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Research Article

Development and Evaluation of NexaDB: A Moodle-Based Project-Based Learning Environment for Database Competency in Vocational Education

Cintiya[1], Mohammad Wildan Habibi[1*], Rindu Puspita Wibawa[1], Martini Dwi Endah Susanti[1], Julius Jonas Mbawala[2], Muhammad Angga Pratama[1]

[1]Universitas Negeri Surabaya, **Indonesia**
[2]Saint Augustine's University, **Tanzania**
Correspondence Author: mohammadhabibi@unesa.ac.id

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Abstract

Database learning in vocational education requires learning environments that can connect theoretical knowledge with practical project activities and coding practice. However, existing learning practices at SMKN 4 Bojonegoro remain predominantly teacher-centered and provide limited integration between project-based learning, digital learning materials, and database coding practice. This study aims to develop and evaluate NexaDB, a Moodle-based Learning M, anagement System that integrates Project-Based Learning (PjBL) and the Code Runner plugin to support students' cognitive and psychomotor database competencies. The study employed a Research and Development approach using the ADDIE model and a quantitative quasi-experimental non-equivalent control group design with pretest and posttest. The participants were 72 Grade XI Software Engineering students at SMKN 4 Bojonegoro, consisting of an experimental group using NexaDB with PjBL and a control group receiving the existing teacher-centered instruction. The results showed higher N-Gain scores in both cognitive and psychomotor competencies in the experimental group than in the control group. The independent-samples t-test indicated significant differences between the groups in cognitive competency ($t=12.70$, $p<.001$) and psychomotor competency ($t=7.364$, $p<.001$). The effect sizes (Cohen's d) and 95% confidence intervals further indicated the magnitude and precision of the intervention effect. The novelty of this study lies in integrating Moodle, Code Runner, and PjBL into a single learning environment that connects database concepts, coding practice, project development, assessment, and feedback. The findings contribute theoretically to the integration of project-based and technology-supported learning in vocational database education and provide a practical learning platform for teachers and students.

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Introduction

Rapid developments in the field of information and communication technology have resulted in great changes in the education sector. Technology is crucial in human activities in this digital age [1]. The creation of supporting technology innovations brings convenience in completing various tasks and work. Each innovation is designed to provide good benefits, such as providing various conveniences, as well as as a new method of carrying out activities, especially in the field of information technology which has gained a lot of benefits from existing innovations [2]. In education, technology also provides benefits by strengthening interaction and cooperation, adapting teaching methods and subject matter to the needs of students, and providing more objective assessment of learning outcomes [3].

Changes in information and communication technology affect the education sector as a whole, especially in learning in SMK. Based on an interview conducted with the Head of the RPL Expertise Concentration at SMK Negeri 4 Bojonegoro, in the RPL expertise competencies, students learned a number of technical skills, one of which was database subjects. The database learning process at SMKN 4 Bojonegoro faces a number of challenges. Students have difficulty in understanding certain materials and difficulty managing the materials and assignments that have been given by the teacher. This problem is further exacerbated by the application of teaching methods that are still centered on teachers. The use of inappropriate teaching methods will result in a less than optimal impact on student competence [4]. Therefore, innovation and creativity in media and learning models are needed to improve students' cognitive and psychomotor competencies.

Previous studies have reported that Project-Based Learning (PjBL) can support students' conceptual understanding, problem-solving skills, and practical competencies through authentic project activities [5], [6]. However, the effectiveness of PjBL depends on the availability of learning environments that can support students throughout the project process, including access to learning materials, practical activities, task submission, and assessment.

Recent studies have demonstrated that Moodle-based learning environments can support flexible access to learning materials, assignment management, assessment, and student interaction [7], [8]. However, existing Moodle implementations commonly function as general-purpose learning management systems, and their effectiveness depends on how learning activities and interactive features are integrated into the instructional process. In database learning, students require not only access to instructional materials but also opportunities to practice coding and develop database projects within a structured learning sequence. To address this limitation, this study develops NexaDB, a Moodle-based learning environment that integrates Project-Based Learning with the Code Runner plugin.

Based on the educational problems and research gap identified in the literature, this study aims to develop and evaluate NexaDB, a Moodle-based learning environment integrated with Project-Based Learning (PjBL) and the Code Runner plugin for database learning. The study focuses not only on the development of the learning environment but also on its effectiveness in supporting students' database competency. Accordingly, the research questions are formulated as follows:

1. To what extent does the implementation of the Moodle-based NexaDB LMS integrated with Project-Based Learning improve students' database competency?
2. Why does the integration of Project-Based Learning and the Code Runner plugin within the NexaDB LMS support students' database learning and competency development?
3. To what extent does learning using the Moodle-based NexaDB LMS integrated with Project-Based Learning differ in its effectiveness from the existing instructional approach in improving students' database competency at SMKN 4 Bojonegoro?

Based on the third research question, the following hypotheses were formulated:

H_0: *There is no significant difference in the improvement of database competency between students who learn using the Moodle-based NexaDB LMS integrated with Project-Based Learning and students who learn using the existing instructional approach at SMKN 4 Bojonegoro.*

H_1: *There is a significant difference in the improvement of database competency between students who learn using the Moodle-based NexaDB LMS integrated with Project-Based Learning and students who learn using the existing instructional approach at SMKN 4 Bojonegoro.*

Literature Reveiw

Project-Based Learning (PjBL) provides students with opportunities to construct knowledge through authentic projects, problem-solving, and practical activities. Previous studies have shown that PjBL can improve students' conceptual understanding and practical competencies [9], [10]. However, implementing PjBL in digital environments can present challenges in managing project activities, learning processes, and student interactions, indicating the need for appropriate technological support [11].

Moodle provides an integrated Learning Management System (LMS) for managing learning materials, assignments, assessment, and student interaction. A systematic review by Gamage et al [12]. shows that Moodle has been widely adopted to support teaching and learning, particularly in STEM education. However, Moodle is a general-purpose LMS, and its effectiveness depends on how its features are integrated with specific instructional approaches. Research comparing Moodle with other LMS platforms also indicates that usability and learning needs should be considered when implementing Moodle-based learning environments [12], [13].

Although PjBL and Moodle have been widely studied, limited research has focused on integrating PjBL, Moodle, and embedded coding practice specifically for vocational database learning. Therefore, this study develops NexaDB as a Moodle-based learning environment that integrates PjBL with Code Runner to connect learning materials, coding practice, project development, and assessment within a single learning environment. This integration represents the main novelty of the study and is expected to improve students' database competency.

Methodology

A. Research Design

This research uses the Research and Development (R&D) method, which is a research method applied to develop or test products used in the education and learning process [14]. The development model applied is ADDIE. ADDIE stands for Analysis, Design, Development, Implementation, and Evaluation [15]. This study applies a quantitative approach. In addition, the database competency improvement analysis design used was quasi-experimental and Non-equivalent Control Group Design design using pretest-posttest [16]. The quasi-experimental method (Figure 1) uses two classes, namely the experimental class that receives a certain treatment and the control group that does not receive the treatment. The data needed was carried out through *pretest* and *posttest* to compare differences in competence before and after treatment [17].

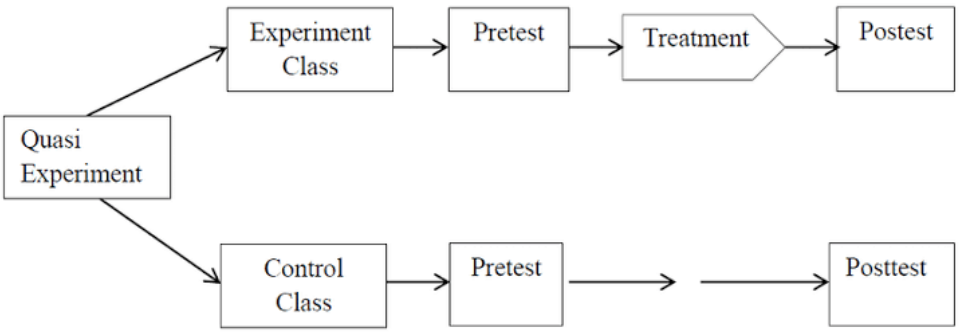

Figure 1. Quasi experimental research procedure

B. Participants

The technique implemented in sampling is *purposive sampling* on the condition that students have learned the basics of databases. Purposive sampling was used because the study required participants who had already completed the basic database competencies needed to participate in the intervention and complete the pretest and posttest. The two classes were selected based on their comparable academic level, curriculum, learning content, and previous exposure to basic database concepts. Both groups consisted of Grade XI students in the Software Engineering (RPL) program and followed the same school curriculum. The experimental class consisted of 36 students from XI RPL-3, while the control class consisted of 36 students from XI RPL-4, resulting in a total of 72 participants.

C. Research Instruments and Data Analysis

1. Research Instruments

a. Interview: The interview was conducted with the aim of finding various information or problems that existed at SMKN 4 Bojonegoro.

b. Observation: Observation activities are in the form of observation of the teaching and learning process in the classroom. Observation aims to understand the characteristics of students, identify gaps in the learning process, and know important needs as a basis for designing solutions for the needs of students.

c. Validity Assessment: Expert validation sheets are used to evaluate research materials which include teaching module validation, material validation, pre-test validation, post-test and case study as well as learning media validation.
d. Pre-Test and Post-Test: Pre-Test and Post-Test are one of the measurement tools that are recommended to be implemented because of an effective direct assessment [18].
e. Result documentation: The result documentation stage is documenting each process.

2. Data Analysis Techniques

a. Analysis of Expert Validation Results: The assessment of validation results by experts is carried out with the intention of measuring the level of validity of the product that has been produced [19]. The percentage of expert validation results is as follows:

$$Nilai = \frac{\sum Scores\ obtained}{\sum Maximum\ score}\ x\ 100$$

From the results of the formula above, the following percentage criteria (Table 1) are obtained:

Table 1. Expert validation category

Presentation Range	Criteria
81 – 100 %	Highly Valid
61 – 80 %	Valid
41 – 60 %	Quite Valid
21 – 40 %	Invalid
0 – 20 %	Highly Invalid

b. Competency Improvement Analysis: This analysis is conducted to compare the level of student competency before and after being given a competency test related to the database. The research design (Table 2) used is as follows [20]:

Table 2. Pretest-posttest Research Design

Kelompok	Pretest	Perlakuan	Posttest
Eksperimen	O_1	X	O_2
Kontrol	O_1'	—	O_2'

After obtaining *the pretest* and *posttest* scores, the researcher analyzes the scores obtained. The analysis applied was to test the normality of gains in the results. Here is the formula used to calculate the normality of gain according to the Meltzer method.

$$N\ Gain = \frac{Spost - Spre}{Smaks - Spre}$$

After obtaining the normality of gain, the following is a presentation of the categories (Table 3) that will be used [21]:

Table 3. Category N-Gain

Range	Category
$0{,}70 \leq n \leq 1{,}00$	Height
$0{,}30 \leq n < 0{,}70$	Intermediate
$0{,}00 \leq n < 0{,}30$	Low

c. Analysis of Media Implementation Results

1) Shapiro Wilk Normality Test: The Normality Test has the purpose of determining whether or not the residual value follows a normal distribution. In addition, Shapiro wilk normality tests can be performed for small to medium sample quantities [22]. This test was performed using JASP software. The assessment is considered to be normally distributed if the significance value is greater than a = 0.05.

2) Homogeneity Test: Homogeneity test is used to find out whether some variation in the population is true or not [23]. The homogeneity test aims to ensure that both classes, namely the Experimental Class and the Control Class, have the same level of data diversity. The homininia criterion is that if the Significance value (p) > 0.05, then the data is homogeneous.

3) Independent Sample T-Test is a statistical method used to find out whether two unrelated groups have different mean values. The purpose of this test was to compare the averages between two groups that had no relationship with each other. The following is a manual calculation of the independent-sample t-test with the following formula:

$$t_{hitung} = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}$$

Results and Discussion

This study developed and evaluated NexaDB, a Moodle-based Learning Management System integrated with Project-Based Learning (PjBL) to improve students' database competency. The study involved an experimental group using NexaDB with PjBL and a control group using the existing teacher-centered instructional approach.

A. Media Development Results

a. Analysis: The Head of RPL Expertise Concentration provides direction on what needs students need in the learning process in the NexaDB LMS (Table 4 and Table 5). Among them are as follows:

Table 4. NexaDB LMS functional requirements

Aspects	Remarks
Compatibility	The NexaDB LMS can be accessed by using Mozilla Firefox, Google Chrome, and Safari.
Security	Restrictions on the types of data that can be uploaded. Uploadable data includes pdf files and links. Account creation can only be done by admins, thus avoiding ungenuine account registration or misuse of access rights.

Table 5. Non-functional needs of NexaDB LMS

Features	Role
Login	All role
Manajemen Pengguna	Admin
Manajemen Kelas	Admin
Manajemen Materi Pembelajaran	Teachers and admins
Akses Materi	Teachers and Students
Manajemen PjBL	Teachers and admins
Akses PjBL	Students
Manajemen Kuis	Teachers and admins
Akses Kuis	Students
Manajemen Nilai	Teachers and admins

b. Design: In the design phase, we will describe the design of system behavior modeling and display design on the Learning Management System NexaDB. Moodle has an OOP structure, so in the development process, the use of UML is used to map user interactions. The following are the usecases used (Figure 2):

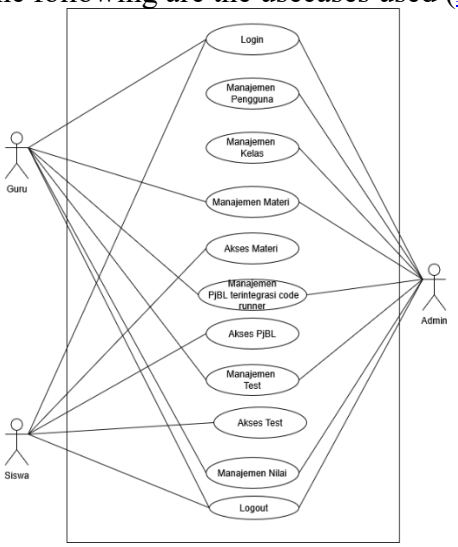

Figure 2. Usecase NexaDB LMS

c. Development: NexaDB LMS development using Laragon as a local server. Moodle was developed using the PHP programming language and uses MySQL as the database management system,

as well as using an Object-Oriented Programming (OOP) structure. Application testing is done using BlackBox Testing, which only focuses on using the application without the need to understand how the program code works in it. In addition to system development, in the development stage, teaching modules, materials and making assessment instruments (pretest/posttest questions and case studies) are also carried out. Below are the results of the development of the NexaDB LMS (Figure 3):

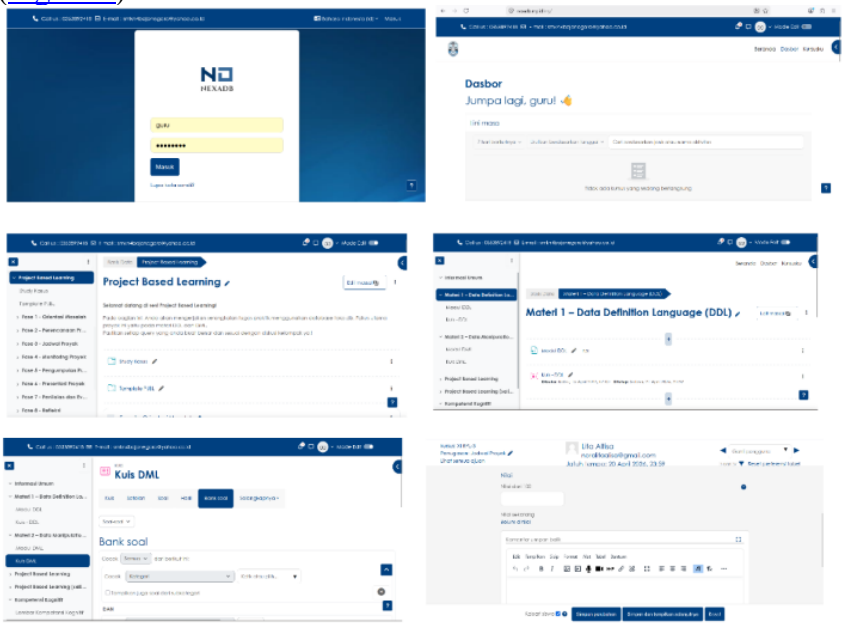

Figure 3. NexaDB LMS view

d. Implementation: The implementation of the moodle-based NexaDB LMS was carried out face-to-face in the new school year 2025/2026 at SMKN 4 Bojonegoro, applying the Project-Based Learning (PjBL) learning model to improve database competence. The stages of implementation include:

1) Preparation: Socialization of the use of NexaDB LMS, creation of learning materials, post-test pre-test questions, psychomotor case studies and teaching modules, as well as coordination with database subject teachers.
2) Learning: Carried out face-to-face for 3 meetings (3JP @45 minutes), The intervention was conducted over three face-to-face meetings, with the experimental and control groups receiving instruction separately. Both groups covered the same database learning objectives and learning duration.
3) Mentoring: Teachers accompany students through the NexaDB LMS in experimental classrooms and direct interaction in the control class, monitor each student's progress, provide feedback, and ensure projects are in line with learning objectives.

e. Evaluation: The evaluation stages are carried out using 2 approaches, which are as follows.
   1) Formative evaluation: In the stages of developing the NexaDB LMS, it was carried out by 2 UNESA Information Technology Education Lecturers and 1 teacher at SMKN 4 Bojonegoro. The assessment provided by the validator has the function to evaluate and improve the LMS based on the suggestions that have been proposed before the LMS is implemented to SMK Negeri 4 Bojonegoro.
   2) System Evaluation: System evaluation is required to ensure its conformity with predetermined functional and non-functional specifications. The evaluation of the system used 3 UNESA students and 2 students of SMKN 4 Bojonegoro.

B. Discussion of Research Results

a. Expert validation analysis: The validation results explain the feasibility of learning products based on the assessment of several experts using the linkert scale method. Below are the results of expert validation (Table 6):

Table 6. Expert validation results

Expert Validation	Percentage Value	Remarks
Teaching Module	91%	Highly Valid
Teaching Materials	91%	Highly Valid
Pre-test and Post-test	93%	Highly Valid
Media	89%	Highly Valid

b. Competency improvement analysis: The impact of treatment after being given treatment, obtaining good results as evidenced through N-Gain analysis. Based on the calculation results, The average value of N-Gain gets a high category for the experimental class and intermediatefor the control class. Here are the results of N-Gain (Table 7).

Table 7. Competency improvement results

Competencies	Classes	Mean N-Gain	Kategori
Cognitive	Eksperiment	0.726	Height
	Control	0.406	Intermediate
Psychomotoric	Eksperiment	0.710	Height
	Control	0.472	Intermediate

c. Analysis of media implementation results: Before conducting the Hypothesis Test, the data is tested in several stages. The following are the test stages:
   1) Normality test: The test results show that the data is distributed normally, with a recap of the following values (Table 8):

Tabel 8. Normality value data

Competencies	Classes	Data	P-Value	Category
Cognitive	Eksperiment	Pre-test	0.726	Normal
	Control	Posttest	0.406	Normal
Psychomotoric	Eksperiment	Pre-test	0.710	Normal
	Control	Posttest	0.472	Normal

From the data in Table8, the four data are greater than 0.05 (>0.05), thus meeting the assumption to be carried out in the next test.

2) Homogeneity test: A homogeneity test, which is used to test whether the data variants are the same (homogeneous) or not. The results of the homogeneity test (Table 9) are as follows:

Table 9. Homogeneity data

Competencies	Data	P-Value	Category
Cognitive	Pre-test	0.759	Homogeneous
	Post-test	0.739	Homogeneous
Psychomotoric	Pre-test	0.136	Homogeneous
	Post-test	0.471	Homogeneous

Results on Table 9 prove about *p* is greater than 0.05 (>0.05), so it can be eligible to continue the next test.

3) Hypothesis test: Hypothesis test is used to answer the research hypothesis that has been formulated. The following are the decision-making criteria used in the hypothesis test:

T table > T count = H_0 accepted and H_1 rejected
T table < T count = H_0 rejected and H_1 accepted

The following are the results of the cognitive and psychomotor hypothesis test (Table 10 and Table 11):

Table 10. Cognitive Hypothesis Test Results

Independent Samples T-Test

	t	df	p
Post-Test	10.95	70	< .001

Note. Student's t-test.

Table 11. Psychomotor Hypothesis Test Results

Independent Samples T-Test ▼

	t	df	p
Post-Test	7.781	70	< .001

Note. Student's t-test.

Based on the results of the cognitive hypothesis test in Table 10 and the psychomotor hypothesis test in Table 11, the cognitive t-count value was 10.95 and the psychomotor t-count was 7.781. The value of t calculated was then compared with the t table at the significance level of 0.05 and df 70, which was 1.994. Since t calculates the > t tables (10.95 > 1.994) and (7.7814 > 1.994) and the significance value *of p* < 0.001, H0 is rejected and H1 is accepted. This finding indicates that there was a significant difference in database competency improvement between students who learned using the Moodle-based NexaDB LMS integrated with PjBL and students who received the existing teacher-centered instructional approach. Therefore, H0 was rejected and H1 was accepted. on the improvement of database competency at SMKN 4 Bojonegoro.

Conclusion

The NexaDB Learning Management System was developed based on Moodle using Laragon as a local server, with PHP as the programming language, MySQL as the database management system, and an Object-Oriented Programming (OOP) structure. The system was evaluated through formative and system evaluations. The formative evaluation involved two lecturers from the Information Technology Education program at Universitas Negeri Surabaya and one teacher from SMK Negeri 4 Bojonegoro, while the system evaluation involved students from Universitas Negeri Surabaya and SMK Negeri 4 Bojonegoro using Black-Box Testing. The evaluation results indicated that NexaDB met the required functional and non-functional specifications and was suitable for implementation in database learning. The implementation of NexaDB integrated the syntax of Project-Based Learning (PjBL) into the learning process, enabling students to access learning materials, practice database coding, complete project activities, submit assignments, and receive feedback within an integrated learning environment. The findings showed that students who learned using NexaDB integrated with PjBL achieved greater improvements in cognitive and psychomotor database competencies than students who received the existing teacher-centered instructional approach. Thus, the integration of PjBL with a Moodle-based LMS provides a practical approach for connecting conceptual database knowledge with authentic project-based practice. From a theoretical perspective, this study contributes to the integration of Project-Based Learning, Moodle-based learning environments, and embedded coding practice in vocational database education. The findings support the use of technology-supported project learning to facilitate active learning and the development of both conceptual and practical competencies. From an educational perspective, NexaDB provides students with opportunities to actively construct knowledge through project activities while practicing database skills in a structured digital environment. From a practical perspective, NexaDB provides teachers with an integrated platform for organizing learning materials, project activities, coding exercises, assignments, assessment, and feedback.

Limitations

The implementation involved a relatively limited number of students from one vocational school and was conducted over a limited learning period, which may restrict the generalizability of the findings to other educational contexts. In addition, the study focused specifically on database learning and did not examine the long-term effects of NexaDB implementation. Future research should therefore involve larger and more diverse samples across multiple vocational schools and longer implementation periods to examine the scalability, sustainability, and generalizability of the system. Further development could integrate learning analytics and artificial intelligence to monitor student learning progress, provide adaptive feedback, identify individual learning difficulties, and personalize project-based learning activities.

Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this manuscript, the authors utilized Grammarly and Quilbot to improve grammatical accuracy and enhance overall readability. Following the application of this tool, the authors thoroughly reviewed and revised the content as necessary and assume full responsibility for the integrity and accuracy of the published work.

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Author Contributions

Cintiya and Mohammad Wildan Habibi,: Conceptualization, data curation, software, formal analysis, supervision, validation, investigation, methodology, writing – original draft, project administration, writing – review & editing. Julius Jonas Mbawala, Rindu Puspita Wibawa, and Martini Dwi Endah Susanti: Data curation, software, formal analysis, validation, visualization, methodology, writing – original draft, project administration, writing – review & editing. Muhammad Angga Pratama: Data curation, software, formal analysis, methodology, writing – original draft, writing – review & editing.

Availability of data and materials

The data used in this study are available from the authors upon reasonable request.

Competing interests

The authors declare that there are no competing interests.

Additional information

The authors declare that there is no additional information to report.

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