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Analyzing Spatial Ability Outcomes and Students' Responses of E-Module Inquiry Learning Integrated Virtual Laboratory (IL-VIL) on Human Cardiovascular Concept

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Abstract: The human cardiovascular system presents challenges for students due to its abstract and complex nature. Spatial ability plays a crucial role in understanding the 3D structures and dynamic processes within the system. Integrating e-modules with virtual laboratories offers a promising method to enhance students' visualization and comprehension of these abstract concepts. This research aims to analyze the spatial ability outcome and student's responses of E-Module Il VIL in Human Cardiovascular System. A descriptive quantitative approach was used, utilizing surveys, observations to gather data on students' experiences and the quesionary test of spatial abilities following their use of the E-Module IL-VIL in Human Cardiovascular System concept. The research sample consisted of 31 students in Surakarta City participated in the learning process using thee E-Module IL-VIL. The results indicated significant improvements in students' spatial abilities, particularly 28.83% improvement in mental rotation, 35.89% in spatial orientation, and 19.74 in spatial visualization. A total of 96.8% of students agreed that the IL-VIL accibility, engaging, flexible, and beneficial, while only 3.2% disagreed. These findings demonstrate the effectiveness of E-Module IL-VIL as an educational tool for enhancing students' spatial ability and comprehension of complex scientific subjects.

Keywords: E-Module; human cardiovascular; inquiry learning; spatial ability; virtual laboratory

Introduction

The human cardiovascular system, a key topic in science education, presents unique challenges due to its abstract and complex nature. Concepts such as the structure and function of the heart, blood vessels, and blood circulation are difficult for students to visualize and understand without direct experience. This often leads to misconceptions, such as confusion about the direction of blood flow or the roles of the pulmonary and systemic circuits, which in turn contributes to lower academic achievement (Barak et al., 2015; Berkowitz & Stern, 2018; Widiana et al., 2024).

Howard Gardner's theory of multiple intelligences highlights the need to accommodate different types of intelligence, particularly in subjects like cardiovascular education that require both logical reasoning and spatial visualization. For instance, spatial ability is critical in helping students mentally manipulate and understand the 3D structure of the heart and the pathways of blood circulation. Research suggests that fostering spatial intelligence through visual aids, such as diagrams, 3D models, and virtual reality, can significantly improve students' comprehension of abstract scientific concepts (Chen et al., 2020; Clemenson et al., 2020; Gardner, 2011)

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Spatial ability is correlated to learning outcomes in complex subjects like the human cardiovascular system because it facilitates students' capacity to visualize and manipulate abstract concepts. In subjects involving intricate structures and dynamic processes, such as blood flow or the heart's anatomy, spatial skills help students mentally represent and rotate 3D models, thereby enhancing comprehension. This correlation is observed particularly in science education, where spatial visualization allows for better interpretation of diagrams, models, and simulations (Badmus & Jita, 2022; Chen et al., 2020).

Spatial ability is defined as the capacity to generate, retain, retrieve, and transform well-structured visual images. This skill encompasses various dimensions, including spatial perception (understanding spatial relationships with respect to the body's orientation), spatial visualization (the ability to mentally manipulate objects), and mental rotation (the capacity to rotate 2D or 3D objects in the mind). Each of these dimensions contributes to the broader understanding of spatial tasks, such as understanding the spatial orientation of the heart or the pathways of blood circulation (Chen et al., 2020; Clemenson et al., 2020).

To effectively implement spatial ability in educational contexts, teachers can incorporate 3D models, interactive simulations, and virtual laboratories that engage students in hands-on learning. These tools allow students to practice manipulating visual representations, which helps them internalize abstract concepts. By integrating activities that focus on spatial reasoning—such as using 3D diagrams, models, or virtual environments—students can better grasp the spatial dimensions of scientific topics, leading to improved comprehension and performance (Achachagua & Chinchay, 2022; Chen et al., 2020; Fajriyanti & Sayekti, 2022)

Virtual laboratories are closely correlated with the development of spatial ability, particularly in learning complex subjects like the human cardiovascular system. This correlation arises because virtual labs provide interactive, 3D simulations that engage students in visualizing and manipulating abstract scientific concepts. Through these virtual environments, students can explore spatial relationships within the cardiovascular system, enhancing their spatial reasoning and overall comprehension of the material (Buchori et al., 2023; Sriadhi et al., 2022; Warouw et al., 2024)

Virtual laboratory is defined as a digital environment where users can conduct simulated experiments and interact with scientific phenomena without the constraints of a physical lab. These simulations allow students to test hypotheses, observe real-time feedback, and experiment with variables, mimicking the hands-on learning of a traditional lab. To implement virtual laboratories effectively in education, they should be integrated into inquiry-based learning activities, where students can actively engage with the material. By allowing students to visualize the dynamics of blood flow or heart function, for example, virtual labs can make abstract concepts more tangible and understandable. Educators can enhance this experience by incorporating assessments and tasks that require students to apply their spatial reasoning skills to interpret and manipulate these virtual models (Buchori et al., 2023; Laricheva & Ilikchyan, 2023; Sriadhi et al., 2022)

E-modules integrated with virtual laboratories create a more comprehensive and interactive learning environment for students, particularly when dealing with complex subjects like the human cardiovascular system. The integration of e-modules and virtual labs allows for a seamless combination of theoretical instruction and hands-on, experiential learning. This enhances students' ability to connect abstract concepts with real-world applications, which is crucial for improving their understanding and retention of difficult scientific material (Zakiyah & Dwiningsih, 2022).

The potential for integrating e-modules with virtual labs lies in the ability of e-modules to provide structured learning content, assessments, and guided instructions, while virtual labs offer dynamic, interactive simulations. This combination allows students to move from passive learning (through reading or video) to active participation in scientific processes, thus engaging multiple intelligences, such as spatial, logical-mathematical, and kinesthetic (Williams et al., 2019; Yulando et al., 2019)

The primary benefits of integrating e-modules and virtual laboratories include greater flexibility in learning, increased student engagement, and enhanced understanding of complex topics through practical application. E-modules provide on-demand access to instructional content, allowing students to learn at their own pace, while virtual labs offer the opportunity to experiment with theoretical knowledge in a controlled, risk-free environment (Utami et al., 2022; Yulando et al., 2019).

To integrate e-modules effectively, educators can embed virtual laboratory activities directly within the digital lessons. This can be done by including links to simulations, interactive tasks, and reflective exercises within the e-module structure, ensuring that students apply the theoretical concepts they learn in a practical context. Moreover, assessments within e-modules can be designed to evaluate not only content knowledge but also the application of spatial reasoning and problem-solving skills developed through virtual lab activities (Williams et al., 2019; Yulando et al., 2019).

Given these findings, there is a growing need to develop and integrate virtual laboratory tools into science curricula, particularly in areas where students struggle with spatial visualization. In the context of human cardiovascular systems, a virtual laboratory can provide students with the opportunity to explore and manipulate models of the heart, blood vessels, and circulatory processes in a way that fosters deeper understanding and retention. Through inquiry-based learning approaches, students can be encouraged to actively investigate how these systems work, making the learning experience both interactive and student-centered (Twizeyimana et al., 2024).

Therefore, the development of an Inquiry Learning Integrated Virtual Laboratory (IL-VIL) focused on the human cardiovascular concept represents a promising approach to improving students' spatial abilities and enhancing their understanding of abstract science topics. This study aims to design and implement an e-module that integrates virtual laboratory activities with inquiry-based learning strategies, allowing students to interactively and engagingly explore the human cardiovascular system. In doing so, the research seeks to address the limitations of traditional science instruction and provide a more effective pathway for students to master abstract concepts through enhanced spatial visualization.

Method

The study involved 31 students who participated in the learning process using E-Module IL VIL in Human Cardiovascular Topic and observer overseeing the activities were also included to provide observational data. Data was collected through survey, observation, and interview to gather student's responses about their experiences from learning activities using e-module IL VIL in Human Cardiovascular Topic. Data processing utilized descriptive quantitative methodologies to derive significant insights from the provided data. Quantitative analysis was carried out with descriptive statistics to summarize the survey and assessment data. Each question was statistically represented, with table showing percentage distribution of responses. Descriptive statistical methods, including editing, coding, categorizing, and tabulating questionnaire items, were employed for data analysis.

Result and Discussion

The E-Module IL VIL in Human Cardiovascular Topic provides student interactive learning and visualization of bloods, organs, and mechanism of human cardiovascular topic through systematic activity using virtual laboratory. Its also contain assessment for learning to evaluate the student understanding level and feedback to ensure student receive reflection in the learning objective. The E Modul IL VIL was validated by multimedia, science learning plan, and cardiovascular topict expert to ensure its educational effectiveness and reliablity are suitable in learning objectives. After the expert validity, the E Modul IL VIL was tested on small scale of student to ensure its feasbility.

Implementation of E-Module IL VIL in Human Cardiovascular System

The learning process using E-Modul IL VIL Human Cardiovascular topic involves a structured student activity thorugh inquiry stages, to ensures student recive comprehensive understanding about the topic. Its began with an orientation about the activity of heartbeat by using video and student demontration on their body. This stages invlove student asimilation process on identification of phenomenon and their prior knowledge. The process will derected student in couriousity and awarness in learning process to dig more information through reasoning thinking (Münzer & Zadeh, 2016).

After conducting identification of phenomenon, student makes a problem question as their couriousity process. It help student construct the learning objective thought the learning activity using virtual laboratory. This stages involve asimilasion between identification result and understanding of their own kowledge (Lazonder & Harmsen, 2016). Table.1 is the main student problem formulation result.

Tabel 1. Student problem formulation result

Item	Problem formulation by student
Item 1	What is the main organ of human cardiovascular?
Item 2	What is the component of blood?
Item 3	How the human cardiovascular system works?
Item 4	What is the relation between human activity and cardiovascular system?

Table 1. shows of problem formulation by student will be the objective in learning process to achieve. This problem formulation show how student understand the orientation through their prior understanding. Problem formulation "What is the main organs of human cardiovascular?" directed by the student identification of heartbeat that works in their body, but they yet knows the part of organs are participate in that phenomenon. In this case student facing abstract concept, becaouse they doesn't see the actual part of body that works to make the heart beat. Moreover its creat couriousity through abstraction understanding.

Second stage of inquiry learning is formulating hypotheses following the problem formulation. In this stage, students are encouraged to propose tentative answers or explanations based on their prior knowledge and the identified phenomena. For example, students may hypothesize that the heart is the central organ responsible for pumping blood or that increased physical activity elevates the heart rate due to greater oxygen demand by the muscles. These hypotheses help guide their exploration during the virtual laboratory activities, directing them toward specific elements of the cardiovascular system that they need to observe and analyze (Barak et al., 2015). The poblem question in Tabel 1, direct the student activity in inquiry process. The hypothesis formulation by student shows in Tabel 2.

Table 2. Student hypotesis formulation result

Item	hypothesis formulation by student
Item 1	The human organs in cardiovascular system is heart, lungs, tubes, and blood
Item 2	The componenet of bloads is oxygen and water
Item 3	Pumped by heart
Item 4	Heart is important to human life

In the inquiry learning process, students are expected to formulate hypotheses in their own words based on the problem questions they created earlier. This stage not only helps to measure their prior knowledge but also serves as a bridge between their existing understanding and the new information they will gain through experimentation. The hypotheses generated by students reflect their basic grasp of the cardiovascular system, even if not entirely accurate, and provide a foundation for deeper exploration (Cole et al., 2022; Lazonder & Harmsen, 2016; Twizeyimana et al., 2024).

For instance, as shown in Table 2, students formulated hypotheses like "The human organs in cardiovascular system are heart, lungs, tubes, and blood," which indicates their attempt to list the components they believe are part of the system. Another example is "The component of blood is oxygen and water," reflecting a partial understanding of blood composition, which will later be clarified and expanded through learning activities (Fajriyanti & Sayekti, 2022).

Third stages is student exploration thorough E-Module IL VIL in Human Cardiovascular System. In this stage, students engage in active exploration using the E-Module IL-VIL, specifically designed to help them investigate the human cardiovascular system. This stage emphasizes hands-on, inquiry-based learning where students delve into the virtual laboratory provided by the module. The module includes interactive simulations and models of the cardiovascular system, allowing students to visualize and manipulate various components such as the heart, blood vessels, and blood flow (Clemenson et al., 2020).

Through this exploration, students are guided to experiment and test the hypotheses they formulated in the previous stage (de Back et al., 2020). For instance, if a student hypothesized that "the heart is responsible for pumping blood," they can now interact with the virtual model of the heart to observe how it contracts, how blood circulates through arteries and veins, and how oxygenated and deoxygenated blood are distributed throughout the body. The example of virtual laboratory shows in Figure 1.

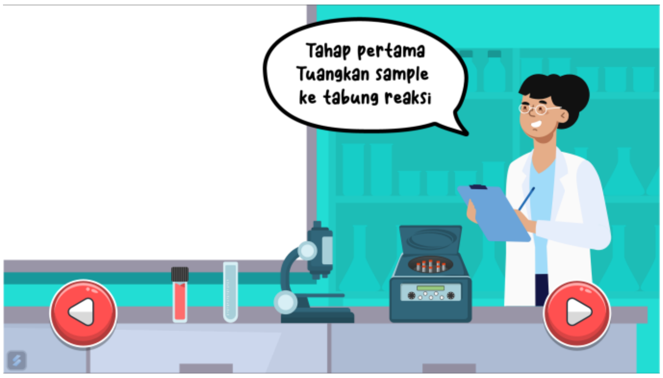
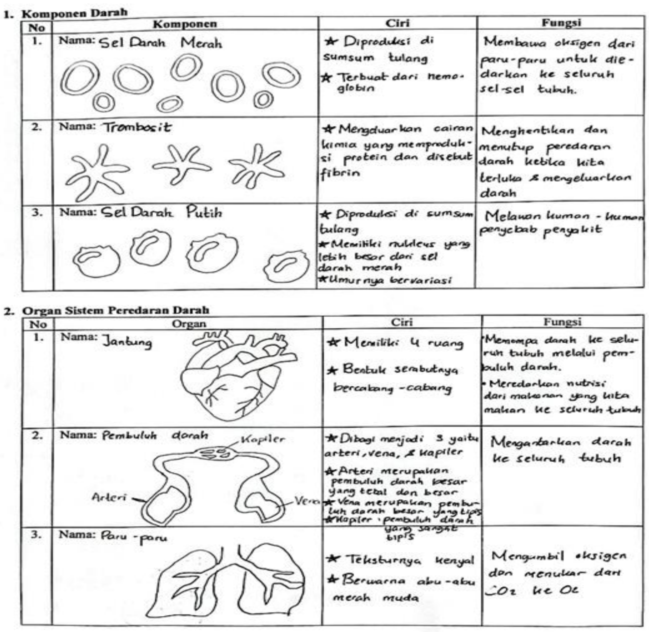


Figure 1. Virtual laboratory for exploring component of blood

The virtual lab provides opportunities for students to conduct experiments that would be difficult to replicate in a traditional classroom setting (Buchori et al., 2023; Clemenson et al., 2020). For example, students can simulate changes in heart rate under different conditions, such as during exercise or rest, and observe how the cardiovascular system responds. They can also explore the composition of blood, including how red and white blood cells, platelets, and plasma contribute to the system's overall functioning. Key Activities in the Exploration Stage, consist of three main topics. The first activity is virtual Dissection of the Heart. In this activity students can virtually "dissect" the heart, exploring its internal structures such as the atria, ventricles, valves, and arteries. This allows student to gain a spatial understanding of how blood flows through the heart. The second activity is simulating Blood Circulation. This activity enables students to observe blood circulation, including how oxygenated blood is transported from the lungs to the rest of the body, and how deoxygenated blood returns to the heart and lungs for oxygen replenish men. The third activity is Testing Hypotheses, this activity allows students manipulate different variables (such as exercise intensity or blood volume) to see how these changes affect heart rate and blood pressure, helping them confirm or revise their initial hypotheses (Valfa et al., 2023; Widiana et al., 2024).

Stage fourth data collection, students engage in data collection through virtual simulations provided by the E-Module IL-VIL on the Human Cardiovascular System. This stage allows students to manipulate and explore virtual models of the heart, blood vessels, and circulatory processes in real-time, observing the impact of various conditions such as exercise, rest, and changes in blood volume on the system. The use of a virtual laboratory is essential for enabling students to explore abstract concepts that are difficult to observe in real-life classroom settings. For instance, students can virtually dissect the heart or observe the blood flow in arteries and veins, which fosters a deeper understanding of the cardiovascular processes at work (Achachagua & Chinchay, 2022; Münzer & Zadeh, 2016).

Throughout this experimentation phase, students collect data, such as heart rate, blood flow velocity, and oxygen saturation levels under different conditions. These virtual simulations allow students to test their hypotheses, compare expected outcomes with observed data, and make inferences based on the results (Clemenson et al., 2020). The result of data collected by student shows in figure 2.



1. Komponen Darah

No	Komponen	Ciri	Fungsi
1.	Nama: Sel Darah Merah	★ Diproduksi di sumsum tulang ★ Terbuat dari hemoglobin	Membawa oksigen dari paru-paru untuk diedarkan ke seluruh sel-sel tubuh.
2.	Nama: Trombosit	★ Mengeluarkan cairan kimia yang memproduksi protein dan disebut fibrin	Menghentikan dan menutup peredaran darah ketika kita terluka & mengeluarkan darah
3.	Nama: Sel Darah Putih	★ Diproduksi di sumsum tulang ★ Memiliki nukleus yang lebih besar dari sel darah merah ★ Umurnya bervariasi	Melawan kuman-kuman penyebab penyakit

2. Organ Sistem Peredaran Darah

No	Organ	Ciri	Fungsi
1.	Nama: Jantung	★ Memiliki 4 ruang ★ Bentuk serabutnya bercabang-cabang	• Memompa darah ke seluruh tubuh melalui pembuluh darah. • Meredarkan nutrisi dari makanan yang kita makan ke seluruh tubuh
2.	Nama: Pembuluh darah (Kapiler, Arteri, Vena)	★ Dibagi menjadi 3 yaitu arteri, vena, & kapiler ★ Arteri merupakan pembuluh darah besar yang tebal dan besar ★ Vena merupakan pembuluh darah besar yang tipis ★ Kapiler: pembuluh darah yang sangat tipis	Mengantarkan darah ke seluruh tubuh
3.	Nama: Paru-paru	★ Teksturnya kenyal ★ Berwarna abu-abu merah muda	Mengambil oksigen dan menukar dari CO2 ke O2

Figure 2. Data gathered by student through virtual laboratory

Stages fift data analysis, students are tasked with comparing the virtual experiments' results with their initial hypotheses. For example, they might conclude that their hypothesis about increased heart rate during physical activity was correct, as their observations showed a significant rise in heart rate and blood flow. This stage involves critical thinking and reasoning, as students are required to explain their findings in the context of human cardiovascular functioning and link their observations back to the theoretical knowledge they acquired earlier (Chen et al., 2020).

Through this process, students refine their understanding of how the cardiovascular system works, recognizing the roles of the heart, blood, and blood vessels in maintaining bodily functions. The virtual environment aids in reinforcing abstract concepts, such as how oxygenated and deoxygenated blood are circulated, by providing a visual and interactive representation of the processes.

The final stage of inquiry-based learning involves drawing conclusions from the analyzed data. Students synthesize the information they gathered from the virtual laboratory and the hypotheses they tested to construct new knowledge about the human cardiovascular system. This reflective process solidifies their understanding, allowing them to articulate the relationships between different components of the system, such as the heart, lungs, and blood vessels, and how these components work together to sustain life (Lazonder & Harmsen, 2016).

Additionally, students can relate the cardiovascular system's functioning to real-world applications, such as understanding how lifestyle factors (e.g., exercise, diet) influence heart health. This comprehensive knowledge construction, supported by the structured inquiry stages and virtual laboratory interaction, ensures that students gain a holistic understanding of the human cardiovascular system (Lazonder & Harmsen, 2016).

The structured approach of the E-Module IL-VIL, integrating inquiry-based learning with virtual laboratory experiences, enhances students' spatial reasoning and scientific thinking. By guiding students through each phase of inquiry—starting from observation and hypothesis generation, to experimentation and conclusion—they develop critical thinking, problem-solving, and reasoning skills (Anjarsari & Suyatna, 2023). Furthermore, the interactive nature of the virtual lab enables students to visualize abstract concepts, significantly improving their spatial understanding of complex systems like the cardiovascular system (Chen et al., 2020; Clemenson et al., 2020; Sriadhi et al., 2022).

Structured inquiry learning process, combined with the virtual laboratory, facilitates a deeper and more comprehensive understanding of the human cardiovascular system. It not only supports the development of students' spatial abilities but also fosters curiosity and engagement, ultimately contributing to better learning outcomes in science education.

Student spatial ability outcome

Spatial ability refers to the capacity to visualize, manipulate, and mentally transform objects and spaces, a skill that plays a critical role in various learning domains. In this research spatial ability outcome determinized using one group pretest and posttest. The instrument are 12 items following the domain of spatial abilit by Ramful et al. (2017), shows in Table 3.

Tabel 3. Spatial ability dimensions

Dimension	Description
Mental Rotation	Ability to understanding how the structure of an object changes from various perspectives
Spatial Orientation	ability to comprehend and determine the position of objects in space relative to one's own position or to other objects
Spatial Visualization	ability to manipulate, analyze, and mentally transform visual representations or spatial patterns

(Ramful et al., 2017)

The result of the student spatial ability outcome was analyzed by comparing the pre-test and post-test scores to determine the difference in student understanding of abstract objects in the human cardiovascular system. This comparison allowed for an assessment of how effectively the inquiry-based learning and virtual laboratory (IL-VIL) approach improved students' ability to visualize and manipulate spatial information related to the cardiovascular system. The result of student spatial ability shows in Tabel 4.

Tabel 4. Student spatial ability result

Dimension	Pre-Test (%)	Post Test (%)
Mental Rotation	50.20	79.03
Spatial Orientation	41.73	77.62
Spatial Visualization	71.57	91.13
Average	54.50	82.59

According to Table 4, we can make the graph for each aspect. Figure 3 shows the graph of the average percentage of students spatial ability outcome.

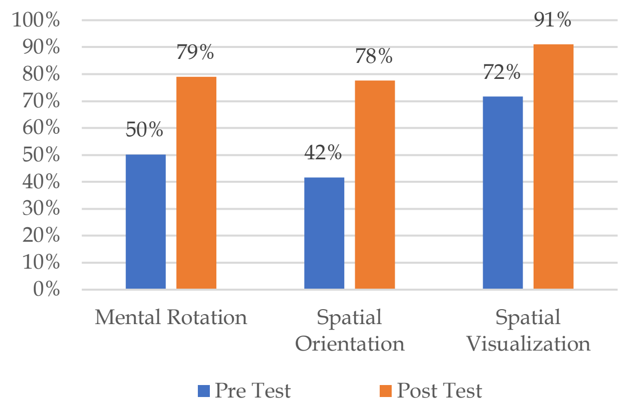


Figure 3. Graph of the percentage of student spatial ability pretest and posttest outcome

The pre-test average for mental rotation was 50.20%, while the post-test average rose to 79.03%, indicating a 28.83% improvement. This suggests that students significantly enhanced their ability to mentally rotate and understand different perspectives of the cardiovascular structures, such as visualizing the heart from different angles or understanding how blood circulates through the heart and body.

Spatial orientation, which reflects the ability to understand the relative position of objects in space, showed the most pronounced improvement. The pre-test average of 41.73% increased to 77.62% in the post-test, representing a 35.89% rise. This improvement highlights the effectiveness of the virtual laboratory in helping students better comprehend the spatial relationships between organs like the heart, lungs, and blood vessels within the cardiovascular system.

In this case, the use of a virtual laboratory provides an ideal environment for fostering these spatial skills (Rahmi et al., 2022). By allowing students to interact with 3D models of organs like the heart, lungs, and blood vessels, they are engaging in activities that improve their spatial visualization—the ability to mentally manipulate images of objects and perceive their spatial relationships from different perspectives(Valfa et al., 2023). Research has shown that practice in visualizing and rotating objects in 3D space significantly enhances spatial ability, a process that is facilitated by tools like virtual labs, which offer dynamic, hands-on experiences (Badmus & Jita, 2022; Chen et al., 2020).

Spatial visualization, which involves mentally manipulating and transforming visual representations, was the strongest skill in both the pre-test and post-test. Students' pre-test performance averaged 71.57%, and after the intervention, this increased to 91.31%, marking a 19.74% improvement. This outcome indicates that the E-Module IL-VIL effectively supported students in visualizing abstract concepts, such as how blood flows through the heart chambers or how oxygen and carbon dioxide are exchanged in the lungs. The E-Module IL-VIL likely provided a combination of explanatory text and visual diagrams or animations, helping students encode and retain information more effectively. The visual component, in particular, aids in constructing mental models of how anatomical systems function, making abstract processes like circulation and respiration easier to understand. This dual representation fosters stronger cognitive connections, leading to the 19.75 % improvement in spatial visualization skills (Badmus & Jita, 2022; Buckley et al., 2019; Chen et al., 2020).

The results of this study indicate that integrating virtual laboratories and inquiry-based learning into the curriculum, as done through the E-Module IL-VIL, can significantly enhance students' spatial abilities. By providing interactive and visually rich learning experiences, students can better understand complex systems and concepts that are otherwise challenging to grasp. This improvement in spatial abilities is crucial not only for mastering topics like the human cardiovascular system but also for future success in STEM-related fields, where spatial reasoning plays a key role in problem-solving and conceptual understanding.

Student respons using E-Module IL VIL

In product development, researchers need responses from users regarding the product being developed. In this context, the users of the E-Module IL VIL are students which participated in this research. The responses were gathered through questionnaire. Questionnaire of student's responses of E-Module IL VIL in Human Cardiovascular System Concept was reviewed on five aspects, ease of use, interest, flexibility, benefit, and relevance (Zulirfan et al., 2021). This questionnaire use likert scale, 1 to 4 (strongly disagree to strongly agree). Table 5 shows the items of questionnaire to gather the data of students' responses of E-Module IL VIL in Human Cardiovascular System Concept.

Table 5. Aspect of student respons surveys

Aspect	Items
Acesibility	E-Module IL VIL in Human Cardiovascular System Concept is easy to understand
Interest	Enjoy learning using E-Module IL VIL in Human Cardiovascular System Concept
Flexibility	E-Module IL VIL in Human Cardiovascular System Concept are acceseble enywhere and anytime
Benefits	E-Module IL VIL in Human Cardiovascular System Concept are facilitating abstract concept
Relevance	Content and component E-Module IL VIL in Human Cardiovascular System Concept are relevant to learning objective

Accessibility means how simple and intuitive a product is to access and use (Chaker et al., 2021; Qu et al., 2022). Interest means the level of curiosity, engagement, or attention that a person has towards a product (Setiawan, 2021). Flexibility means the ability of a product to adapt to different situations, needs, or user preferences (Ejaz, 2021). Benefits means the positive outcome or advantage gained from using a product (McNally et al., 2010). Relevance means relatedness or the degree to which something is closely connected or applicable to a specific context, situation, or individual's needs and interests (Cross, 2021). Each student which participated in this research fill the questionnaire according to their feeling after using E-Module IL VIL in Human Cardiovascular System Concept. The result of student respons shows in Tabel 6.

Table 6. Student respons of E Modul IL VIL

Aspects	Percentage of each aspect (%)			
	Strongly sagree	Agree	Disagree	Strongly disagree
Acesibility	29.60	68.50	1.90	0.00
Interest	33.30	66.70	0.00	0.00
Flexibility	31.50	66.70	1.90	0.00
Benefits	38.90	61.10	0.00	0.00
Relevance	35.20	63.00	1.90	0.00
Average	33.30	65.70	0.90	0.00

According to Table 2, we can make the graph for each aspect. Figure 4 shows the graph of the average percentage of students' responses regarding E-Module IL VIL in Human Cardiovascular System Concept.

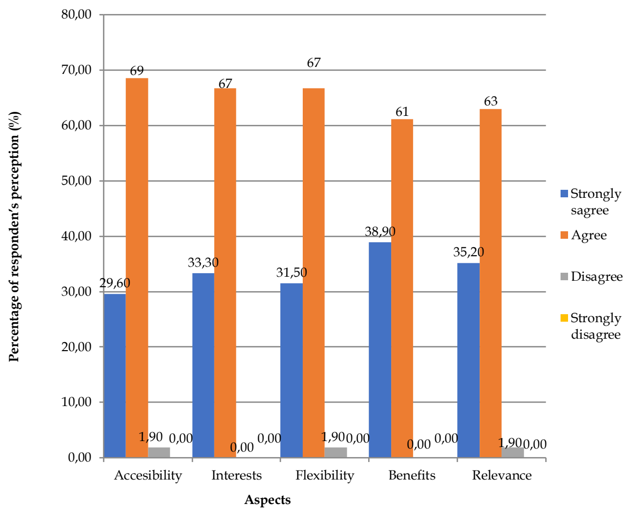


Figure 4. Graph of the average percentage of student responses from each aspect

Accessibility refers to the ease with which students were able to access and navigate the E Module. As illustrated in Figure 3, a combined total of 98.10% of students either agreed (69%) or strongly agreed (29.60%) that the module was easy to use and understand. This high level of accessibility is crucial in digital learning environments, as it enables students to focus on the content rather than the mechanics of the platform itself. According to Qu et al. (2022), an intuitive and accessible system reduces cognitive load, allowing learners to engage more effectively with the material. The minimal disagreement (1.90%) suggests that almost all users found the module approachable, which is a key factor in promoting widespread adoption of e-learning tools.

The module's ability to maintain students' interest is another critical aspect of its success. Figure 3 shows that

100% of students either agreed or strongly agreed that they enjoyed using the module. Specifically, 67% of respondents agreed, while 33.30% strongly agreed. This suggests that the module was not only informative but also engaging. Interest is a vital component in sustaining attention and motivation during the learning process, as noted by Setiawan (2021). The absence of negative responses in this category reinforces the idea that the module successfully captured students' curiosity and maintained engagement throughout the learning process.

Flexibility, or the ability of the module to accommodate different learning styles and schedules, was also highly rated. A total of 98.50% of students either agreed (67%) or strongly agreed (31.50%) that the module could be accessed anywhere and at any time, which reflects the flexibility and convenience of the digital format. The ability to learn at one's own pace and on one's own schedule is a major advantage of e-learning platforms, as highlighted by Ejaz (2021). A small percentage (1.90%) expressed dissatisfaction with this aspect, suggesting that while the module was generally perceived as flexible, there may have been occasional issues related to availability or access in specific contexts, such as technical difficulties or limited internet access.

The benefits of the e-module, particularly in terms of facilitating the understanding of complex cardiovascular concepts, were well-received by students. A total of 63% agreed, and 38.90% strongly agreed, indicating that the vast majority of respondents found the module to be beneficial to their learning. The fact that 0% disagreed or strongly disagreed underscores the effectiveness of the module in helping students grasp abstract concepts. As McNally et al. (2010) explain, the perceived benefits of an educational tool directly influence its impact on learning outcomes. By providing clear explanations and interactive elements, the module appears to have enhanced the students' comprehension of the Human Cardiovascular System.

Relevance, defined as the alignment between the module’s content and the students' learning objectives, was another area where the module performed well. A total of 98.2% of students either agreed (63%) or strongly agreed (35.20%) that the content was relevant to their educational goals. Relevance is a critical factor in learning, as students are more likely to engage with material that is directly applicable to their studies and future careers (Cross, 2021). The minimal disagreement (1.90%) suggests that nearly all students found the module's content to be pertinent and closely related to their academic objectives in the study of the cardiovascular system.

The study's findings demonstrate that the E-Module IL VIL on the Human Cardiovascular System Concept was highly effective across all measured aspects: accessibility, interest, flexibility, benefits, and relevance. The overwhelmingly positive student feedback, with the majority agreeing or strongly agreeing in all categories, suggests that the module successfully met its educational objectives and was well-received by users.

The high accessibility ensured ease of use, allowing students to focus on learning rather than struggling with the platform. The module’s ability to capture and maintain interest contributed to an engaging learning experience, which is essential for deep learning and retention. Its flexibility allowed students to tailor their learning experience to fit their schedules and preferences, making it a highly convenient tool. The perceived benefits of the module reflect its success in helping students comprehend complex material, and its relevance ensured that students saw the module as directly applicable to their academic and professional goals.

Given these results, it is recommended that the E-Module IL VIL be integrated into the broader curriculum for teaching the Human Cardiovascular System, with potential for adaptation to other subject areas. Future research could focus on the long-term retention of knowledge gained through the module, as well as expanding its application to different disciplines or more diverse student populations.

Conclusion

The E-Module IL-VIL facilitated significant improvements in students' spatial abilities, including mental rotation, spatial orientation, and visualization. The average improvement in mental rotation was 28.83%, spatial orientation saw a 35.89% increase, and spatial visualization improved by 19.74%. These data confirm the module’s success in enhancing students' capacity to grasp abstract cardiovascular concepts. Feedback from students indicated a positive reception of the IL-VIL module. A total of 96.80% of the participants either agreed or strongly agreed that the module was easy to use, engaging, flexible, and beneficial to their learning process. Only 3.20% of the students expressed disagreement. The structured inquiry-based approach, combined with interactive virtual lab simulations, enabled students to actively explore and manipulate 3D models of the cardiovascular system, significantly boosting their comprehension and retention of the subject matter.

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No potential conflict of interest was reported by the authors.

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