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Developing an Excretory System Mastery Booklet to Improve Students' Learning Outcomes

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ABSTRACT

Learning the excretory system requires students to connect anatomical terminology with physiological processes that are difficult to observe directly. This study developed an excretory system mastery booklet and described its feasibility, students' learning outcomes, and students' responses. The research and development procedure comprised five stages: information gathering, product planning, initial product development, a preliminary field trial, and revision following the trial. The six-page PDF booklet integrated anatomical exploration through coloring, a simple model of urine formation, and reflective journaling adapted from a Frayer-style organizer. Expert evaluation questionnaires, a student response questionnaire, and a knowledge test provided the data, which were analyzed descriptively. The reported mean feasibility ratings were 93.75% for content and 94% for media. The learning-outcome table included 30 students: five scored 75–83, twenty scored 84–92, and five scored 93–100. The source reported that all students met the school's minimum mastery criterion. Student responses were reported as 82% very positive and 8% positive; the remaining 10% was not accounted for in the source table. Revisions replaced glitter with sand and simplified the instructions. The results support the booklet's feasibility and show favorable achievement after its use. However, the absence of pretest data and a comparison group prevents a causal conclusion that the booklet improved achievement. Further trials should verify the response distribution, clarify the trial class, and evaluate learning gains and retention.

Keywords: masterybooklet; learning outcomes; excretory system

INTRODUCTION

The original development project was motivated by difficulties in teaching biology during a period of renewed distance learning. At SMA Negeri Bali Mandara, teachers used Google Classroom and WhatsApp groups alongside images and videos to support instruction. The source manuscript reports that excretory-system teaching in the 2020/2021 academic year had left many students below the school's minimum mastery criterion. It does not provide a numerical baseline or individual scores for that earlier cohort. This contextual account therefore identifies the instructional problem rather than serving as a pretest for the subsequent product trial.

Effective online instruction requires purposeful learning activities in addition to access to a digital platform. Rapanta et al. (2020), writing about university teaching during the pandemic, emphasized the design of learning experiences and teacher presence. Although that context differs from secondary-school biology, it provides a relevant rationale for supplementing online

explanations with activities that students can undertake and discuss. The booklet developed in the present study was intended to make those activities accessible in a concise PDF resource.

The teacher's initial diagnosis and interviews identified two practical difficulties. First, students struggled to remember scientific terms and the locations of excretory organs. Second, existing images and videos did not adequately help them understand the stages of urine formation in the nephron. These observations suggested a need to connect anatomical representations with actions and verbal explanations. Research on multimedia design indicates that the organization of representations matters, especially for complex material; simply adding visual media is insufficient (Noetel et al., 2022).

A masterybooklet was designed as a short sequence of tasks rather than a condensed textbook alone. Its three sections were "Let's Explore," "Let's Do," and "Let's Write a Journal." Students colored anatomical diagrams, carried out a simple physical representation of urine formation, and recorded vocabulary, observations, learning, and questions. This design responds to the school's identified needs while keeping the materials manageable and inexpensive. The study examined the development process, product feasibility, achievement after implementation, and student responses.

The research questions were: (1) How was the excretory system masterybooklet developed and revised? (2) What feasibility ratings did the product receive? (3) What learning outcomes were reported after students used the product? and (4) How did students respond to its use? These questions are descriptive. They distinguish preliminary classroom evidence from a controlled evaluation of effectiveness.

LITERATURE REVIEW

Masterybooklet as an Activity-Based Learning Resource

In this study, "masterybooklet" denotes the author's six-page learning booklet designed to support understanding of the excretory system. The word "mastery" expresses the product's instructional aim; it does not establish that a formal mastery-learning intervention was implemented. The PDF brings together diagrams, practical tasks, QR-linked instructions, and a structured journal. The format is intended to guide a sequence of learning actions and provide a record of students' thinking.

Brod (2021) reviewed generative strategies including concept mapping, explaining,

predicting, questioning, testing, and drawing, and showed that their suitability can differ with learners' age. For secondary-school students, this supports considering appropriately guided visual and explanatory tasks. The present booklet combines several forms of activity, but coloring a supplied diagram should not be treated as equivalent to generating a drawing from memory. Its contribution depends on how learners use the task to identify and relate anatomical structures.

Visual Organization and Physiological Processes

Color can be used as a cue to distinguish related structures and connect labels with diagrams. Alpizar et al. (2020) found an overall learning benefit from signaling in multimedia environments, while also documenting variation between studies. This evidence supports purposeful cues rather than a claim that particular colors necessarily improve memory. In the present product, anatomical coloring was intended to organize attention and support identification of organs and their parts; the study did not isolate the effect of color.

Understanding an organ system also requires connecting its components with their interactions and overall function. Gregorčič and Torkar (2022) examined this issue in a study of the circulatory system using a structure–behavior–function framework. Their findings offer a useful conceptual comparison for excretory-system instruction, although the present study used simple materials rather than augmented reality. A physical analogy can make a process discussable, but its correspondence with the actual biological mechanism must be made explicit.

Reflective Journaling and Learning Outcomes

The booklet's journal adapted a Frayer-style layout into four prompts: new vocabulary, what students learned, what they observed, and what they did not yet understand. This version differs from a conventional vocabulary-definition organizer. It was intended to connect naming, action, observation, and reflection. Fiorella (2023) described explaining, visualizing, and enacting as complementary modes of sense-making; this framework provides a rationale for linking the booklet's three sections rather than treating them as unrelated exercises.

The choice of learning strategy should also match the intended knowledge. Langbroek et al. (2024) reviewed the relation between study strategies and factual, conceptual, and procedural knowledge in secondary-school subjects. For the present product, naming kidney structures is a different demand from explaining how urine is formed. A classroom test may include both, but its interpretation depends on the test blueprint. The source does not report item-level results that

would separate those learning demands.

Recent evidence also supports examining explanatory prompts in digital resources. Tan et al. (2025) found that self-explanation was associated with better academic performance in digital learning environments. This does not demonstrate the effectiveness of the present journal, because the booklet trial did not compare prompted and unprompted conditions. It does justify retaining prompts that ask students to articulate relationships and identify uncertainty, provided the teacher checks the scientific accuracy of their responses.

Cognitive Load and Purposeful Visual Design

Excretory-system tasks require learners to coordinate unfamiliar labels with several interacting processes. Sweller (2020) explains why educational technology should be designed around the limits of working memory, while Castro-Alonso et al. (2021) distinguish instructional and learner-managed ways of addressing cognitive load. For this booklet, the design implication is to present a manageable sequence, place relevant labels near the structures they identify, and guide attention to one relationship at a time. Cognitive load was not measured in the trial.

Visual appeal should serve the learning objective. Sundararajan and Adesope (2020) synthesized evidence on seductive details, whereas Wong and Adesope (2021) examined emotional design in multimedia learning. These reviews address different aspects of visual presentation; together, they support evaluating both instructional relevance and affective appeal. The present booklet's colors should therefore have explicit anatomical meanings, and decorative elements should be checked for distraction rather than assumed to improve learning.

Drawing, Scaffolding, and Monitoring Understanding

Ainsworth and Scheiter (2021) distinguish several pedagogical purposes for drawing and emphasize support matched to the task. Cromley et al. (2020) compared evidence for technology-based and paper-and-pencil drawing, showing why the learning activity deserves attention alongside its medium. Dechamps and Skulmowski (2025) further emphasize task characteristics and boundary conditions. These sources motivate an extension in which students add labels, arrows, and brief explanations to a nephron diagram. They do not make the booklet's supplied coloring task equivalent to learner-generated drawing.

Support for drawing needs empirical scrutiny. Schmidgall et al. (2020) found benefits for some outcomes from drawing, but the two additional supports they tested did not improve

outcomes over unsupported drawing. Jamet and Michinov (2022) likewise investigated verbal and visual support rather than treating all scaffolds as interchangeable. Leutner and Biele (2025) synthesized instructional support for drawing-to-learn, emphasizing integration. A future booklet should therefore test whether its prompts help students connect a drawing with the corresponding biological explanation.

Visual tasks can also reveal how accurately students judge their understanding. Kollmer et al. (2020) examined drawing and spatial scaffolds in relation to metacognitive monitoring, while Fiorella and Jaeger (2023) studied learner- and instructor-generated visualizations using biology texts. These findings support asking students to compare their explanation with their diagram and identify uncertainties. They also suggest assessing judgment accuracy directly; a completed, attractive diagram is not by itself evidence of accurate understanding.

Retrieval, Explanation, and Feedback

Retrieval practice offers a complementary approach to the booklet's reflective prompts. McDermott (2021) reviews how practicing recall supports later access to learned material, and Agarwal et al. (2021) review applications in schools and classrooms. Carpenter et al. (2022) consider retrieval alongside spacing. A possible revision is to include short, low-stakes questions answered before reopening the booklet, followed by correction and another opportunity to retrieve the ideas later. This procedure was not documented in the original trial.

Explanation tasks should require students to organize ideas, not simply reproduce sentences. Fiorella and Kuhlmann (2020) investigated drawings during learning by teaching, while Lachner et al. (2022) reviewed teaching without an audience and Ribosa and Duran (2022) synthesized creating teaching materials for others. Their findings motivate a possible journal prompt asking students to explain urine formation to a younger learner using a labeled sketch. This would be a new activity, because teaching others was not reported in the current implementation.

The processes behind explanation and recall should also be distinguished. Kobayashi (2022) critically evaluates the retrieval-practice account of learning by teaching, so an explanation task should not automatically be described as retrieval unless students actually recall information. Moreover, the feedback synthesis by Wisniewski et al. (2020) supports careful attention to what feedback communicates. Teacher comments on the journal should identify inaccurate biological relationships and invite revision; the current study provides no separate estimate of feedback effects.

Renal Physiology and Technology-Supported Learning

Perry et al. (2023) unpacked renal structure and function into a framework for physiology education, providing a subject-specific rationale for linking anatomical features with their roles. Gonzalez et al. (2025) tested an augmented-reality learning sequence in renal physiology with biomedical students. These studies provide conceptual and technological comparisons for the present design. The masterybooklet uses a simpler medium and a secondary-school population, so neither framework adoption nor technology-related benefits should be presumed without a suitable local evaluation.

The renal-physiology literature also shows that teaching format and instructional strategy warrant separate attention. Anders et al. (2022) reported stronger renal examination performance in medical-student cohorts receiving interactive retrieval practice. Haydar et al. (2023) compared remote and face-to-face renal-pathophysiology teaching. Both concern medical education, but they support examining what learners do within a format rather than inferring effectiveness from the format alone. For the masterybooklet, task completion, explanation quality, and retention would be useful additional outcomes.

QR-linked explanations could be evaluated as a supplement to the PDF. Mayer et al. (2020) discuss design principles for instructional video, and Noetel et al. (2021) synthesize video studies in higher education. Peart et al. (2022) examine animations in undergraduate physiology, rather than this school-level excretory-system booklet. These sources justify considering concise, purposeful demonstrations with pauses for learner explanation. They do not establish that the QR-linked resources in the present product caused the reported achievement.

METHODS

Design and Development Procedure

The source describes a research and development project adapted from the historical Borg and Gall framework. Five stages were implemented because of limitations in time, personnel, and cost: information gathering, product planning, initial product development, a preliminary field trial, and revision after the trial. The historical model attribution is retained here as a description of the method actually used; it is not reassigned to a recent journal source. The contemporary references in this revised manuscript support the instructional rationale.

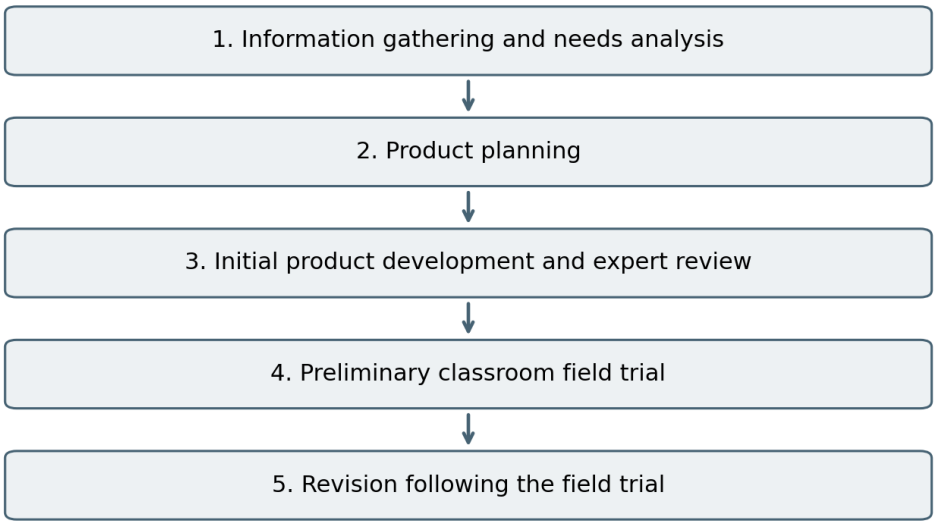


Figure 1. Five-stage development procedure for the masterybooklet

Information gathering included analysis of learning conditions, students' needs, and the curriculum. Curriculum work involved mapping basic competencies, preparing annual and semester programs, and reviewing the syllabus. Planning involved choosing textbook references, compiling content, determining the design, and organizing the three activity sections. Initial development involved selecting suitable images, accessible materials, and a journal layout, followed by content and media review. The product was revised before classroom use and again after the preliminary trial.

Participants and Implementation

The setting was SMA Negeri Bali Mandara in Buleleng, Bali, Indonesia. The learning-outcome table contains 30 Grade XI science-track students. The abstract of the original manuscript identifies XI MIPA 3, whereas the implementation account identifies XI MIPA 1. Because the source does not resolve this discrepancy, the present article refers to Grade XI students without asserting a confirmed class designation. The source mentions a content expert and a media expert, but both evaluation tables contain two rating rows; the identities associated with those rows are not specified.

The preliminary trial used discovery learning over two meetings. In the first meeting, students completed the exploration activity. In the second, they completed the practical activity

and journal. The source gives the duration as "2 × 45" per meeting with an ambiguous time-unit notation. This report therefore retains the two-meeting sequence without claiming a verified total teaching duration. The test and response questionnaire were administered after the booklet activities. No pretest or contemporaneous comparison group is reported.

Data Collection and Analysis

Table 1. Data types, collection procedures, and instruments

Data type	Collection procedure	Instrument
Product feasibility	Expert appraisal recorded in the source as observation	Content and media feasibility questionnaires
Student responses	Questionnaire-based appraisal recorded as observation	Student response questionnaire
Learning outcomes	Knowledge testing after implementation	Knowledge test

Qualitative feedback from the reviewers was used to revise the product. Quantitative data consisted of feasibility ratings, student response categories, and test-score frequencies. Descriptive analysis was used. The mean-score notation in the source was $\bar{X} = \Sigma X/N$, where ΣX denotes the sum of scores and N denotes the number of observations or respondents appropriate to the calculation. Feasibility percentages in Tables 3 and 4 can be reproduced by dividing each row's total score by its maximum possible score and multiplying by 100.

Table 2. Five-category score conversion reported in the source

Score interval	Grade	Feasibility category
$\bar{X} >$ Mi + 1.50 Sbi	A	Very good
Mi + 0.50 Sbi < $\bar{X} \leq$ Mi + 1.50 Sbi	B	Good
Mi – 0.50 Sbi < $\bar{X} \leq$ Mi + 0.50 Sbi	C	Satisfactory
Mi – 1.50 Sbi < $\bar{X} \leq$ Mi – 0.50 Sbi	D	Poor
$\bar{X} \leq$ Mi − 1.50 Sbi	E	Very poor

Note. $\bar{X}$ = mean score; Mi and Sbi are the source's ideal-score parameters. The source prints Mi = (ideal maximum − ideal minimum)/2 and Sbi = (ideal maximum − ideal minimum)/6. The printed Mi expression requires verification if Mi is intended to represent an ideal midpoint. Raw response scores and instrument bounds are unavailable; the reported categories are therefore retained without recalculation.

The source defined feasibility as reaching at least the "good" category and judged classroom success by whether students met the school's minimum mastery criterion (KKM). The

numerical KKM is not reported. Achievement was therefore summarized using the score intervals and counts provided in the source. No significance tests, effect sizes, means, or standard deviations were estimated from the grouped scores. Category attainment after instruction was not treated as a direct measure of change from baseline.

RESULTS AND DISCUSSION

Development and Expert Review

The initial needs analysis led to a product addressing scientific vocabulary and the visualization of urine formation. The resulting masterybooklet contained six pages in PDF format and three activity sections. The exploration tasks used diagrams of excretory organs, including the skin and kidneys. The practical section used accessible objects such as cups, gauze, small pebbles, and pieces of paper. The journal recorded terminology, learning, observations, and unanswered questions. QR codes provided access to supporting instructions.

Table 3. Content feasibility ratings

Rating row	1	2	3	4	5	6	7	8	Feasibility (%)
1	5	5	4	5	4	5	5	4	92.5
2	5	5	5	4	4	5	5	5	95
Mean									93.75

Note. The numbered columns reproduce the eight item positions; the source does not provide the item wording. Each row has a maximum of 40 points. The two rating rows are retained without assigning additional expert identities.

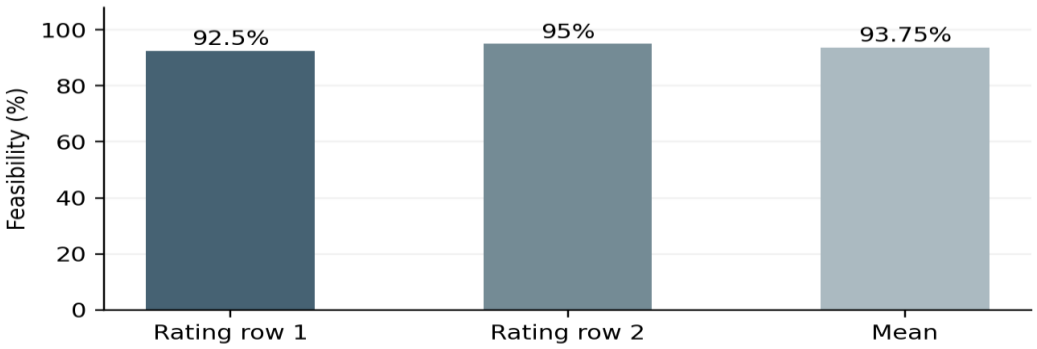


Figure 2. Content feasibility percentages

The content table yielded 37 of 40 points for rating row 1 and 38 of 40 for rating row 2. Their percentages were 92.5% and 95%, respectively, with a mean of 93.75%. These ratings

support the favorable appraisal of the content within the scope of the instrument. They do not, by themselves, establish the psychometric validity of the knowledge test or prove an effect on achievement.

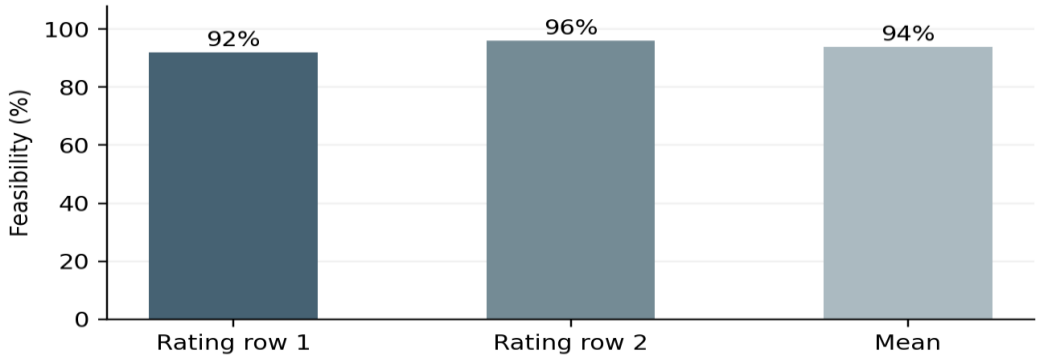
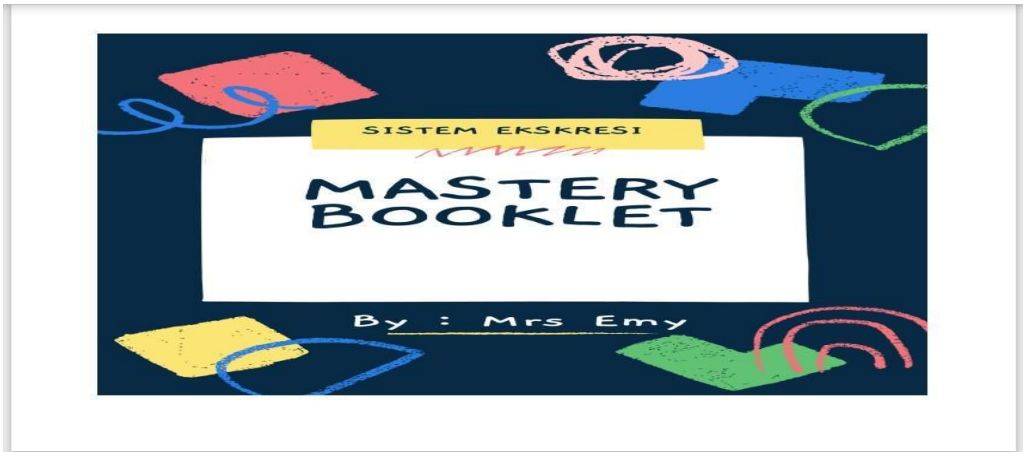


Figure 3. Media feasibility percentages

The media table yielded 23 of 25 points and 24 of 25 points, corresponding to 92% and 96%. Their mean was 94%. The product was revised following content and media review. The source provides screenshots of the revised cover, activity pages, and journal, but it does not give a complete itemized account of all pretrial reviewer comments. Figures 4–6 retain those product records.



Note. Original classroom product retained as documentary evidence. The Indonesian cover label "Sistem Ekskresi" means "Excretory System."

Figure 4. Cover of the masterybooklet after expert review

Note. Original classroom product retained as documentary evidence. The Indonesian cover label "Sistem Ekskresi" means "Excretory System."



Figure 5. Exploration and practical activity pages

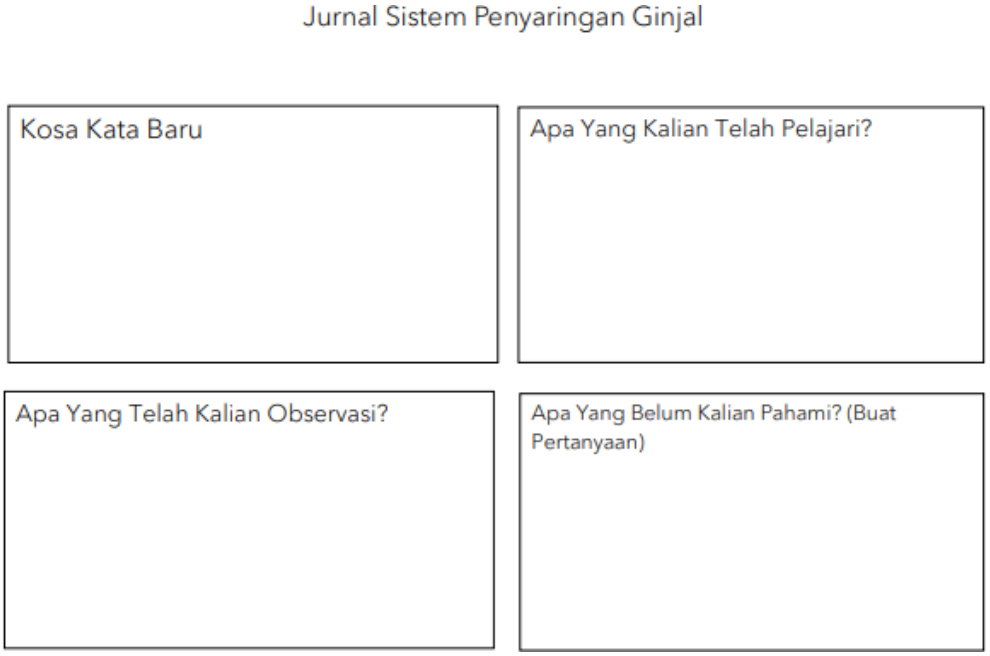


Figure 6. Structured learning journal in the masterybooklet

English reading guide: "Kidney Filtration System Journal"; "New Vocabulary"; "What Have You Learned?"; "What Have You Observed?"; and "What Do You Not Yet Understand? (Write a Question)."

Learning Outcomes after Implementation

The postimplementation knowledge-test distribution is shown in Table 5. Five students scored 75–83, twenty scored 84–92, and five scored 93–100. The counts sum to 30 students. The "good" interval contained the largest group. Percentages shown in Table 5 were calculated directly from these reported counts and rounded to two decimal places; they are descriptive additions rather than new observations.

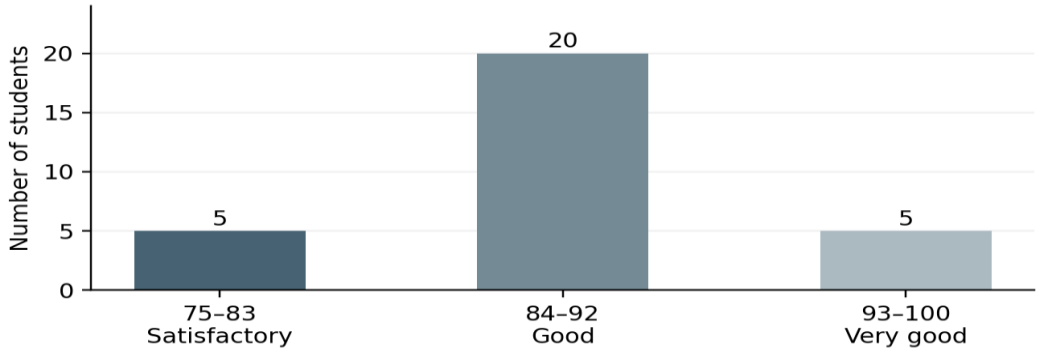


Figure 7. Number of students in each reported score interval

The source interprets the results as indicating that all students exceeded the school's minimum criterion. The grouped-score table is compatible with favorable attainment after instruction, but it does not quantify improvement. Earlier difficulties were described for an earlier teaching context without linked baseline scores. Consequently, no before-and-after gain can be calculated, and the contribution of the booklet cannot be separated from discovery learning, teacher guidance, or students' prior knowledge.

Student Responses and Final Revision

The largest reported response category was "very positive" (82%), followed by "positive" (8%). The source's narrative describes students enjoying the booklet activities and finding the physiological processes easier to understand. These qualitative observations are retained as the author's classroom account; the manuscript does not specify an interview protocol, transcript analysis, or response counts that would support additional qualitative statistics. The incomplete percentage distribution limits the interpretation of overall acceptance.

Two changes were made after the preliminary trial. Glitter was replaced with sand because students had difficulty obtaining the original material. Instructions were simplified to improve comprehensibility. The revised QR-linked materials list is shown in Figure 8. These changes

demonstrate that the trial informed a practical revision of the product. The source does not report another trial of the final revised version, so no separate outcome estimate is available for that version.

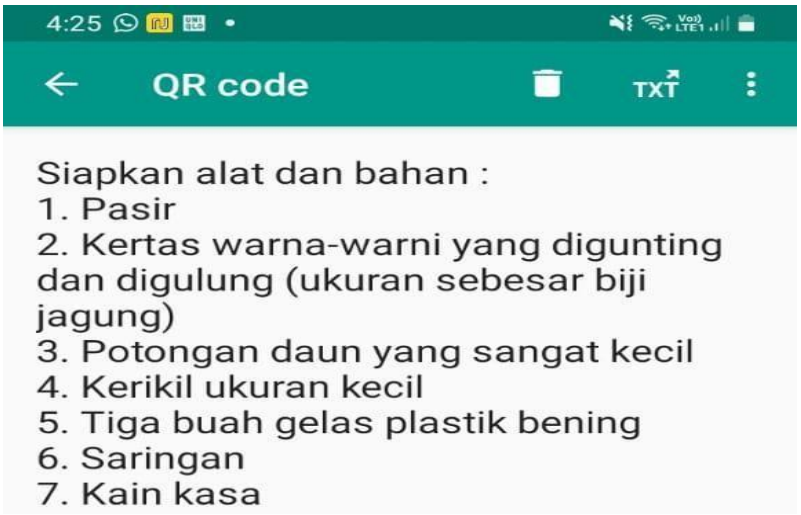


Figure 8. Revised materials list accessed through a QR code

English reading guide: prepare sand; cut and rolled colored-paper pieces approximately the size of a corn kernel; very small pieces (the source does not identify the material); small pebbles; three transparent plastic cups; a strainer; and gauze. The screenshot records the substitution of sand for glitter.

Interpretation of the Instructional Design

The activities offer a coherent response to the two needs identified by the teacher. Coloring asks students to locate and differentiate structures; the physical activity gives them an observable process to discuss; the journal invites them to articulate learning and uncertainty. These are proposed instructional mechanisms, not mechanisms directly tested by the present data. The product combines several supports, and its preliminary trial cannot determine which section contributed most to the observed achievement.

The color-based exploration should be interpreted as an attention and organization strategy. The signaling evidence synthesized by Alpizar et al. (2020) supports using cues that highlight relevant relationships. It does not justify attributing the test distribution to color alone or assuming a specific memory advantage for green and yellow. Pairing color with clear labels and a consistent

anatomical key would make the intended relationships easier to inspect; this is a recommendation for further refinement.

The practical activity can provide a shared reference for discussing how materials are retained or pass through a filter. It remains an analogy. A classroom strainer does not reproduce the biological selectivity, transport processes, and regulation of a nephron. Teachers should therefore help students state what each object represents and where the analogy breaks down. The structure–behavior–function perspective illustrated by Gregorčič and Torkar (2022) offers a useful way to organize those questions without assuming that their findings directly validate this different activity.

The journal can connect visual identification with the practical observations. Fiorella's (2023) framework suggests examining whether visualization and enactment support meaningful explanation. In this product, useful evidence would include students explaining relationships among structures and processes, rather than merely listing terms. Such evidence was not systematically scored in the source. A future version could use a simple rubric for accurate vocabulary, causal explanation, correspondence between model and nephron, and identification of unanswered questions.

Guidance also needs to match the learners and the intended outcomes. Brod (2021) cautioned that generative strategies vary in their age-related suitability. Langbroek et al. (2024) highlighted the need to distinguish knowledge types when selecting study activities. Together, these perspectives suggest separating factual naming questions from conceptual explanation questions in the test. The current aggregate intervals do not reveal whether students mastered both demands equally well.

The availability of a PDF and QR codes does not establish that the resource works independently of teacher support. Tan et al. (2025) reported benefits of self-explanation in digital environments, providing a rationale for explanatory prompts in future booklet versions. Noetel et al. (2022) likewise supports attention to clear multimedia organization. These findings inform design choices; neither study estimates the effectiveness of this particular six-page booklet. The trial's favorable ratings and score distribution remain local, preliminary evidence.

The broader secondary-school evidence offers a relevant comparison for digital support. Hillmayr et al. (2020) synthesized digital tools in secondary mathematics and science, indicating that implementation context belongs in the interpretation of results. Theobald et al. (2020) examined active learning and achievement gaps in undergraduate STEM. The latter population

differs from this trial, and equity outcomes were not measured here. Together, these studies motivate checking access to materials, participation, and achievement across learners when evaluating an expanded implementation.

An activity-based resource also requires evidence of intellectual engagement. Skulmowski (2024) discusses the opportunities and challenges of learning through activity, including the risk that doing an activity does not produce the intended learning. The booklet's practical model should therefore be followed by questions about filtration, reabsorption, and secretion, with explicit discussion of what the model represents. The revised instructions can make the physical procedure clearer, but understanding should be evaluated through students' biological explanations.

For remote use, engagement and attainment should remain separate outcomes. Bond et al. (2020) mapped student engagement and educational technology research in higher education, while Martin et al. (2020) reviewed online teaching and learning research. Their broader evidence motivates recording interaction with the resource and the instructional support students receive. In this study, favorable response categories are acceptance data; they cannot substitute for a verified measure of learning gains or demonstrate the effectiveness of independent online use.

Limitations

The study has several reporting and design limitations. It involved one school, a short implementation, and only five stages of a longer development framework. The original abstract and implementation account disagree on the trial class. Although the achievement counts establish a sample of 30 for the test table, the response denominator and the identities associated with expert rating rows are unclear. The response percentages leave 10% unaccounted for, and the source's ideal-midpoint formula requires verification.

The source does not report a pretest, a comparison group, individual test scores, the numerical KKM, item-level outcomes, instrument reliability, or delayed testing. Its knowledge test therefore supports a descriptive account of achievement after implementation, rather than a causal effectiveness claim. Students' positive reactions do not independently establish learning gains. Future research should resolve the reporting gaps and test the revised product with a stronger design before recommending broad implementation on the basis of effectiveness.

CONCLUSION AND RECOMMENDATIONS

The project produced a six-page excretory system masterybooklet through five stages: information gathering, planning, initial development, a preliminary field trial, and revision. The

product combined exploration through anatomical coloring, a simple practical representation, and reflective journaling. The reported mean feasibility ratings were 93.75% for content and 94% for media. Of the 30 students in the achievement table, five scored 75–83, twenty scored 84–92, and five scored 93–100. The source reported that all students met the school's minimum mastery criterion.

Student responses were reported as 82% very positive and 8% positive, although the remaining 10% was not explained. Revisions replaced glitter with sand and simplified instructions. These findings support the feasibility of the resource and indicate favorable achievement after use. They do not establish that the booklet caused an improvement, because comparable baseline and control data were unavailable.

The revised resource warrants further development and evaluation. The author should first verify the trial class, expert-rating identities, response denominator and percentages, numerical mastery criterion, scoring formula, and meeting duration. Subsequent trials should use a clearly specified knowledge test, pretest and posttest measurements, a comparison condition, and delayed assessment where possible. The practical analogy should be accompanied by discussion of its biological limits, and the journal should be assessed for explanation quality. Further stages of development can then evaluate the final version in additional classes and schools.

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