that: 1) the media expert validation with a percentage of 88.45%; 2) the material expert validation with a percentage of 93.15%; and 3) the language expert validation with a percentage of 86.93%. All results indicate very valid categories. Thus, the developed worksheet is applicable for further use.

The media feasibility test was useful to determine the teacher-student responses based on the questionnaires after using media in mathematics learning. Table 10 shows the results of teacher and student responses.

Table 10. Teacher and Student Response Results

Indicators	Average (%)	Categories
Teacher Questionnaire	87.5	Very eligible
Student Questionnaire	90	Very eligible

Table 10 shows the teacher-student responses after using interactive digital worksheets in learning with a percentage of 87.5% for the teacher and 90% based on the students. Thus, interactive digital worksheets are very suitable for learning activities.

The researchers also examined the student digital interactive worksheet product based on the N-Gain analysis. Figure 2 shows the results.

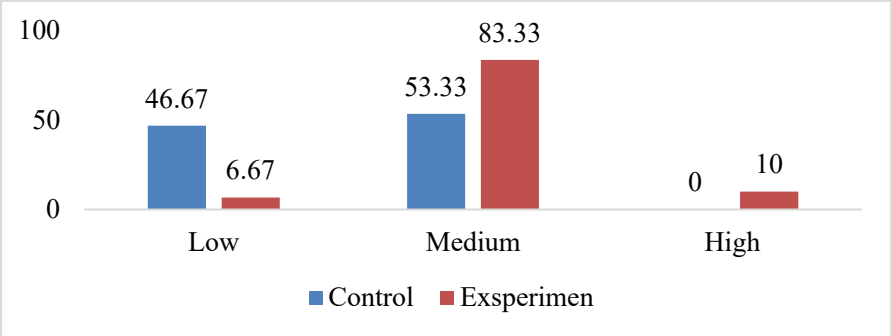

Figure 2. N-Gain Frequency Distribution Graph of Mathematical Critical Thinking Skills

Figure 2 shows the N-Gain scores of the control group: a percentage of 46.67% of students with low category, a percentage of 53.33% of students with moderate category, and none of the students with high category. On the other hand, the N-gains scores of the experimental group are 6.67% for students in the low category; a percentage of 83.33% for students in the moderate category, and a percentage of 10% for students with the high category. The average N-Gain for the control group is 0.31 while the experimental group is 0.50. The means indicate the critical thinking skill increment after applying the interactive digital worksheet. This worksheet is more effective than the conventional media.

The subsequent test was the effectiveness test of the developed worksheet with the independent sample t-test. Table 11 shows the results.

Table 11. Independent T-Test Test Results

Independent Samples Test										
Levene's Test for Equality of Variances		t-test for Equality of Means								
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Results	Equal variances assumed	1,416	,239	-3,202	58	,002	-6,733	2,103	-10,943	-2,524
	Equal variances not assumed			-3,202	56,517	,002	-6,733	2,103	-10,945	-2,521

The result of the independent sample t-test of the developed worksheet obtains a sig (2-tailed) of 0.002 < 0.05 with the post-test mean score of 74.41 for the control group and 81.26 for the experimental group.

The results show the mean score of students' critical thinking abilities in mathematics learning about fractions of the experimental group is higher than the control group. Thus, the interactive digital worksheets based on critical thinking skills could improve students' numeracy literacy skills effectively.

4. Discussion

Developing mathematics learning management using interactive digital worksheets is necessary, feasible, and effective for improving students' critical thinking abilities. Subekti & and Prahmana (2021) also found the implementation of electronic-based learning media could improve critical thinking skills. Elementary school students need creative and critical thinking skills and excellent learning material (Daher et al., 2017). In this research, the interactive digital worksheet could improve the critical thinking skill mean at a moderate level with a high mean score. Thus, interactive digital worksheets could improve students' critical thinking skills effectively. Developing teaching materials in the form of worksheets based on learning models effectively improves students' critical thinking abilities. Mathematics critical thinking skills are important to develop in mathematics learning, especially in indicators of interpretive critical thinking skills. Interactive teaching and learning tools in mathematics learning could develop problem-solving skills and critical thinking abilities. The application of interactive worksheets for learning activities could improve the effectiveness of the overall educational process. Collaborative learning in mathematics subjects with the assistance of interactive digital worksheets is effective in facilitating students' material understanding. For this reason, learning is an effort to focus students' cognitive abilities and develop students' abilities to explore and connect important ideas in interactive worksheets (Cheng & Chuang, 2019)

5. Conclusion

The researchers concluded the developed interactive digital worksheet based on critical thinking skills was important for the students. The design of interactive digital worksheets consisted of three components: (1) the analysis of student characteristics; (2) CP analysis; (3) the learning objective determination (TP) and the learning objective flow (ATP) and assessment; and (4) the media, learning method, and teaching material. The implementation component is the application of interactive digital worksheets in learning using a problem-based learning model. The third component is the formative evaluation as feedback to improve the quality of the learning process and summative evaluation to measure student achievement of learning outcomes. The results of the expert validation of interactive digital LKS design achieved excellent feasibility. On the other hand, the results of the design trial of mathematics learning management with interactive digital worksheets were effective in improving students' critical thinking. Thus, the researchers recommended the implementation of the developed worksheet. The researchers also recommend future research to develop more challenging activities.

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Acknowledgments

The author would like to thank the selected elementary schools for their participation. The author would also like to express appreciation to the University's graduate schools for their guidance and constructive analysis of the research results.

Authors contributions

Dr. Sri Utaminingsih, M.Pd. were responsible for concept and research question. Isna Amalia, M.Pd. was responsible for data collection and report writing. Dr. Sumaji, M.Pd. analizing procedure and statistic. All authors read and approved the final manuscript.

Funding

This research used the author's personal funds

Competing interests

The authors declare that none of the work reported in this paper could have been influenced by any known competing financial interests or personal relationships.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Sciedu Press.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.