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PAPER

# Virtual Reality Laboratory Laws of Inheritance Enhancing Students' Technological Literacy

**M Iqbal Najib Fahmi, Siti Zubaidah, Susriyati Mahanal, Deny Setiawan(✉)**

Universitas Negeri Malang, East Java, Indonesia

setiawan.fmipa@um.ac.id

**ABSTRACT**

The lack of introduction and habituation to using interactive media in learning can cause students to have low technological literacy. Virtual reality technology can help us learn the law of inheritance of traits. This research aims to develop learning media using virtual reality technology that is valid, practical, and effective in improving students' technological literacy. The stages we carried out refer to the development model of William W. Lee and Diana L. Owens. Media feasibility is based on the results of material validation, media, small group trials, and media implementation to high school students. Technological literacy was measured using a questionnaire and observation sheet. The subjects consisted of 127 students taking the material on the law of Inheritance of Traits. The results of the study obtained a material validation percentage of 100% (very valid), media validation of 89% (valid), and small group trials of 90% (very practical). The results of the virtual reality laboratory effectiveness test show the significance value of the ANCOVA test of 0.000 is smaller than $\alpha$ ($\alpha = 0.05$). These results indicate that the developed media are valid, practical, and effective for improving students' technological literacy in learning the law of Inheritance of Traits.

**KEYWORDS**

laboratory virtual, VR technology, technological literacy

## 1 INTRODUCTION

Learning in schools must prepare students to have the skills needed in the 21st Century. The 21st Century is characterized by the rapid application of technology and information in various sectors of life. To deal with this situation, students need to have technological literacy, one of the 21st century skills framework. Huggins et al. [1] stated that technological literacy is using, accessing, and evaluating technology to obtain information. Students who have good technological literacy will have a positive impact on solving social problems in the surrounding environment [2][3][4]. Greenstein [5] states that technological literacy can be known from several indicators. These indicators include basic knowledge of computer technology, ability to use digital

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and multimedia products, technical ability to use technology, ability to create designs, ability to choose and use technology, and knowledge of laws and ethics of technology use. Literacy is classified into five levels: exemplary, proficient, basic, and novice.

Technological literacy is very important for everyone today [6][7]. However, various research results show that technological literacy in various regions of Indonesia still needs to improve. For example, the survey results of the Indonesian Internet Service Providers Association (APJII) [8] concluded that most students still need to improve in using technology for literacy or learning. Astuti et al. [9] also concluded that 233 high school students had an average technological literacy in the basic category. The low level of technological literacy in students is caused by the need for more introduction and habituation to the use of technology [10][11]. One way that can be used to develop technological literacy skills in students is through the development of computer technology-based learning media [12]. The use of computer technology-based media can empower students' understanding of basic technological knowledge, digital products, technical use, and the use of technology in everyday life [13][14][15].

If someone has high technological literacy, it is expected that they can use technology to find information from various sources [16][17] to seek further information if there are difficulties in learning the material. One of the difficult materials to learn is biology [18], especially the law of inheritance of traits [19][20]. The material of inheritance of traits is also supported by learning media; one of the media is *D. melanogaster* [21][22][23]. The media is widely used in learning in foreign countries, such as the United States, India, Italy, Brazil [24][25][26][27]. But, in Indonesia, it is still rare to use *D. melanogaster* media.

Several factors make the use of *D. melanogaster* media not optimal in Indonesia. Microscopic size, easy to mutate, the medium is often mouldy, the medium is often infested with fleas, and the lack of *D. melanogaster* cultivators are some of the difficulties experienced by teachers [28] [29]. Genetic button media is one option that can be chosen by teachers in carrying out the practicum of the law of inheritance of traits. However, the genetics button media could be more interactive and representative, making the learning process less interesting and boring for students [30]. Due to these limitations, teachers often eliminate practicum activities and only replace them with assignments. Therefore, a solution is needed to overcome these problems.

The solution the researchers chose was the development of a virtual reality laboratory on the law of inheritance of traits. Virtual reality (VR) technology is an artificial environment with displays and objects that are made to look real [31][32]. The reality presented by virtual reality technology is useful for transferring process skills such as practicum [33][34][35]. Virtual reality has been proven to improve students' technological literacy in abstract and microscopic material [36][37]. Therefore, researchers aim to develop learning media for the practicum of inheritance law in the form of virtual reality laboratories that are valid, practical, and effective in improving students' technological literacy. The study's results can be used as a reference for the development of virtual reality laboratories in biology learning, to increase student knowledge about the potential use of virtual reality, and to be used as a basis for further research, especially in genetics learning.

## 2 METHOD

To conduct this research, we used the Lee and Owen research and development model, which consists of four stages: multimedia needs assessment and analysis, multimedia instructional design, multimedia development and implementation, and evaluation. First, at the multimedia needs analysis and assessment stage, we looked for sources of discrepancies between the expected results and the actual situation. To conduct this analysis, we use needs analysis and front-end analysis. The needs analysis determines the authentic situation, desired goals, and emerging problems, while the front-end analysis determines the aspects necessary to harmonize the multimedia needs. The second stage is multimedia instructional design, where we plan to address the learning gaps. The design is made in several stages, namely the creation of (1) schedule, (2) task list of group members, (3) media specifications, (4) lesson structure, and (5) configuration control and review cycle. The media specification presents a simulation of the practicum of the law of Inheritance of Traits, which includes the use of K3 laboratories, making media, rejuvenating *D. melanogaster*, collecting *D. melanogaster*, crossing F2 *D. melanogaster*, crossing F1 *D. melanogaster*, and calculating crossing results. A simulation guidebook in the media also accompanies the virtual reality application. By utilizing core competencies, basic competencies, and learning objectives per the 2013 Biology Education Curriculum, content analysis aims to adjust the material of the law of Inheritance of Traits with virtual reality laboratory media. At this point, validity and practicality tests were also conducted. Validity is tested by involving learning material experts, educational practitioners, media experts, and students who have studied the material of the law of inheritance of traits. The development stage aims to produce products developed in the previous stage. This stage consists of (1) storyboard development, (2) media design and development, (3) evaluation and revision, (4) delivery, and (5) application of media in the learning process.

Meanwhile, at the product implementation stage, we used a quasi-experimental design with the pretest-posttest nonequivalent control group design described in Table 1.

**Table 1.** Research design

| Group | *Pre-test* | *Treatment* | *Post-test* |
|---|---|---|---|
| *Experiment* | O1 | X1 | O2 |
| *Control class 1* | O3 | X2 | O4 |
| *Control class 2* | O5 | X3 | O6 |

*Notes:* X1: media-assisted learning virtual reality laboratory, X2: genetic button-assisted learning, X3: learning with assignments without any practicum activities.

Based on Table 2, learning media was implemented in 3 classes of SMA Negeri 1 Lawang, namely MIPA 1, MIPA 2, and MIPA 4. The total number of research subjects was 127 students. The classes used as research samples were first tested for equality from the grade XI report card scores in 2021–2022. The test results show that the significance value is 0.2. This value is greater than 0.05, thus indicating that there is no difference in the initial ability of the three classes (the three classes are equivalent). Based on this, random sampling was then carried out by drawing lots. The results obtained in MIPA 1 class as the **experimental class**, namely in learning to do practicum with the help of virtual reality laboratory media, MIPA 2 class as **control class 1**, namely, in learning to do practicum with the help of genetic buttons, and MIPA 4 class as **control class 2**, namely, in learning not to do practicum activities but replace with assignments. Instruments to measure technological literacy are questionnaires and observation sheets. The assessment of students' technological literacy criteria used Greenstein's (2012) technological literacy rubric consisting of exemplary, proficient, basic, and novice levels. The pre-test and post-test results of technological literacy will be tested for Kolmogorov-Smirnov normality and Levene homogeneity first, then analyzed using analysis of covariance (Anakova) with a significance level of 5%.

**Table 2.** Technology literacy criteria

| Percentage | Validity Level |
|---|---|
| 76%–100% | *Exemplary* |
| 51%–75% | *Proficient* |
| 26%–50% | *Basic* |
| 1%–25% | *Novice* |

*Source:* Adapted from Greenstein rubric [5].

In the fourth stage, namely multimedia evaluation, the evaluation stage includes the last stage in media development. The evaluation stage is used to determine or assess product quality in the learning process, both before and after implementation. General procedures related to the evaluation stage include knowing the response or reaction (reaction), evaluating knowledge (knowledge), and evaluating media performance (performance). Analysis of students' reactions or responses to the use of learning media is concluded based on the criteria from Aka et al. [38] in Table 3.

**Table 3.** Product validity or practical criteria

| Validity Criteria | Validity Level |
|---|---|
| X = 100 | Highly valid or practical and can be used without revision |
| 80 ≥ X < 100 | Valid or practical and can be used after minor revision |
| 60 ≥ X < 80 | Less valid or practical and cannot be recommended for future usage with moderate revision |
| 40 ≥ X < 60 | Non-valid or non-practical, required great revision great, and cannot be used |
| 20 ≥ X < 40 | Highly non-valid or non-practical, should not be used and required total revision |

*Source:* Aka et al. [38].

## 3 RESULTS AND DISCUSSION

The final result of this virtual reality laboratory media development is an application teachers can use to support practical learning of the laws of Inheritance of Traits for high school students. The result of the media is a simulation of the practicum of the law of Inheritance of Traits, namely the phenomenon of Mendel's law 1. The following are the results of the media development that has been carried out:

### 3.1 The results of the development and validity of learning media

This product is a virtual reality laboratory learning media that presents a practical simulation of the law of Inheritance of Traits, especially on Mendel 1. The simulation process encourages students to conduct direct investigations to prove Mendel's law's phenomenon. The research object used is 3D modelling that resembles the model organism *D. melanogaster*. The simulation used in Mendel's Law 1 is a cross between normal *D. melanogaster* and ebony strain *D. melanogaster*. The 3D modelling made on *D. melanogaster* available in the virtual reality laboratory consists of normal male and female *D. melanogaster* and male and female ebony *D. melanogaster*. The 3D modelling display of *D. melanogaster* can be seen in Figure 1. Virtual reality in learning media is made with bright colours. The media developed is 40 MB and is equipped with an application usage guidebook (Figure 2). The 3D illustrations used have a high level of resolution, making it easier for students to make observations.

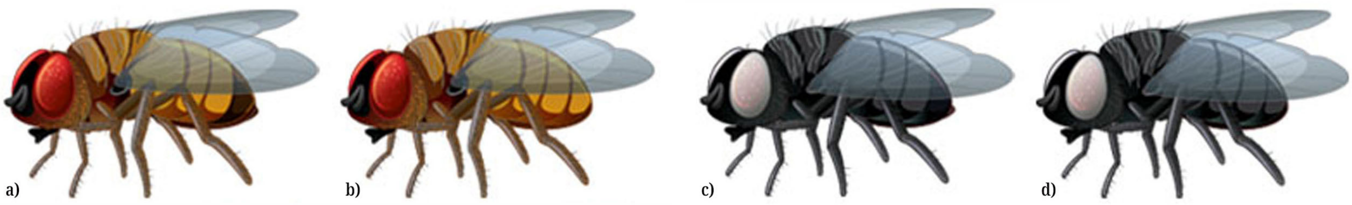
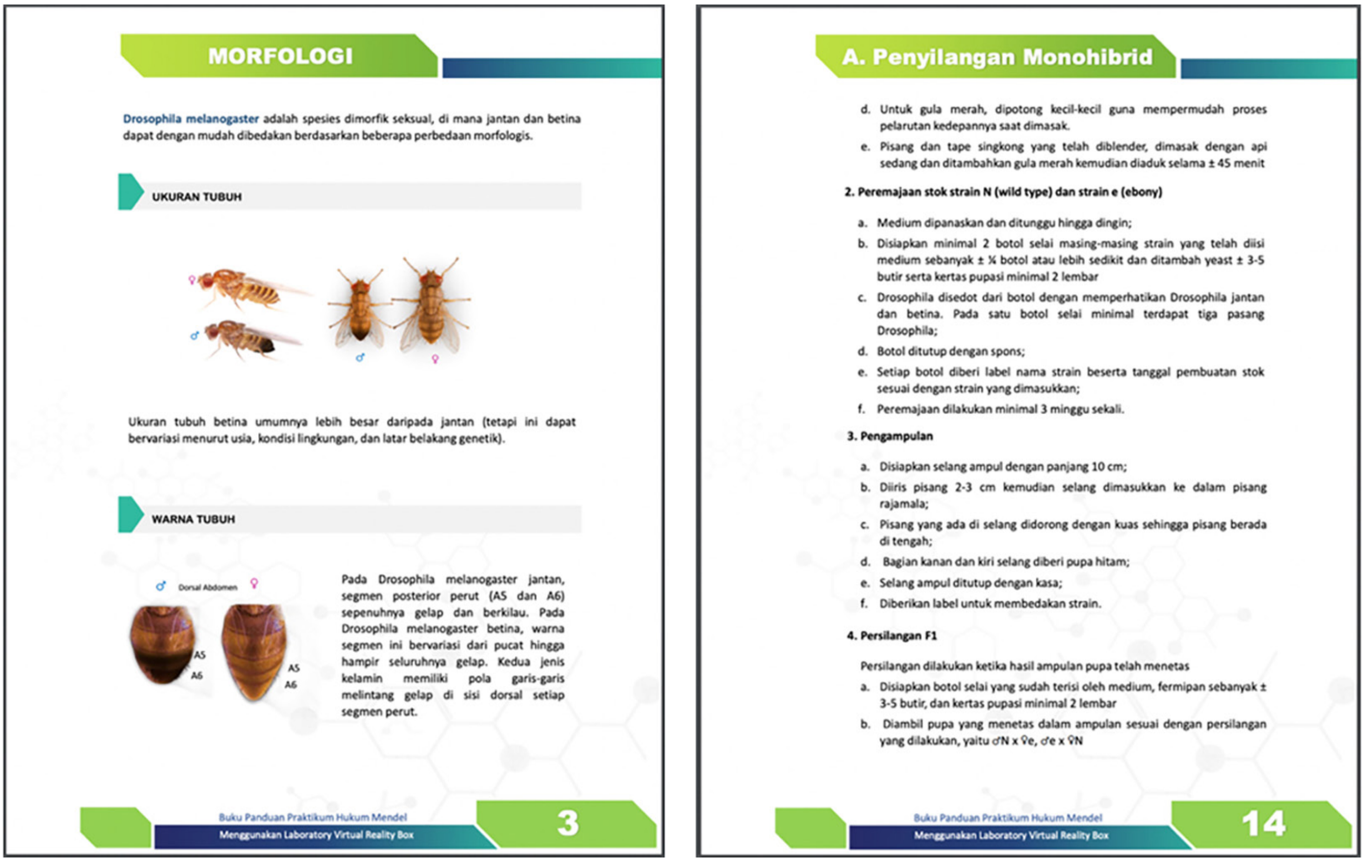



**Fig. 1.** Display of *D. melanogaster* in a virtual reality laboratory. (a) D. male normal melanogaster, (b) female normal *D. melanogaster*, (c) male ebony *D. melanogaster*, (d) female ebony *D. melanogaster*



MORFOLOGI

Drosophila melanogaster adalah spesies dimorfik seksual, di mana jantan dan betina dapat dengan mudah dibedakan berdasarkan beberapa perbedaan morfologis.

UKURAN TUBUH

♀ ♂ ♂ ♀

Ukuran tubuh betina umumnya lebih besar daripada jantan (tetapi ini dapat bervariasi menurut usia, kondisi lingkungan, dan latar belakang genetik).

WARNA TUBUH

♂ Dorsal Abdomen ♀
A5 A6 A5 A6

Pada Drosophila melanogaster jantan, segmen posterior perut (A5 dan A6) sepenuhnya gelap dan berkilau. Pada Drosophila melanogaster betina, warna segmen ini bervariasi dari pucat hingga hampir seluruhnya gelap. Kedua jenis kelamin memiliki pola garis-garis melintang gelap di sisi dorsal setiap segmen perut.

Buku Panduan Praktikum Hukum Mendel
Menggunakan Laboratory Virtual Reality Box
3

A. Penyilangan Monohibrid

d. Untuk gula merah, dipotong kecil-kecil guna mempermudah proses pelarutan kedepannya saat dimasak.
e. Pisang dan tape singkong yang telah diblender, dimasak dengan api sedang dan ditambahkan gula merah kemudian diaduk selama ± 45 menit

2. Peremajaan stok strain N (wild type) dan strain e (ebony)

a. Medium dipanaskan dan ditunggu hingga dingin;
b. Disiapkan minimal 2 botol selai masing-masing strain yang telah diisi medium sebanyak ± ¼ botol atau lebih sedikit dan ditambah yeast ± 3-5 butir serta kertas pupasi minimal 2 lembar
c. Drosophila disedot dari botol dengan memperhatikan Drosophila jantan dan betina. Pada satu botol selai minimal terdapat tiga pasang Drosophila;
d. Botol ditutup dengan spons;
e. Setiap botol diberi label nama strain beserta tanggal pembuatan stok sesuai dengan strain yang dimasukkan;
f. Peremajaan dilakukan minimal 3 minggu sekali.

3. Pengampulan

a. Disiapkan selang ampul dengan panjang 10 cm;
b. Diiris pisang 2-3 cm kemudian selang dimasukkan ke dalam pisang rajamala;
c. Pisang yang ada di selang didorong dengan kuas sehingga pisang berada di tengah;
d. Bagian kanan dan kiri selang diberi pupa hitam;
e. Selang ampul ditutup dengan kasa;
f. Diberikan label untuk membedakan strain.

4. Persilangan F1

Persilangan dilakukan ketika hasil ampulan pupa telah menetas
a. Disiapkan botol selai yang sudah terisi oleh medium, fermipan sebanyak ± 3-5 butir, dan kertas pupasi minimal 2 lembar
b. Diambil pupa yang menetas dalam ampulan sesuai dengan persilangan yang dilakukan, yaitu ♂N x ♀e, ♂e x ♀N

Buku Panduan Praktikum Hukum Mendel
Menggunakan Laboratory Virtual Reality Box
14

**Fig. 2.** Display of a virtual reality laboratory manual showing an initial explanation of *D. melanogaster* and Mendel's law of crossing procedures 1

Figure 1 shows the appearance of the model organism in conducting Mendel's law practicum in virtual reality media. The research objects used were normal male and female *D. melanogaster* and ebony male and female *D. melanogaster*. The 3D model is adjusted to the appearance of the real *D. melanogaster*. According to Chyb and Gompel [39], normal *D. melanogaster* has a brown body, wings longer than the body, and red eyes. Meanwhile, ebony *D. melanogaster* has black body characteristics, wings extending beyond the body, and red eyes. In ebony D. melanogaster, a mutation causes the body to become black. One way to determine whether *D. melanogaster* is male or female is by looking at the back (abdomen) of the body. If the abdomen is black, then *D. melanogaster* is male; if not, *D. melanogaster* is female. Based on Figure 2, a guidebook for using the app is presented. The guidebook provides initial knowledge about the application, introduction to *D. melanogaster*, practicum procedures, and monohybrid crossing procedures using 3D model organisms of *D. melanogaster*. A guidebook can facilitate teachers and users to operate the developed media [40]. In addition, the colour selection in the guidebook uses bright colours, namely a combination of green and dark blue. Bright colours in the media can increase students' enthusiasm for learning [41].

The developed virtual reality laboratory presents a simulation of practicum activities on the law of Inheritance of Traits shown in Figure 3. Students first read the guidebook and then download the application. The use of the media begins with students reading the guidebook. First, students will choose the K3 they will use, then make *D. melanogaster* food made from bananas, tape, and brown sugar. After completion, students rejuvenate or move *D. melanogaster* to the new media (food) using the provided tools. Next, students perform the pupation procedure, which is putting pupae into the pupation hose to find males and females to be crossed (F1). When the flies have hatched, normal *D. melanogaster* and ebony *D. melanogaster* are crossed according to Mendel's law 1. Then, the results of the cross were calculated to compare the percentage of offspring produced.

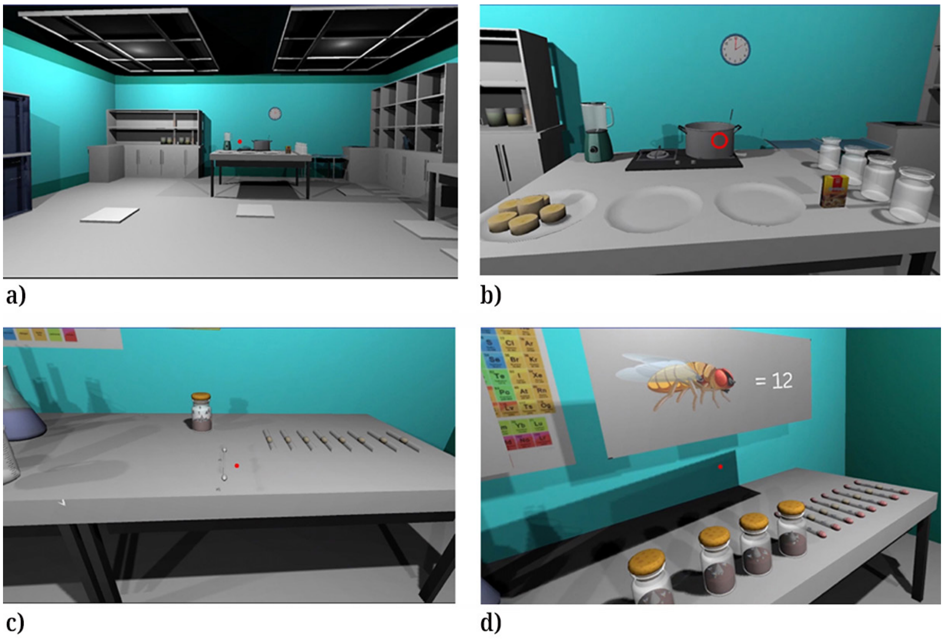



**Fig. 3.** (a) Display of the virtual reality laboratory in practicum, (b) display of tools for making medium, (c) display of rejuvenation and collection processes, (d) F1 and F2 crosses

Researchers conducted material validation using a questionnaire instrument. Material expert validators are biology lecturers who have met the qualifications, namely, at least a master's degree and teach genetics courses. The results of material validation can be seen in Table 4.

**Table 4.** Material expert validation results

| Indicator | Percentage (%) | Criteria |
|---|---|---|
| Suitability to learning objectives | 100% | Very Valid |
| Material accuracy | 100% | Very Valid |
| Material Presentation | 100% | Very Valid |
| Language | 100% | Very Valid |
| Total Average | 100% | Very Valid |

Table 5 shows the results of material validation, which has a value of 100%. Compared with the eligibility criteria in Table 3, the developed media is included in the category of highly valid and suitable for use. Suggestions given to the guidebook can be added with an explanation of the *D. melanogaster* cycle.

After the material validation is complete, the media validation is then carried out. Validators for this media development material are biology lecturers with expertise in developing media. The validation results can be seen in Table 5.

**Table 5.** Media expert validation results

| Indicator | Percentage (%) | Criteria |
|---|---|---|
| Landing page design | 90% | Valid |
| Virtual laboratory visualization | 89% | Valid |
| Animation display | 90% | Valid |
| Ease of use of the application | 88% | Valid |
| Total Average | 89% | Valid |

Based on the data above, the average media validation results show a value of 89%. When compared with the eligibility criteria in Table 3, the media developed is included in the valid category and is suitable for use. The suggestions are that the size of the 3D modelling of *D. melanogaster* in the media be enlarged, and the guidebook gives additional information regarding the minimum requirements for device/android specifications to be able to use the application.

After all the validation series have been completed, small group trials are carried out. The small group trial was conducted using the latest version of the development product after being revised based on the input and suggestions given by the validators. In this trial, nine students of SMAN 1 Lawang had taken the subject of the law of Inheritance of Traits. The results of the small group trial can be seen in Table 6.

**Table 6.** Small group trial results

| Indicator | Percentage (%) | Criteria |
|---|---|---|
| Media display | 91% | Practical |
| Information clarity | 88% | Practical |
| Media effectiveness (student perception) | 92% | Practical |
| Ease of use of the application | 89% | Practical |
| Total Average | 90% | Practical |

The trial results showed an average value of 90%. When compared with Table 3, the media developed is included in the practical category and can be used with minor improvements. Comments given by most students emphasize the ease of installing the application and the virtual reality display presented. The validation process aims to ensure that the material presented is valid and suitable for use as learning media. The research of Susanto et al. [42] and Kanadli [43] show that, in development research, it is required to go through a validation process before being used in the learning or implementation process. The validity value indicates the extent to which the results obtained are reliable and in accordance with the knowledge or validity content [44]. Based on the validity and practical values, it shows that the media developed is included in the valid and practical categories, so that the media can be implemented.

### 3.2 Virtual reality laboratory to improve students' technology literacy

The interviews and observations conducted by researchers on teachers and students found that the media used in learning is still conventional, so students often feel bored and less interested in learning. This finding impacts students' technological literacy, which needs to be optimally developed. This can be seen in students' difficulties in selecting technology and using digital products. The lack of habituation can cause the low technological literacy of SMAN 1 Lawang students to use interactive technology in the learning process. According to Julia and Isrokatun [45], low technological literacy can lead to communication and information technology failure. Strengthening technological literacy is done to prepare students according to the needs of the 21st Century [46][47]. Students and teachers must also be able to utilize and evaluate appropriate technology in learning. This ability is expected to provide optimal service to the learning process [48][49].

The implementation process of virtual reality laboratory learning media is carried out to determine its effectiveness in improving students' technological literacy. Before the implementation process, students were given a pre-test to determine their initial ability level before using the learning media. Then, learning is carried out using the developed learning media. The pre-test questions were given to the experimental, control class 1, and control class 2. Then, at the end of learning, students are given post-test questions to determine the level of learning media.

The results of the normality and homogeneity tests on technological literacy aspects show a significance value > 0.05, so $H_0$ is rejected, or $H_1$ is accepted, indicating that the data obtained are normally distributed. The data in the experimental and control classes are homogeneous. After fulfilling the requirements, the anacova test was carried out with a significance level of 5% to draw hypothesis conclusions. The Anacova test was conducted to evaluate the treatment effect and differences in technological literacy between the experimental class, control class 2, and control class 1. The Anacova test can be seen in Table 7.

**Table 7.** Results of covariance analysis (Anacova) on technology literacy aspects

| Tests of Between-Subjects Effects | | | | | |
|---|---|---|---|---|---|
| Dependent Variable: Technology Literacy | | | | | |
| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
| Corrected Model | 1560.907[a] | 2 | 780.454 | 213.189 | .000 |
| Intercept | 645578.704 | 1 | 645578.704 | 176346.835 | .000 |
| kelas | 1560.907 | 2 | 780.454 | 213.189 | .000 |
| Error | 384.389 | 105 | 3.661 | | |
| Total | 647524.000 | 108 | | | |
| Corrected Total | 1945.296 | 107 | | | |

*Note:* [a]R Squared = .802 (Adjusted R Squared = .799).

Based on Table 7, the significance value in the class column is 0.000 (< 0.05). According to Rosoff and Dobler [50], a significance value below 0.05 indicates rejection of $H_0$ or acceptance of $H_1$, which means there is a significant difference in technological literacy skills between the experimental class, control class 1, and control class 2. This indicates that the use of the developed learning media significantly affects students' technological literacy skills. In addition, the Anakova test shows that the effect of teaching materials on students' technological literacy skills is 80% (partial eta squared = .802).

Students' technological literacy was assessed from 5 indicators, namely (1) basic knowledge of computer technology, (2) digital and multimedia products, (3) technical use of technology, (4) design, (5) selection and use of technology, (6) law and ethics. These five indicators were measured by filling out a technology literacy questionnaire. The results of differences in technological literacy abilities in each indicator are presented in Figure 4. The technological literacy of students in the experimental class showed the highest results in each aspect. Students in the experimental class had an exemplary level of technological literacy, while in the control class, 1 and 2 students had a proficient level. The developed media helps students recognize and understand technology use in learning. Learning virtual reality technology can encourage students to design, develop and utilize technology [51][52].

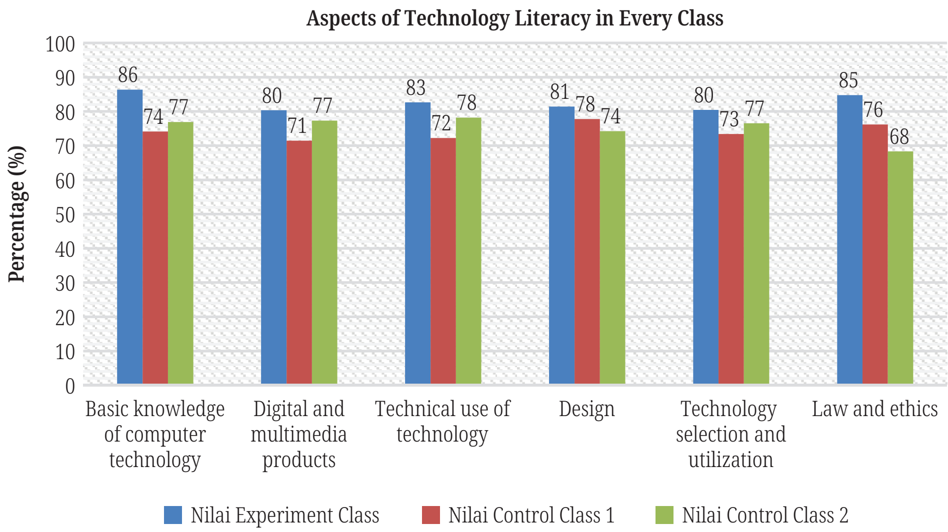



**Fig. 4.** Results of technology literacy analysis

Furthermore, Petrov & Atanasova's research [53] states that the artificial environment of virtual reality makes users feel like they are in a real environment. This phenomenon makes students more familiar with and accustomed to computer-based environments. Research by Singh et al. [54] shows that virtual reality laboratories can improve students' understanding of technology. This understanding consists of basic knowledge of technology, technical use, and the use of technology in everyday life [55][56]. The high technological literacy of students in the experimental class is due to the addition of virtual reality technology. Virtual reality media provides interactive computer-based experiences to students to encourage their knowledge of technology [57].

Although virtual reality laboratory learning media significantly differs in students' technological literacy in each class, researchers believe this is also due to media use in the control class that does not describe technology-based media as in the experimental class. Based on this study, the researcher recommends comparing virtual reality laboratory media on the material of the law of Inheritance of Traits using *D. melanogaster* realia media. Technological literacy and understanding of inheritance law are essential in the 21st century. Media development to improve these abilities is needed to create good technological literacy in genetics learning.

## 4 CONCLUSION

The media developed as a virtual reality laboratory is suitable for use in the learning process of the law of Inheritance of Traits. The results of material validation showed 100% with a very valid category, media validation of 89% with a valid category, and media practicality of 90% with a practical category. The Anacova test results show a significance value of 0.000 less than $\alpha$ ($\alpha$ = 0.05), so it can be concluded that there is a significant difference between the experimental class, control class 1, and control class 2. It can be concluded that the virtual reality laboratory media on the material of the law of Inheritance of Traits developed is valid, practical, and effective in improving students' technological literacy. The use of virtual reality (VR) technology for learning development is still relatively new, especially in Indonesia, so striving for equal access and improving skills in using VR is very important. In future studies, researchers suggest comparing the media that has been developed with classes that use the object of research, *D. melanogaster* realia media.

## 5 ACKNOWLEDGEMENT

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## 7 AUTHORS

**M Iqbal Najib Fahmi:** Undergraduate Students, Researcher, Universitas Negeri Malang, Jalan Semarang 5, Malang 65145, Indonesia (E-mail: m.iqbal.2303418@students.um.ac.id).

**Siti Zubaidah:** Professor, Researcher, Universitas Negeri Malang, Jalan Semarang 5, Malang 65145, Indonesia (E-mail: siti.zubaidah.fmipa@um.ac.id).

**Susriyati Mahanal:** Professor, Researcher, Universitas Negeri Malang, Jalan Semarang 5, Malang 65145, Indonesia (E-mail: susriyati.mahanal.fmipa@um.ac.id).

**Deny Setiawan:** Lecturer, Researcher, Universitas Negeri Malang, Jalan Semarang 5, Malang 65145, Indonesia (E-mail: setiawan.fmipa@um.ac.id).