Bioedukasi
Jurnal Biologi dan Pembelajarannya

Vol. 23 No 3, October 2025, page 442-448
e-ISSN: 2580-0094; p-ISSN: 1693-3931
DOI: 10.19184/bioedu.v23i3.53749
bioedukasi.jurnal.unej.ac.id/index.php/BIOED

Development of Guided Inquiry-Based Microbiology Modules Based on the Identification of Contaminant Molds in Tomato Fruit to Improve Students' Science Process Skills

Naufal Wima Al Fahri[1], Utami Sri Hastuti[2*], Safwatun Nida[3]
[1,2]Biology Education, Faculty of Mathematics and Natural Sciences, State University of Malang
[3]Natural Science Education, Faculty of Mathematics and Natural Sciences, State University of Malang

Article Info

Article history:
Received July 24, 2025
Revised October 14, 2025
Accepted October 24, 2025

Keywords:
ADDIE
Contaminant mold
Microbiology
Module development
Science Process Skills
Tomato

ABSTRACT

Students often experience difficulties in identifying microbiological specimens due to limitations in preparing and interpreting microscopic slides. This problem is evident in the context of tomato fruits (Solanum lycopersicum), which are widely consumed agricultural commodities but are highly perishable and susceptible to microbial contamination, especially by molds. To address this challenge, this study aims to develop a guided inquiry-based microbiology learning module using tomato mold identification as a case study, with the goal of improving students' Science Process Skills (SPS). The research was conducted in two stages: (1) laboratory experiments to identify contaminant molds in tomatoes and (2) development of a learning module using the ADDIE model (Analyze, Design, Develop, Implement, Evaluate). The sample consisted of 62 microbiology students from the Biology Education Program, Faculty of Mathematics and Natural Sciences, State University of Malang. A non-randomized control-group pretest–posttest design was employed, the increase in posttest results compared to the pretest was calculated using the *N-gain* score. Results showed that students' SPS was still relatively low, particularly in the observing indicators (30.43%) and hypothesizing indicators (43.48%). The developed module integrates real laboratory findings into structured inquiry-based activities, emphasizing hands-on practice, critical thinking, and contextual relevance to agricultural microbiology. Its distinctive features include the use of authentic microbial identification data, scaffolding through guided inquiry steps, and alignment with SPS indicators. This module is expected to provide an effective solution for enhancing students' SPS in microbiology learning

Corresponding Author:
Utami Sri Hastuti,
Biology Education, State University of Malang
Jalan Semarang 5, Malang 65145, Indonesia
Email: utami.sri.fmipa@um.ac.id

1. INTRODUCTION

The urgency of improving students' Science Process Skills (SPS) in microbiology learning has become increasingly important, as these skills reflect students' ability to think logically, conduct investigations, and solve scientific problems. However, many students still experience difficulties in mastering SPS, particularly in indicators such as observing and hypothesizing, which are fundamental for conducting practical activities effectively. This educational gap highlights the need for effective learning modules that not only provide theoretical content but also actively train students to practice SPS through structured and meaningful laboratory activities.

One relevant and authentic context to address this need is the identification of contaminant molds in tomato fruit. Tomatoes are one of the agricultural commodities that are widely used as food and industrial

materials which make their needs increase overtime (Nuviani et al., 2023). Tomato plants is a shrub or annual plants that have high economic value. Tomato production is strongly influenced by the environmental factors, this factor is important to achieve maximum growth. The tomatoes harvesting process has an important role in the shelf life of tomatoes. Any damage during tomato harvesting can cause a decrease in the quality of tomatoes and in addition, physical damage to tomatoes causes by microbes that can cause damage in tomato fruits. Tomato fruit is a climatic fruit that will continue to ripen after harvest; this causes the shelf life of the fruit will decrease. As tomato fruit ripens, the natural sugar content in the fruit will increase. this condition is suitable as a substrate for mold to grow and reproduction (Zulfatunna'im et al., 2022).

Mold contamination on tomato fruit can be examine through observations activity in the laboratory. However, there are obstacles encountered in making mold slides, because the hyphal structure and reproductive organs of molds are not intact, so there are difficulties in describe and identify the mold structure based on the microscopic structure of the mold body observation, this fact caused the students can not understand the concepts of mold body structure, characteristics and reproductive organs of mold and also mold classification (Sundari, 2012). The research results by Sholihah & Sofiyana (2019) explained that there is obstacle in the learning process of Microbiology courses, namely the unavailability of teaching materials to support learning activities.

The increasing of concepts understanding related to contaminant molds requires student's skills that play an important role in learning activity, including Science Process Skills (SPS). These skills show a reflection of student's scientific attitudes. Someone who has good SPS will be easier to learn, so every student need to have the first ability of SPS, so can help in practicum activities (Lubis et al., 2022). Practical activities carried out in higher education require the lecturers activity as mentors or as facilitators and students must be active in the learning process that was appropriate with Biology learning objectives (Rahayu & Eliyarti, 2019). The needs analysis result of 23 students from the Biology Education study program, faculty of Mathematics and Natural Sciences, State University of Malang in August-October 2024 showed that student's SPS was still relatively low in the **observation** results, students who answered correctly were only 30.43%. In the **hypothesizing** indicator, students who answered correctly were only 43.48%. These results prove that students' science process skills still need to be improved. The Science process skills are important to support the ability to think logically, so students are able to solve problems around them (Faizah & Kamal, 2024).

The science process skills improvement in the learning process can be done by use the application of student-oriented learning models. The learning model that can train the SPS is the guided *inquiry* learning model. This learning model is designed to help students to gain a deep understanding of the scientific method (Wijayanti & Azis, 2015). Learning activities about "The Description and Identification of Contaminant Molds on Tomato Fruit" will give opportunities the students to apply SPS by making direct observations (Kiay, 2018). The guided *inquiry* learning model can encourage students to explore their own knowledge activity so the students can become independent, active, and skilled in problems solving based on the information and knowledge the they have obtained (Amijaya et al., 2018).

The guided *inquiry* learning model syntax in Microbiology learning according to Llewellyn (2013) consist of: exploring phenomena, focusing on problems, planning investigations, conducting investigations, analyzing data and evidence, building new knowledge and communicating new knowledge. The application of the learning model can be accommodated through the use of teaching materials related to Course Learning Outcomes (CLO), which will help students to be able to do active learning (Istia'nah et al., 2020). Learning modules can be use as an alternative in overcoming the limitations of learning media, so it is hoped that there will be an improvement in the quality of learning.

The results of the needs analysis on students show that 100% students give an opinion that it is necessary to develop a module for the practical about "Identifying Contaminant Molds on Tomatoes". This is also reinforced based on the need analysis for lecturers, they clamified that there are limitations in the literature used, so the modules need to be developed.

Based on this description, it is necessary to develop a Microbiology learning module based on the "Identification of Contaminant Molds on Tomato Fruit" based on the guided *inquiry* learning model to improve student's SPS.

2. RESEARCH METHOD

This study employed a research and development (R&D) design conducted in two stages. The first stage was laboratory experimental research aimed at identifying contaminant molds in tomato fruits, identification of contaminant mold on tomatoes was carried out using the slide culture method. The second stage was the development of a microbiology learning module using the ADDIE model, with the experimental results serving as the scientific basis for module content. The developed module was then tested in classroom practice to improve students' Science Process Skills (SPS).

The research was conducted at the Biology Education Program, Faculty of Mathematics and Natural Sciences, State University of Malang, from February to May 2025. The sample consisted of 50 undergraduate

students enrolled in the Microbiology course. These students were distributed into two parallel classes (A and B offerings). Random sampling was used based on the GPA equivalency test from the previous semester to ensure homogeneity between the groups. One class was assigned as the experimental group and the other as the control group.

The research design followed a non-randomized control-group pretest–posttest design (Leedy & Ormrod, 2015). The experimental class was taught using the guided inquiry-based microbiology module developed through the ADDIE model (Analyze, Design, Develop, Implement, Evaluate), while the control class used conventional learning resources provided by the lecturer. The ADDIE model was chosen because it provides a systematic framework for developing instructional materials that are both learner-centered and empirically tested. Figure 1 illustrates the five stages of the ADDIE model (Branch, 2009).

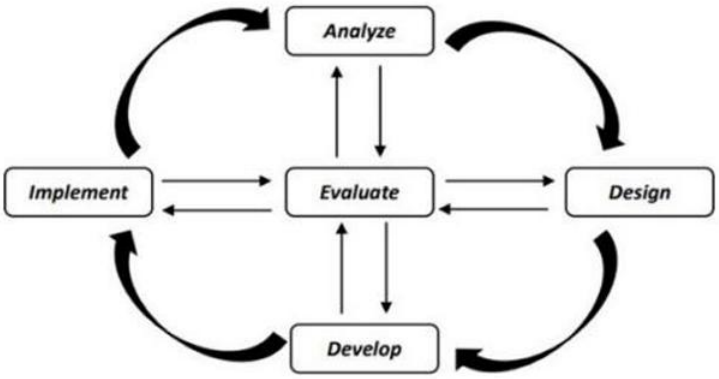

Figure 1: Modification from Branch (2009).

The research sample is students who take Microbiology courses as many as 2 *offerings*, namely A and B. Determination of the sample of this study using random sampling technique, based on the GPA value equality test in the previous semester and using one experimental class and one control class. The design used in this research was *Non-randomized control-group pretest posttest* (Leedy & Ormrod, 2015). The research design involved one experimental class and one control class that were randomly assigned.

3. RESULT AND DISCUSSION

The module was developed through several stages of the ADDIE model, namely Analyze, Design, Develop, Implement, and Evaluate. Each stage contributed to shaping the microbiology module to improve students' Science Process Skills (SPS). *Needs analysis showed that students' SPS was relatively low, particularly in observation (30.43%) and hypothesizing (43.48%) indicators. The design and development stages produced a microbiology module with characteristics of being self-instructional, self-contained, stand-alone, adaptive, and user-friendly. The description of the module development steps using the ADDIE development model is explained below.*

Analyze stage

The analysis stage was conducted through a needs analysis questionnaire distributed to undergraduate students of the Biology Education Program who had taken Microbiology courses, as well as to lecturers teaching the same subject. The data were collected from August to October 2024 using Google Forms. The results showed that students experienced persistent difficulties in understanding mold structures, characteristics, and classification, particularly when observing contaminant molds in tomatoes. These challenges negatively affected students' SPS, especially in the indicators of observing and hypothesizing.

The lecturer responses also emphasized the lack of sufficient teaching materials to support microbiology learning. Nearly all lecturers (100%) agreed that there was an urgent need to develop new modules that integrate real laboratory results with contextual everyday problems. This finding indicates that microbiology learning resources must be designed not only as references but also as structured teaching materials that actively engage students.

The results of the analysis stage confirmed the necessity to design a guided inquiry-based microbiology module. To ensure its relevance and usability, the module was expected to have several characteristics: self-instructional, self-contained, stand-alone, adaptive, and user-friendly. These criteria provided the foundation for developing teaching materials that could address student difficulties while improving SPS. This stage also involves conducting laboratory research to observe

contaminant mold on tomatoes, which will be used as the basis for developing the module. Based on laboratory research using the slide culture observation method at this stage, it was shown that there were five species of contaminant mold found in tomatoes, namely *Rhizoctonia* sp., *Alternaria alternata*, *Fusarium graminearum*, *Geotrichum candidum* and *Annellophora catenata*.

Design Stages

This stage is carried out by making a list of tasks to be designed, namely Semester Learning Plan (SLP), Course Session Plan (CSP), designing modules and module validation, pretest and posttest questions designing that are in accordance with the indicators of science process skills and question validation, assessment sheet instruments designing and module evaluation rubrics developed in the form of student response questionnaires and observation sheets for the implementation of the Guided *Inquiry* learning model syntax.

***Develop* stage**

The purpose of this phase was to produce content and a prototype of the instructional product in the form of a Microbiology module. The module was developed with a structured layout, including the table of contents, learning activities, instructional materials, and student worksheets (SW) based on the Guided Inquiry model. The validity of the developed module was assessed by experts in instructional media, focusing on the content feasibility, formation and layout, usability, language appropriateness, alignment with student characteristics, and integration with the targeted learning variables.

The developed module was validated by experts in learning media and learning tools, microbiology materials, and expert practitioners. The detailed results of the validators are presented in Table 2. The detailed results of the validators are presented in Table 1.

Table 1. detailed results of the validators

No.	Validator	Average score	Percentage (%)	Category
1.	Teaching materials and learning tools	5	99,6%	Very valid
2.	Microbiology content experts	5	99,1%	Very valid
3.	Expert practitioner	5	98,5%	Very valid

Based on the overall validation results by the validators, it shows a very valid category Akbar (2013). The aspects evaluated by the content experts included the alignment of content with the expected learning outcomes (CPMK and sub-CPMK), content accuracy, breadth and currency of the material, ability to stimulate student curiosity, presentation techniques, presentation aids, instructional delivery, and logical coherence. The validation aspect from the Microbiology content included the depth of content, clarity of presentation, the material currently, language feasibility, presentation technique, supporting media, and usability. The aspect evaluated by instructional practitioners included breadth of material description, clarity of material presentation, currency of material, language suitability, presentation techniques, presentation support and ease of use. Practicality test was also conducted by 20 students through a field trial, and the results showed a practicality score of 90.2%, indicating that the module is very practical category for student.

The purpose of validation by expert validators is to obtain a valid, effective, and practical module based on the validity test from expert assessments and to obtain criticism and suggestions for improvement to perfect the developed module. The development of microbiology modules that comply with the module writing structure will make it easier for students to learn the material, achieve learning objectives, and acquire specific competencies (Rahmi et al., 2021). The results of expert validation obtained very feasible criteria, were able to attract students' interest and motivation to learn, and obtained very good responses and improved written test results, making them suitable for use (Nindiawati et al., 2021).

***Implement* stage**

This phase aimed to assess the effectiveness of the Microbiology module in enhancing students' science process skills and critical thinking skills, which were measured through pretest and posttest scores. The descriptive analysis results of students' science process skills in the experimental and control classes are presented in Table 2.

Table 2. Mean Pretest-Posttest Score and Difference in Improvement of Student Science Process Skills

No	Class	Student Science Process Skills			Description
		Pretest	Posttest	Improvement	
1	Experiment	75,6	88	12,4	Increased (16.40%)
2	Control	61,2	70	8,8	Increased (14.38%)

The improvement of students' science process skills in the control and experimental classes is illustrated in Figure 2 below.

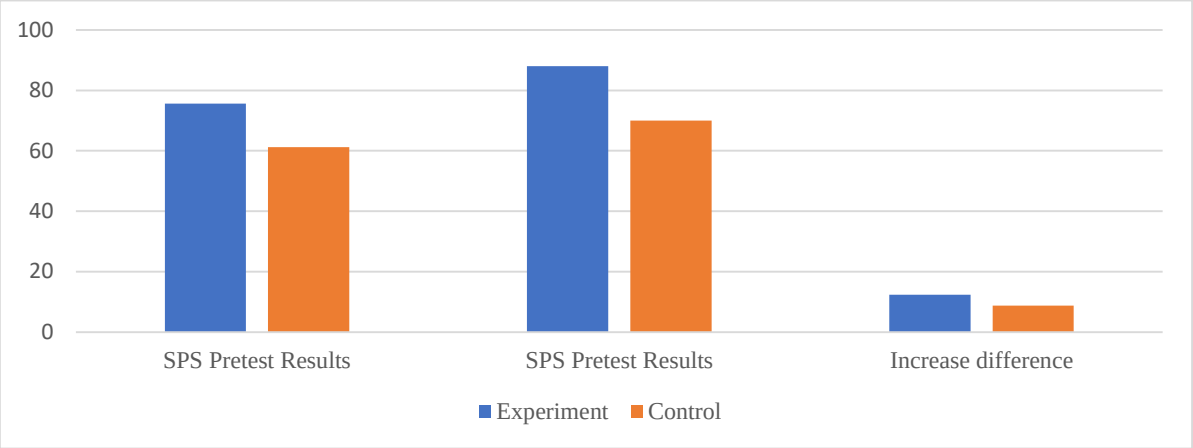

Figure 2. Student Science Process Skills Improvement

Based on the Figure 2, it can be seen that there was an increase in learning outcomes, with an increased of 12.4 points in the experimental class and 8.8 points in the control class. The highest improvement occurred in the experimental class, showing an increased 16.40%. The results of the N-gain score analysis based on students' pretest and posttest scores in science process skills are presented in Table 3.

Table 3. *N-gain score of Pretest* and *Posttest* values

		Min	Max	Mean	Std. Dev
N-gain_score	24	.00	1.00	.6375	.35168
N-gain_Score_Percent	24	.00	100.00	.63.7500	35.16782
Valid N (listwise)	24				

Referring to Table 4.18, the developed Microbiology module demonstrated a moderate level of effectiveness with an N-gain score of 0.6375. This value corresponds to an N-gain percentage of 63.7500, which is categorized as moderately effective.

***Evaluate* Stage**

This phase was carried out at the end of each ADDIE stage by taking into consideration feedback and suggestions provided by the validators and students. Practical activities are an essential component of Biology learning. Laboratory work enables students to develop the ability to identify problems and communicate research findings. Science process skills help students learn how to solve everyday problems, which means these skills must be developed directly through experiential learning. An opportunity to get direct experiences during the learning process will give the students to better understand the biology concepts (Hasibuan & Yani, 2024).

The content of learning resources in the Microbiology module should not only help students acquire conceptual understanding, but also promote the development of critical thinking, science process skills through laboratory activities, and building the scientific attitudes (Nafilah et al., 2020). A research-based module integrates theoretical knowledge with investigative activities, enabling students to gain a concrete understanding of how concepts are applied in the real life. This modules also contribute significantly to the achievement of course competencies (Fajarwati et al., 2018).

4. CONCLUSION

This Microbiology module was developed using the ADDIE instructional design model, which consists of five stages: Analyze, Design, Develop, Implement, and Evaluate. The module has been validated by the validators in instructional materials, lesson planning, Microbiology content, and instructional practice. The validation results confirmed that the module is valid. Furthermore, the module was effective in improving students' science process skills, as indicated by the pretest and posttest results. Therefore, it is feasible for use in Microbiology learning activities.

5. ACKNOWLEDGEMENT

The author would like to express sincere gratitude to the validators for their valuable input and suggestions: Dr. Sitoresmi Prabaningtyas, M.Si. (content expert), Drs. Triastono Imam Prasetyo, M.Pd. (media/material expert), and Muhammad Andry Prio Utomo, S.Si., M.Si. (Microbiology learning practitioner).

6. REFERENCES

Akbar, S. (2013). *Instrumen Perangkat Pembelajaran*. PT Remaja Rosdakarya.

Amijaya, L. S., Ramdani, A., & Merta, I. W. (2018). Pengaruh Model Pembelajaran Inkuiri Terbimbing Terhadap Hasil Belajar Dan Kemampuan Berpikir Kritis Peserta Didik Effect. *Journal Pijar MIPA*, *13*(2), 94–99. DOI: 10.29303/ jpm.v13.i2.468

Branch, R. M. (2009). Approach, Instructional Design: The ADDIE. In *Department of Educational Psychology and Instructional Technology University of Georgia* (Vol. 53, Issue 9).

Faizah, H., & Kamal, R. (2024). Pengembangan Modul Praktikum IPA Berbasis Keterampilan Proses Sains pada Program Studi PGMI. *Jurnal Basicedu*, *8*(1), 466–467. https://doi.org/10.31004/basicedu.v8i1.7074

Fajarwati, L. P., Kiswandianta, R. B., & Pujiati. (2018). Penyusunan modul mikrobiologi berbasis penelitian purifikasi dan uji aktivasi enzim selulase dari Kapang Trichoderma viride. *Coference Proceedings*, *September*, 217–224. https://www.bing.com/search?q=Penyusunan+Modul+Mikrobiologi+Bebrbasis+Penelitian+Purifikasi+dan+Uji+Aktivasi+Enzim+Selulase+dari+Kapang+Trichoderma+viride.&cvid=ba7c7a795f374df3a9b1325d3c26030a&FORM=ANAB01&PC=HCTS

Hasibuan, V. U., & Yani, F. (2024). *Analisis Keterampilan Proses Sains Berbasis Praktikum di Universitas Haji Sumatera Utara*. *4*, 94–102.

Istia'nah, D., Hastuti, U. S., & Gofur, A. (2020). Pengembangan Handout Berbasis Hasil Penelitian Daya Antagonisme Kapang Antagonis dan Kapang Patogen pada Tanaman Tomat. *Bioscientist : Jurnal Ilmiah Biologi*, *8*(2), 301. https://doi.org/10.33394/bjib.v8i2.2764

Kiay, M. I. (2018). Meningkatkan Keterampilan Proses Sains Siswa dengan Metode Eksperimen pada Mata Pelajaran IPA di SMP Negeri 4 Gorontalo. *JPs: Jurnal Riset Dan Pengembangan Ilmu Pengetahuan*, *03*(2), 138–147.

Leedy, P. D., & Ormrod, J. E. (2015). Practical Research Planing and Design. In *Pearson Education, Inc*. Pearson Education, Inc. https://doi.org/10.1093/ecco-jcc/jjy097

Llewellyn, D. (2013). *Teaching High School Science Through Inquiry and Argumentation* (Issue 112). Corwin.

Lubis, R., Fitriani, A., & Herlina, M. (2022). Pengukuran Keterampilan Proses Sains dan Self-Efficacy Mahasiswa Pada Mata Kuliah Mikrobiologi. *BIOEDUSAINS: Jurnal Pendidikan Biologi Dan Sains*, *5*(2), 391–400. https://doi.org/10.31539/bioedusains.v5i2.4566

Nafilah, H., Primiani, C. N., & Sulistyarsi, A. (2020). Penyusunan Modul Mikrobiologi Berbasis Penelitian. *Prosiding Seminar Nasional SIMBIOSIS V*, 86–91.

Nindiawati, D., Subandowo, M., & Rusmawati, R. D. (2021). Pengembangan bahan ajar matematika untuk siswa kelas v sekolah dasar. Edcomtech, 6(1), 140-150.

Nuviani, E. P. I., Martosudiro, M., & Choliq, F. A. (2023). Pengaruh Beberapa Fungisida Terhadap *Alternaria solani* Penyebab Penyakit Bercak Kering Pada Tanaman Tomat (*Lycopersicum esculentum* Mill.) di lapangan. *Jurnal Hama Dan Penyakit Tumbuhan*, *11*(2), 84–92. https://doi.org/10.21776/ub.jurnalhpt.2023.011.2.4

Rahayu, C., & Eliyarti, E. (2019). Deskripsi Efektivitas Kegiatan Praktikum Dalam Perkuliahan Kimia Dasar Mahasiswa Teknik. *Edu Sains Jurnal Pendidikan Sains & Matematika*, *7*(2), 51–60. https://doi.org/10.23971/eds.v7i2.1476

Rahmi, E., Ibrahim, N., Kusumawardani, D. 2021. Pengembangan Modul Online Sistem Belajar Terbuka dan Jarak Jauh untuk Meningkatkan Kualitas 96 Pembelajaran pada Program Studi Teknologi Pendidikan. Jurnal Visipena, 12(1). https://ejournal.bbg.ac.id/visipena/article/view/1476/1228

Sholihah, M., & Sofiyana, M. S. (2019). Analisis Kebutuhan Bahan Ajar Mikrobiologi Untuk Mahasiswa

Program Studi Pendidikan Biologi. *Bioma : Jurnal Biologi Dan Pembelajaran Biologi*, *4*(2), 123. https://doi.org/10.32528/bioma.v4i2.3162

Sundari. (2012). Suatu Model Pengembangan Media Pembelajaran Slide Culture untuk Pengamatan Struktur Mikroskopis Kapang pada Matakuliah Mycologi. *Jurnal SSIOêduKASI*, *1*(1).

Wijayanti, T. Y., & Azis, A. A. (2015). Peningkatan Kemampuan Berpikir Kritis Siswa melalui Penerapan Model Pembelajaran Inkuiri Terbimbing pada Konsep Sel dan Jaringan. *Jurnal Biotek*, *3*(1), 115–123.

Zulfatunna'im, L. D., Bintari, S. H., Mubarok, I., & Dewi, P. (2022). Potensi Ekstrak Akuades Biji Pepaya sebagai Penghambat Pertumbuhan Khamir Penyebab Busuk Buah Tomat dan Stroberi. *Life Science*, *11*(1), 13–28.