


Multimedia-based Biology E-magazine in Genetic Material for High School Students

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Abstract

Abstract

This research aims to develop a multimedia-based Biology E-Magazine (E-BIOMAGZ) as a learning media for genetic material. The research method used is the research and development (R&D) method (potential and problem analysis, data collection, product design, design validation, design revision, and limited product trials). E- BIOMAGZ development was created using the Flip PDF Professional and Canva applications. This research was conducted from May 2023 to March 2024 at SMAN 5 Serang City and Sultan Ageng Tirtayasa University. The eligibility assessment from material experts for E- BIOMAGZ obtained a score of 89,2% in the very worth category and the score from media experts was 93,5% in the very worth category. The results of the student response test obtained a score of 96,5% in the very worthy category. The conclusion obtained is that the multimedia-based Biology E-Magazine (E-BIOMAGZ) on genetic material is declared valid and very worthy of use as a learning media.

Abstrak

Penelitian ini bertujuan untuk mengembangkan Biology E-Magazine (E-BIOMAGZ) berbasis multimedia sebagai media pembelajaran pada materi genetik. Metode penelitian yang digunakan adalah metode penelitian dan pengembangan (R&D) dengan (analisis potensi dan masalah, pengumpulan data, desain produk, validasi desain, revisi desain, dan uji coba produk terbatas). Pengembangan E-BIOMAGZ dibuat dengan menggunakan aplikasi Flip PDF Professional dan Canva. Penelitian ini dilakukan di SMAN 5 Kota Serang dan Universitas Sultan Ageng Tirtayasa. Penilaian kelayakan dari ahli materi untuk E-BIOMAGZ memperoleh nilai sebesar 89,2% dengan kategori sangat layak dan nilai dari ahli media sebesar 93,5% dengan kategori sangat layak. Hasil uji respon siswa memperoleh nilai sebesar 96,5% dengan kategori sangat layak. Simpulan yang didapat yaitu Biology E-Magazine (E-BIOMAGZ) berbasis multimedia pada materi genetik dinyatakan valid dan sangat layak digunakan sebagai media pembelajaran.

Kata kunci: komik; flipbook; interaktif; media pembelajaran; R&D



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1. INTRODUCTION

Information and communication technology development has advanced all fields, including education. Education is greatly helped by the existence of products resulting from technological developments, including e-learning, learning media applications, and independent learning platforms (Cardona-Acevedo et al., 2025). While technology offers many benefits to education, successful integration requires thoughtful planning, training, and ongoing evaluation to ensure that the technology aligns with educational goals and enhances the overall learning experience (Aggarwal, 2023). Products resulting from technological developments are created to reduce obstacles in the learning process. Obstacles that occur during the learning process do not achieve learning objectives.

The process of achieving learning objectives requires tools, including learning media. Learning media are tools used by educators to deliver learning materials to students, making instruction more effective and efficient (Bulkani et al., 2022). This statement follows Rahmanu & Molnár (2024), who states that the existence of learning media will motivate students to learn, provide encouragement to write, speak, and imagine, thereby increasing their motivation to learn. Therefore, educators are required to have creative and innovative ideas. One of them is by creating learning media in the form of digital magazines.

Digital magazines, or e-magazines, are learning resources that contain engaging content with supporting features such as images, videos, and audio (Fuad et al., 2020). In this era, many magazines spread throughout society, including those covering learning, social politics, and style. However, relatively few magazines contain learning materials or are used in the learning process (Setiyawati et al., 2022). The advantage of magazines as a learning media is that they have an attractive and colorful appearance so students can be stimulated to learn. Based on research by Sari & Adlini (2024), learning media in the form of an e-magazine has the potential to motivate students when studying. Apart from that, the results of research by Arifin et al. (2019) using electronic magazine learning media makes learning practical and efficient. Based on research by (Kamza et al., 2024), using e-magazine learning media can support students in independent learning and prevent them from becoming bored because the digital magazine has a fun intermezzo.

The results of the analysis of needs for class XII biology teacher at SMAN 5 Serang City stated that the teacher already knew E-BIOMAGZ meanwhile, material that is difficult to understand is genetic material. This topic has difficulties such as many abstract material concepts and processes, making it difficult for students to understand. This statement is supported by Bedizel (2025), many students do not know the concepts in genetic material, so students experience misconceptions, especially in the process of protein synthesis and the relationship between genes, DNA and chromosomes. Based on this, there is a need for innovative learning media to support the achievement of learning objectives. Innovative learning media will motivate students to learn.

The needs analysis results of grade XII students of SMAN 5 Serang City show that teachers have used learning media during the learning process and students are very interested and enthusiastic about learning when using learning media. As many as 62% of students chose the topic of genetic material as one they found difficult to understand. The problem faced by students in genetic material is that it contains complicated material and involves a very complex process, there are many terms in it so students find it difficult to imagine and describe what is explained. The existence of learning media can make it easier for students to understand the topic of genetic material according to factual, conceptual, procedural, and metacognitive dimensions and the media used can be accessed practically (Khastini & Maryani, 2025). Therefore, through the development of Biology E-magazine (E-BIOMAGZ) it is hoped that new and innovative learning media will help students develop critical skills and enriching their educational experience because E-BIOMAGZ presents visuals with a variety of colors, animations, videos, and games that are packaged in an attractive way.

So that the presence of E-BIOMAGZ on genetic material is expected to create effective and enjoyable learning activities for students. The advantages of using E-BIOMAGZ are that students do not need to bring printed books and they can bring E-BIOMAGZ on their respective cellphones and laptops so that learning can be easily accommodated. Therefore, it is necessary to develop a digital magazine by researchers entitled "Development of Multimedia-Based Biology E-Magazine in Genetic Material".

2. METHODS

The research method used is the research and development method or Research and Development (R&D). The research design used in the development refers to the research and development model according to Sugiyono (2017) which is modified into six steps, namely (1) potential and problems, (2) data collection, (3) product design, (4) design validation, (5) design revision, and (6) product trial. The subjects in this study were media experts, material experts, and grade XII students. Eligibility test with experts (two media experts and two material experts). This limited trial was conducted with 42 students selected using random sampling techniques.

The data collection techniques used in this learning media development research were direct observation in the field and questionnaires. The teaching and learning process, school facilities, and internet access were observed in the observation activity. The instruments used were needs analysis questionnaires, expert questionnaires, and student response questionnaires. The data obtained will be analyzed using quantitative descriptive methods, employing the Likert and Guttman scales for measurement. The expert's response is measured using a Likert scale, which assesses opinions, perceptions, and attitudes. According to Arikunto & Jabar (2018), the level of value on the Likert scale is as follows.

Table 1. The assessment criteria are on a Likert scale

Score	Criteria
5	Very Good
4	Good
3	Fair
2	Poor
1	Very Poor

¹(Arikunto & Jabar, 2018)

The collection of student response data uses quantitative data from Guttman-scale measurements with answer choices "Yes" or "No". Guttman scale measurements aim to obtain consistent answers to a given problem. This is also based on the collection of student response data; no experts are needed, so statements and answers are more concise.

Table 2. The assessment criteria are on a Guttman scale

Score	Criteria
1	Yes
0	No

²(Sugiyono, 2017)

The data results that have been scored are then calculated in each assessed component. Then, the percentage is calculated in each component using a formula that refers to Purwanto (2009):

$$NP = \frac{R}{SM} \times 100\%$$

Description

NP : Percentage value

R : Total score

SM : Maximum value

100% : Fixed value

The percentages obtained are interpreted according to the following criteria:

Table 3. Eligibility score interpretation criteria

Percentage of achievement	Interpretation
81-100%	Very worth
61-80%	Worthy
41-60%	Decent enough
21-40%	Not worth it
0-21%	Very unworthy

³(Arikunto & Jabar, 2018)

3. RESULTS AND DISCUSSION

E-BIOMAGZ is an electronic biology magazine available online at <https://online.flipbuilder.com/qnaly/epxf/>. E-BIOMAGZ contains knowledge content about genetic material, genetic material comics, and genetic material crosswords. E-BIOMAGZ contains multimedia content needed in the learning process such as text, images/illustrations, videos, and hyperlinks to other sources used as references. Data from the results of this study have six stages of research and development procedures carried out, the six stages of procedures carried out are as follows:

3.1. *Potential and Problems*

At this stage, the first and most important thing to do is to conduct a needs analysis of the products made and developed by distributing questionnaires to SMAN 5 Serang City biology teachers and class XII MIPA students. The selection of schools in Serang City is based on considerations of school facilities that can support learning activities and are adequate with the use of digital learning media, one of which is the E-BIOMAGZ learning media which requires hardware devices in the form of smartphones or computers and software in the form of browsers. The potential in this development research is that there is the use of learning media in the form of electronic media such as smartphones and computers in learning activities by students to help find information about materials in biology learning.

The problem in this development research is the lack of understanding of biological material. Based on the results of the needs analysis, several grade XII materials are considered difficult. According to the teacher, genetic material is one of the materials considered difficult. As many as 62% of students also chose genetic material as a reasonably difficult material because it contains concepts that are pretty complicated, difficult to understand, have many terms, and are abstract and complex. In addition, the use of learning media is not yet innovative or varied, so students experience boredom during learning. The learning process still uses the lecture method, which makes students bored, keeps it centered on the teacher, and has students only listen and write what the teacher explains. The development of E-BIOMAGZ is expected to enhance students' and teachers' cognitive development and enthusiasm. In addition, learning with E-BIOMAGZ aligns with students' needs, fosters collaboration, stimulates creativity, and enables analytical thinking to solve problems (Leksono et al., 2021).

3.2. *Data Collection*

After the potential and problem stages, the next step is to collect data supporting E-BIOMAGZ learning media development. This data collection process includes curriculum analysis, macrostructures and microstructures, and literature studies. Curriculum analysis is carried out after conducting a needs analysis. This activity is carried out so that the learning media created can help students master the predetermined competencies (Anas & Hartono, 2024). Based on the results of the curriculum analysis, the curriculum used is the 2013 curriculum. The results of the curriculum analysis are in the form of a description of core competencies (KI) 3 and 4, basic competencies (KD) 3.3, namely analyzing the relationship between the structure and function of genes, DNA, chromosomes in the process of inheritance of traits in living things and applying the principles of inheritance of traits in life and KD 4.3 formulating the sequence of the protein synthesis process in relation to the delivery of the DNA-RNA-Protein genetic code.

Based on the formulation of indicators to be achieved, the next step is to conduct material analysis in the form of basic text analysis (macrostructure and microstructure) which aims to facilitate

researchers in compiling the creation of E-BIOMAGZ to produce E-BIOMAGZ on genetic material. Learning materials are analyzed by creating a microstructure to produce macro proportions arranged into macrostructures. The material analysis results (macro and micro) are used as limitations in compiling E-BIOMAGZ. The data from valid literature studies such as books, scientific articles, and scientific journals are then analyzed and incorporated into material that will be displayed in E-BIOMAGZ.

3.3. Product Design

After analyzing the needs of teachers and students, analyzing the curriculum and materials, the next step is product design. Some things done in the E-BIOMAGZ product design process are making storyboards, designing multimedia-based E-BIOMAGZ, and compiling assessment instruments.

3.3.1. Making Storyboard

Determining the content of E-BIOMAGZ begins with designing a storyboard that serves as a guideline for creating E-BIOMAGZ. This is in accordance with the statement of Aulia et al. (2022) a storyboard is the primary reference when developing a product that contains a description of the form and content of the appearance of the product being developed. The storyboard components include the main part, the opening section, the front cover, editorial greetings, the table of contents, KI, KD, and IPK, and instructions for use. In the content section, the material begins with the stimulus, genetic material profile, DNA replication, protein synthesis, and bionews. The closing section consists of an evaluation in the form of TTS, a list of references, and a back cover. According to Prasetyo et al. (2022), the magazine's cover must contain the masthead, volume, date, main cover line, cover line, and image. Then the content section contains several components: title, deck, body, text, subtitle, pull quote, caption, callouts, kickers, initial caps, indent, headline, spaces, header and footer, running head, and page number. Magazines also have visual elements (color, photos/illustrations/artwork, lines, and typography) and invisible elements (margins and grids).

The content section contains materials that are in accordance with the KD requirements, namely the stimulus section on genetic material, the genetic material profile section containing an initial explanation of genetic material, the structure, function, and type of chromosome section containing an explanation of chromosomes, the gene and allele section containing an explanation of genes and alleles, the DNA section containing an explanation of DNA, the RNA section explaining RNA, the gene, DNA, and chromosome relationship section explaining the relationship between genes, DNA, and chromosomes, the DNA and RNA differences section containing a table of differences between DNA and RNA, the history of genetic material section containing a timeline of scientists who helped develop genetic material, the DNA replication section containing an explanation of DNA replication and its theory and a depiction of the DNA replication process, the protein synthesis section containing an explanation of protein synthesis and a depiction of the protein synthesis process, the biocomic section containing a short dialogue about the differences in genes that affect phenotypes in humans, the codon wheel section containing a picture of a wheel containing nitrogen base codes and examples of cases of using the codon wheel. In the bionews section, there is a phenomenon of genetic material in everyday life, namely the CRISPR article section containing an explanation of the latest technology in genetic material. The evaluation section has a crossword puzzle board with a start button at the bottom to start filling in the TTS. The back cover contains a blurb briefly explaining E-BIOMAGZ (Mahelingga, 2023) and the researcher's history.




No.	Nama Menu	Keterangan
1.	Halaman sampul depan 	a. Nama pengembang b. Logo universitas c. Judul majalah d. Gambar sampul majalah e. Topik majalah f. Tanggal terbit g. Nama Universitas
2.	Salam redaksi 	a. Salam "Redaksi" b. Isi redaksi Deskripsi: Jilidman ini memuat kalimat redaksi dan ucapan terima kasih.
3.	Daftar Isi 	a. Judul content b. Nomor halaman c. Judul setiap halaman d. Gambar judul

Figure 1. Storyboard.

3.3.2. Designing Multimedia-Based E-BIOMAGZ

After designing the storyboard by including magazine elements, the next step is designing E-BIOMAGZ using multimedia elements, as according to Hadi et al. (2022), multimedia is information that integrates text, graphics, images, animation, audio, and video which is designed and controlled using a computer where all types of information can be stored, sent and processed digitally. E-BIOMAGZ was designed using Canva and Flip PDF Professional. Flip PDF Professional is software that makes each page look like a book on a digital display. This software can create and convert PDF or Image/Photo files into a physical album when opened per page. The operation method when editing is easy and it can upload E-BIOMAGZ results for free using e-mail. It is very easy to use, students just need to open it by sliding the page they want to display, to enlarge the image just press the zoom icon, and to open the video and evaluate it just click the play button. Meanwhile, Canva is a graphic design application that can be accessed online which is easy to use for editing, has a very attractive graphic design, and is cheap.

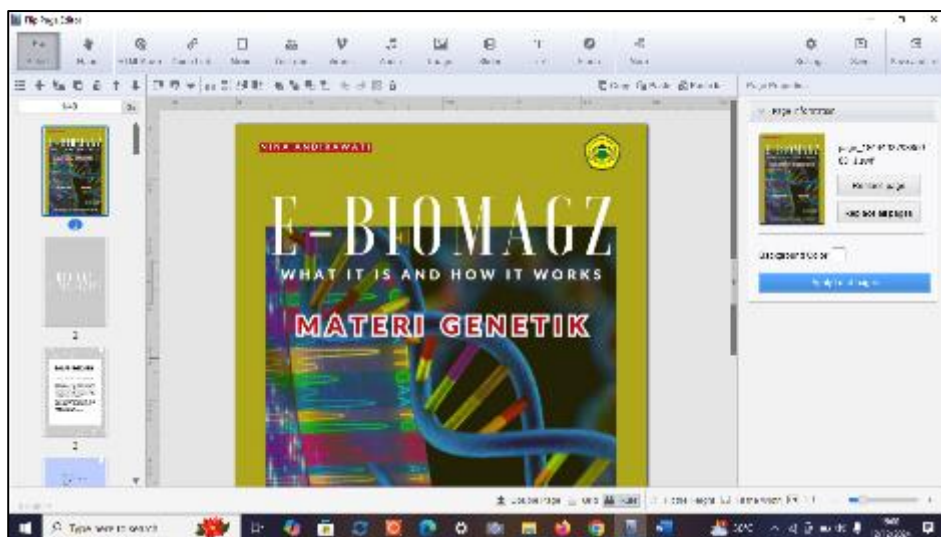


Figure 2. Compiling E-BIOMAGZ with the Flip PDF Professional application.

The following is the product design for Biology E-Magazine (E-BIOMAGZ) that was developed:

1. Opening Section
 - Front Cover

The cover of E-BIOMAGZ consists of the title of the book material, namely E-BIOMAGZ as the masthead, genetic material as the main cover line, cover line, namely the sentence what it is and how

it works, date, picture of genetic material, name of the compiler, university logo, and highlight information in the magazine. The background design chosen on the cover is adjusted to the theme of the material and also the contents of E-BIOMAGZ, which are arranged in such a way as to make the book look attractive and describe its contents.

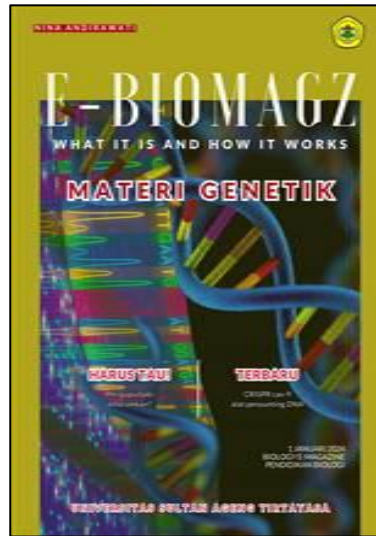


Figure 3. Front cover view of E-BIOMAGZ.

- Editorial Greetings

The editorial greeting section contains words of gratitude because the author was able to complete the creation of E-BIOMAGZ and greetings from the author to the readers as well as a brief description of the contents of E-BIOMAGZ.



Figure 4. Editorial greeting display.

- The Table of Contents

The table of contents is a section that provides information about the contents of E-BIOMAGZ, making it easier for users to search for the desired topic.

1	Salam Redaksi Penjelasan singkat tentang E-Biomagz	
1	Content Daftar isi	
3	KI, KD, dan IPK	
5	Petunjuk Penggunaan Cara penggunaan E-BIOMAGZ untuk guru dan peserta didik sebagai media pembelajaran	
7	Stimulus	
9	Profil Materi Genetik Penjelasan tentang materi genetik dari macam-macam materi genetik	
25	Sejarah Materi Genetik Menceritakan bagaimana awal mula ditemukannya materi genetik	
27	Jelajah bersama Materi Genetik Proses replikasi dan sintesis protein	
35	Biocomic	
		39
		37
		41
		42

Figure 5. Table of contents view.

- KI, KD, and IPK

Students must achieve the basic competency sections 3.3, which analyze the relationship between the structure and function of genes, DNA, and chromosomes in the process of passing on traits in living things and apply the principles of inheritance of traits in life, and 4.3, which formulates the sequence of protein synthesis processes in relation to the delivery of the DNA-RNA-Protein genetic code.

Competency Achievement Indicators (IPK) are compiled with Operational Verbs (KKO) Revised Bloom's Taxonomy, there are 9 IPK, namely distinguishing chromosome structures based on their shape, number, and size (C2), explaining the concept of genes and alleles (C2), explaining the components of DNA (C2), explaining the DNA replication mechanism (C2), distinguishing types of RNA (C2), analyzing the differences between DNA and RNA (C4), analyzing the relationship between genes, DNA, and chromosomes (C4), explaining the stages of protein synthesis mechanisms (C2), and formulating the sequence of protein synthesis processes in relation to the delivery of the DNA-RNA- Protein genetic code (P4).

In E-BIOMAGZ, the cognitive level of Bloom's Taxonomy is used, namely understanding (C2) and analyzing (C4). This is because genetic material contains an understanding of the concept of genetic material and analyzes the process of DNA replication and protein synthesis, and E-BIOMAGZ uses a simple TTS evaluation aimed at making students experience enjoyable learning. After compiling the GPA, the preparation of learning objectives based on ABCD (Audience, Behavior, Condition, and Degree) is carried out, and students can distinguish chromosome structures based on their shape, number, and size correctly through literature reviews.

E-BIOMAGZ still uses the 2013 Curriculum, but E-BIOMAGZ can still be used for biology learning media or as an alternative learning resource. E-BIOMAGZ uses KD 3.3 and 4.3 which are still listed in the Phase F Learning Outcomes of grade 12 in the Independent Curriculum, namely having the ability to describe bioprocesses that occur in cells and the ability to apply the concept of inheritance of traits (Capaian Pembelajaran Mata Pelajaran Pendidikan Kepercayaan Terhadap Tuhan Yang Maha Esa Dan Budi Pekerti Pada Jenjang Pendidikan Dasar Dan Pendidikan Menengah Dalam Kurikulum, 2022).

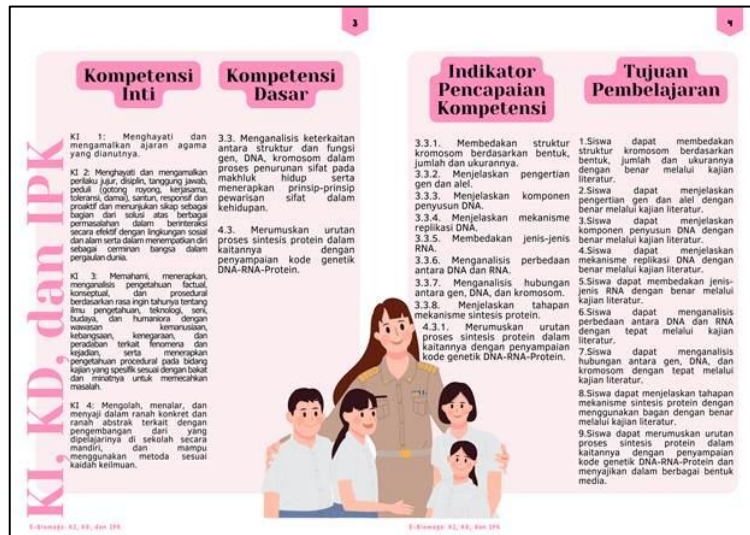


Figure 6. Basic Competency display.

- Instructions for Use

The Instructions for Use page helps users learn how to use E-BIOMAGZ according to their needs.

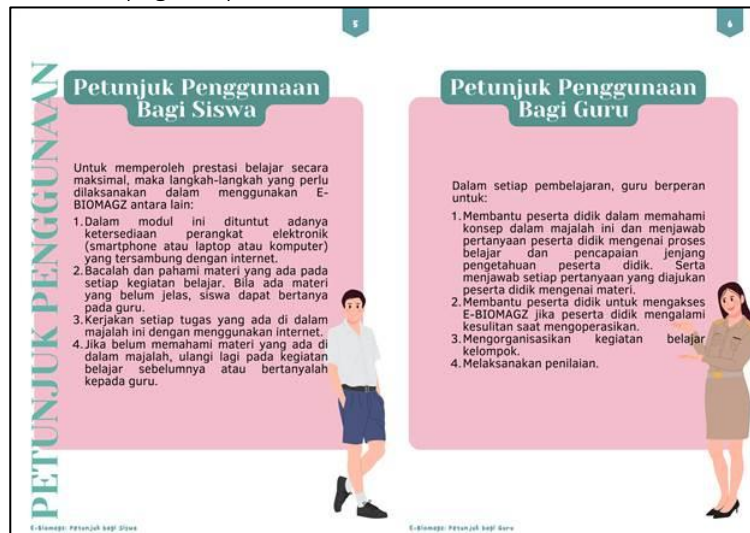


Figure 7. Instructions for Use display.

2. Content Section

The content section of E-BIOMAGZ consists of an explanation of each sub-material on the topic of genetic material. The content section is packaged attractively so that it is easy for readers to understand. The layout of the E-BIOMAGZ should be in a Reasonable order, concise, and easy to comprehend in the absence of the author. Furthermore, the amount of colour and graphic choices available to improve the look of E-BIOMAGZ (Khastini et al., 2021). The content section of E-BIOMAGZ consists of sub-material titles, images, explanations of content text, videos and audio, and comics. The content section of E-BIOMAGZ consists of several parts, including sub-material titles containing an outline of the explanation of genetic material such as a genetic material profile that explains each component of genetic material such as chromosomes, genes, alleles, DNA, and RNA, the relationship between genes, DNA, and chromosomes, the replication process, the protein synthesis process, how to read codons, biocomics, and bionews about the latest facts about genetic material.

Pernahkah kamu berpikir, MENGAPA KITA BISA MEMILIKI CIRI FISIK YANG BERBEDA?

Hal tersebut yang membuat kita memiliki ciri fisik yang berbeda seperti warna kulit, bentuk hidung, tinggi badan, dan sebagainya.

Sifat-sifat makhluk hidup diwariskan melalui pelepasan antara sel kelamin betina dan sel kelamin jantan. Bagian yang bertanggung jawab dalam pewarisan sifat pada tingkat sel ini adalah inti sel. Di dalam inti sel dapat dijumpai kromosom yang memiliki substansi pembawa sifat keturunan. Substansi pembawa sifat keturunan tersebut adalah gen. Selain gen, penampakan atau ciri fisik manusia dan fungsi tubuh kita juga ditentukan oleh pengaruh lingkungan. Lalu bagaimana materi genetik dapat menurunkan sifat-sifat tersebut?

Ger

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(1) Stimulus

Profil Materi Genetik

Materi genetik adalah informasi yang dimiliki oleh makhluk hidup yang dapat diwariskan ke keturunannya. Materi genetik terdapat di seluruh bagian sel makhluk hidup (Campbell & Reece, 2012).

Setelah menyaksikan video di penting yang berfungsi atas dapat kita ketahui dalam penalaran sifat dan bahwa materi genetik ekspresi gen. Komponen terdapat di setiap sel tersebut adalah kromosom makhluk hidup. Di dalam sel, ada gen. Kromosom materi genetik dapat terusun atas protein dan ditemukan di nukleus, asam nukleat, terdapat 2 kloroplast, dan mitokondria. Setiap materi genetik DNA dan RNA.

Mitokondria memiliki membran ganda. Sedangkan kloroplast memiliki 3 membran. Organ-organ ini mengandung sejumlah kecil DNA. DNA inilah yang memprogram sintesis protein (Campbell & Reece, 2012).

(2) Profile Genetic Material

MENGENAL BAGIAN-BAGIAN KROMOSOM LEBIH DEKAT

Kromonema: Pita spiral yang terlipat-pelintiran.

Sentromer: Bagian yang menyempit dari leleh tengah (tidak mengandung gen).

Kromatid: Pembesaran pada kromonema.

Telomer: Bagian ujung kromosom yang menggenggam seluruhnya dengan kromosom lain.

Mengenal struktur, fungsi, dan jenis KROMOSOM

Kromosom terdiri dari DNA (Deoxyribonucleic Acid), RNA (Rybo Nucleic Acid), protein histon, dan non-histon sehingga keseluruhan komponen kromosom adalah kompleks nucleoprotein yang disebut kromatin sehingga

(3) Chromosome Structure View

Apa saja fungsi dari kromosom?

Kromosom berfungsi sebagai tempat penyimpanan materi genetik, penentu sifat jenis kelamin, dan berperan dalam pembelahan sel.

Jumlah kromosom pada manusia

Perempuan mempunyai dua kromosom X, atau disebut kromosom XX. Rumus kromosomnya 22AAXX. Sedangkan pria mempunyai kromosom X dan Y, atau disebut kromosom XY. Rumus kromosomnya 22AAXY (Rohman, 2022).

Macam-macam bentuk dari kromosom

- Akro-sentrik**: Memiliki 2 lengan yang tidak sama panjang, dengan sentromer yang berada dekat ujung bagian kromosomnya.
- Submeta-sentrik**: Memiliki kedua lengan yang hampir sama panjang, dengan sentromer yang terletak hampir di tengah. Bentuknya seperti huruf J.
- Telo-sentrik**: Hanya memiliki 1 lengan dengan sentromer yang terletak di ujung.
- Meta-sentrik**: Memiliki 2 lengan sama panjang dengan sentromer yang terletak di tengah.

(4) Display of Functions and Types of Chromosomes

GEN adalah unit Sequencing struktural yang mengatur sifat-sifat hereditas suatu makhluk hidup (Susilawati dan Bakhtiar, 2018). Gen terdiri dari dua jenis yaitu gen aktif dan gen pasif. Gen aktif merupakan gen yang diekspresikan, sedangkan gen pasif adalah gen yang tidak diekspresikan.

“ Apa itu Alel? ”

Alel merupakan wujud lain dari gen yang berkaitan dengan ekspresi sesuatu watak (fenotip). Alel merupakan sepai gen yang posisinya di lokus yang sama pada kromosom homolog yang berperan bawa sesuatu watak ataupun kepribadian.

Homozigot ialah watak sesuatu orang yang genotipnya terdiri atas alel-alel yang sama buat tiap tipe gen (contohnya MM, mm, MMNn, mmNn, serta sebagainya).

Heterozigot ialah watak sesuatu orang yang genotipnya terdiri atas alel-alel yang berbeda buat tiap tipe gen (contohnya Mm, MmNn, MmNnO, serta sebagainya) (Aristya et al., 2015).

Gen dan kromosom dimanakah letak sebenarnya? Gen terletak di dalam kromosom.

(5) Gene and Allele View

DNA Si Double Helix

Bersumber pada percobaan Watson serta Crick, DNA berupa utas ganda (double helix). DNA (bahasa Inggris: deoxyribonucleic acid) atau asam deoksiribonukleat, yakni polimer dari nukleotida-nukleotida yang terdiri dari 3 komponen basa nitrogen, gula pentosa (deoksiribosa), serta gugus fosfat. Basa nitrogen pada heliks ganda dipasangkan dengan campuran yang disebut Adenin (A) dengan Timin (T), serta Guanin (G) dengan Sitosin (C). Adenin serta guanin merupakan basa purin yang memiliki 2 cincin organik. Sebaliknya sitosin serta timin merupakan basa yang memiliki nitrogen yang disebut pirimidin yang mempunyai satu cincin organik (Campbell & Reece, 2012).

Penemuan Rosalind Franklin

Franklin seorang kristalografer sinar-X asal Inggris melakukan beberapa percobaan penting yang menghasilkan foto yang memperlihatkan struktur DNA. Dari foto tersebut dapat disimpulkan letak relatif antar basa-basa nitrogen di sepanjang heliks tersebut (Kurniawan & Satrio, 2022).

(6) DNA View

RNA

Apa itu RNA? Apa saja jenis dari RNA?

mRNA (messenger RNA)
mRNA (messenger RNA) yang berperan membawa kode genetik (kodon) dari kromosom yang ada di inti sel mengarah ke ribosom yang terletak di sitoplasma.

tRNA (transfer RNA)
tRNA (transfer RNA) berperan selaku penerjemah kodon mRNA serta yang bawa asam amino ke ribosom.

rRNA (ribosomal RNA)
rRNA (ribosomal RNA) berperan selaku perakit polipeptida.

RNA (ribonucleic acid) merupakan makromolekul polinukleotida yang mempunyai wujud untai tunggal. RNA berfungsi dalam sintesis protein. RNA mempunyai untai polimer yang lebih pendek dari pada DNA sebab dibangun melalui proses transkripsi dari fragmen-fragmen DNA. Ada 3 tipe RNA, ialah mRNA (messenger RNA), tRNA (transfer RNA), dan rRNA (ribosomal RNA). Pasangan basa RNA adalah Guanin (G) dengan Sitosin (C). Sedangkan pada RNA, Timin digantikan dengan Urasil (U), sehingga Adenin (A) dengan Urasil (U).

(7) RNA View

Hubungan Gen, DNA, dan Kromosom

Perhatikan gambar berikut! Pernahkah kamu berpikir, bagaimana hubungan antara Gen, DNA, dan Kromosom?

Setelah mengetahui fungsi dari masing-masing organer materi genetik. Ternyata setiap organer tersebut berhubungan satu sama lain, lho! Mungkin banyak yang menjelaskan satu persatu organer materi genetik tanpa menjelaskan bagaimana hubungan di antara semua organer. Mari kita analisis bersama bagaimana hubungan organer tersebut.

GEN adalah seluruh sekuen DNA secara urut yang mengkode kode-kode khusus (Nur & Yamamoto, 2022). Seperti kolagen yang memiliki kode (CTC-CTA-TGC-GTG) pada DNA cumi-cumi Jepang (Rahman et al. 2021).

DNA adalah untai ganda polinukleotida yang membawa rangkaian informasi genetik sistematis yang akan diturunkan pada keturunannya (Yuwono, 2019). Jadi, DNA memiliki struktur kode yang mengkodekan gen pada untainya.

DNA memiliki untai yang sangat panjang sehingga perlu dilipat pada protein yang disebut protein histon. Ikatan protein histon dan DNA membentuk suatu struktur yang disebut kromatin. Protein histon juga menyediakan energi (interaksi elektrostatis) untuk melipat DNA sehingga kromatin dapat dikemas dalam volume yang jauh lebih kecil membentuk loop. Lalu, serit kromatin dikompres atau dimampatkan sehingga membentuk struktur kromatid yang volumenya lebih kecil. Kumpulan kromatid yang dimampatkan membentuk sebuah struktur yang disebut kromosom. Kromosom adalah tempat penyimpanan materi genetik, penentu sifat jenis kelamin, dan berperan dalam pembelahan sel (Dewi R. 2021). Alel merupakan sepi gen yang posisinya di locus yang sama pada kromosom homolog yang berperan bawa sesuatu watak ataupun kepribadian.

(8) View of the Relationship between Genes, DNA, and Chromosomes

Perbedaan DNA & RNA

Pembeda	DNA	RNA
Bentuk Struktur	Untai ganda (double helix) dan perjang	Untai tunggal dan pendek
Letak	Pada kromosom (inti sel), mitokondria, plasmid, kloroplast, & sentriol	Di sitoplasma sel, ribosom, nukleus.
Zewa gula	Deoksiribosa	Ribosa
Basa Nitrogen	Timin, Adenin, Guanin, dan Sitosin	Urasil, Adenin, Guanin, dan Sitosin
Fungsi	Sebagai materi genetik (bahan baku) untuk sintesis protein.	Alat dalam sintesis protein.
Kadar Jumlah	Tinggi, karena tidak terpengaruh oleh aktivitas sintesis protein.	Tidak tetap, dipengaruhi sintesis protein.
Kebekuan	Permanen	Periode pendek & mudah terurai.

(9) DNA and RNA Differences Display

History of Genetic Material

1869 - Friedrich Miescher menemukan DNA dari spermatozoa ikan kerapuu.

1900 - Erwin Chargaff menemukan bahwa di dalam DNA jumlah adenin sama dengan timin, dan jumlah guanin sama dengan sitosin. Ini dikenal dengan teori Chargaff, inseminasi bukan pada baji dengan sperma buku terbukti difaktakan.

1920 - Phoebus Levene menemukan gula ribosa dalam asam nukleat, yang kemudian dikenal dengan DNA.

1957 - Francis Crick dan George Gamow merumuskan "Central Dogma" yang menjelaskan era keria DNA dalam mendasarkan proses sintesis protein...

1953 - James Watson dan Francis Crick menjelaskan struktur 3 dimensi DNA, menggunakan data difraksi sinar x yang dikumpulkan oleh Rosalind Franklin dan Maurice Wilkins.

(10) History of Genetic Material View

Replikasi DNA

Replikasi Semikonservatif
Pada replikasi semikonservatif untai berlipin mengalami pemutusan terlebih dahulu sehingga kedua untai polinukleotida akan saling terpisah. Masing-masing untai tetap dipertahankan dan akan bertindak sebagai cetakan (template) bagi pembentukan untai polinukleotida baru.

Replikasi Konservatif
Pada replikasi konservatif seluruh untai berlipin DNA awal tetap dipertahankan dan akan mengarahkan pembentukan untai berlipin baru.

Replikasi Dispersif
Pada replikasi dispersif kedua untai polinukleotida mengalami fragmentasi di sejumlah tempat. Kemudian, fragmen-fragmen polinukleotida yang terbentuk akan menjadi cetakan bagi fragmen nukleotida baru sehingga fragmen lama dan baru akan dijumpai berselang-seling di dalam untai berlipin yang baru.

Replikasi DNA adalah suatu proses penggandaan untai ganda dari DNA. Sebelum adanya penemuan model replikasi DNA secara teoritis terdapat tiga hipotesis tentang replikasi DNA yaitu:
1. Replikasi konservatif
2. Replikasi semikonservatif, dan
3. Replikasi dispersif.

(11) DNA Replication Theory View

Proses Replikasi DNA

1. Inisiasi Replikasi
Pemutusan kedua untai DNA induk terjadi tempat-tempat khusus yang disebut titik ori (origin of replication). Protein yang dalam inti sel dan organer-organer yang memiliki replikasi DNA mengawali untai memiliki DNA. Replikasi terjadi dalam 3 ori dan menempel pada DNA kemudian memisahkan kedua untai.

2. Elongasi Molekul DNA
Polimerisasi nukleotida pada replikasi DNA selalu berlangsung dalam arah 5'→3'. Pemisahan untai DNA dilakukan dari ujung primer. Akibat adanya 2 untai DNA yang orientasinya berlawanan, maka sintesis 2 macam sintesis DNA. Pertama sintesis kontinyu (sintesis DNA baru yang searah) atau leading strand, dan sintesis diskontinyu (sintesis DNA baru yang berlawanan arah) atau lagging strand. Sintesis DNA pada untai yang diskontinyu mengawali fragmen terputus-putus, yang masing-masing mempunyai arah 5'→3'. Terjadinya sintesis DNA diskontinyu disebabkan RNA primer selanjutnya akan terdegradasi oleh aktivitas DNA polimerase I. Bagian RNA yang terdegradasi selanjutnya digantikan dengan molekul DNA dari DNA polimerase I. Proses replikasi DNA diakhiri dengan terminasi replikasi. Titik tempat penghakhiran replikasi disebut titik terminasi.

Perhatikan video penggambaran proses replikasi DNA!

video replikasi dna

(12) DNA Replication Process View

(13) Protein Synthesis View

(14) Biocomic View

(15) Codon Wheel View

(16) Bionews CRISPR View

(17) Bionews Benefits of CRISPR in Humans

Figure 8. E-BIOMAGZ Content Sections.

3. Closing Section

- Crossword Evaluation

The evaluation section contains a crossword puzzle game that can be completed by answering questions listed on each puzzle block. This section consists of the title BIOGAMES TTS Genetic Material, TTS display, and a button/icon with the word "PLAY" that can be clicked to take students to the WordWall website display if the device is connected to an internet connection.



Figure 9. Crossword evaluation view.

- Reference List

The reference list is a list of references used in compiling E-BIOMAGZ which contains the book's title or journal's title and the author's name as a valid reference source.



Figure 10. Reference list view.

- Back Cover

Part of the back cover display contains the title E-BIOMAGZ genetic material and the compiler's history. This biography contains the place and date of birth, history of education taken, experience in the world of education, and achievements ever achieved.



Figure 11. Back cover view and author history.

3.3.3. Compiling Expert Assessment Instruments

The assessment instrument contains several assessment aspects to measure the appropriateness of the content of the material, language, presentation of the material, and graphics of the learning media that has been created (Pedoman Penilaian Buku Pendidikan, 2022). The assessment for material experts consists of aspects of curriculum, content eligibility, and language (Daryanes et al., 2023). The assessment for media experts consists of aspects of cover design, content design, multimedia, product anatomy, and programming. The assessment instrument designed adopts aspects compiled by (Pedoman Penilaian Buku Pendidikan, 2022), it has been checked and revised based on the results of the judgment of the Biology Education lecturer at Sultan Ageng Tirtayasa University.

3.4. . Design Validation

The design validation stage aims to obtain a product quality assessment to be used as a learning media. It is carried out by a team of material experts and media experts consisting of two material experts and two media experts. The material expert team consists of lecturers in biology education who have conducted research in molecular genetics and lecturers in science education who have conducted research in microbiology. The media expert team consists of a lecturer in biology education, the biology of developing learning media, and a lecturer in science education, the science of developing learning media.

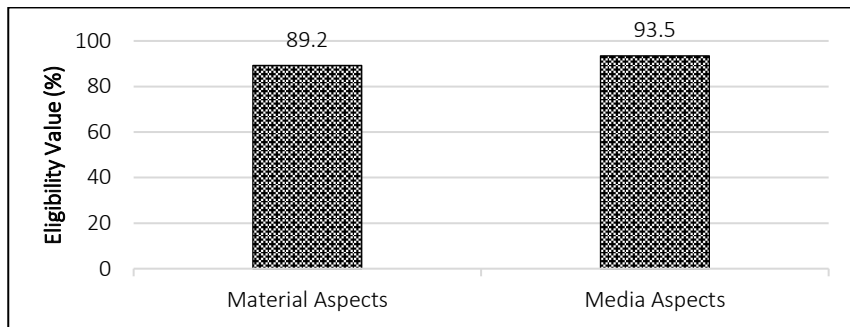


Figure 12. Expert assessment results.

The material expert's validation results obtained a value of 89.2% and the media expert's obtained a value of 94%. The overall validation results obtained an average percentage value of 91.35%. Based on these results, the development of E-BIOMAGZ as a biology learning medium received a category that is very worthy of use as a biology learning media.

1. Material Expert

The assessment of material validation includes several aspects, namely the curriculum aspect, content eligibility, and language. The value for each aspect of the curriculum is 84%, the content eligibility aspect is 94%, and the language aspect is 90%. The overall results of the instrument assessment by the material expert team were that the average percentage value obtained a value of 89.2% with the eligibility category based on the E-BIOMAGZ table as a biology learning media, namely very worthy.

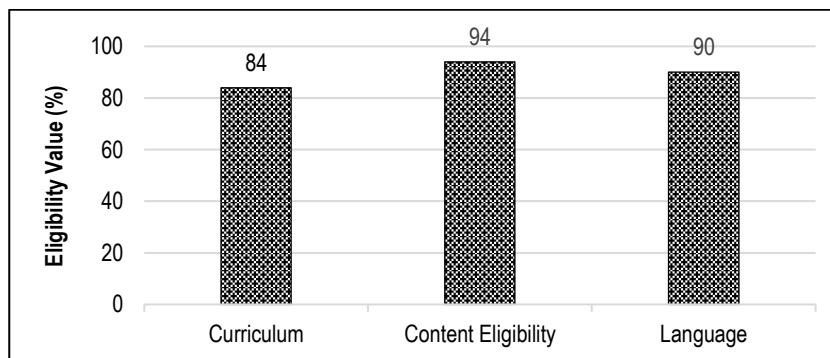


Figure 13. Material expert validation results.

2. Media Expert

The assessment of material validation includes several aspects, namely cover design, content design, multimedia, product anatomy, and programming. The value for each aspect of cover design is 86%, the content design aspect is 98%, the multimedia aspect is 98%, the product anatomy aspect is 80%, and the programming aspect is 100%. The overall results of the instrument assessment by the media expert team show that the average percentage value is 94% with an eligibility category based on the E- BIOMAGZ table as a biology learning media, which is very worthy.

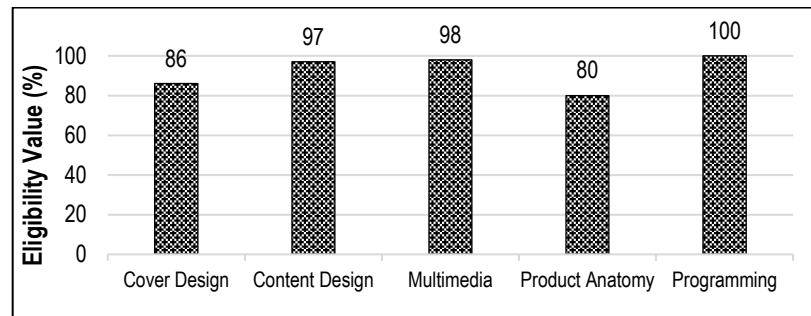


Figure 14. Media expert validation results.

3.5. Design Revision

After validating the learning media design by a team of material experts and a team of media experts, the next step is to revise the deficiencies and input on the learning media that was developed, namely:

1. Curriculum Aspect

According to the material expert team, improvements in the curriculum aspect are in the relationship between genes, DNA, and chromosomes section and in the evaluation section. Before the revision, E-BIOMAGZ had not explained the relationship between genes, DNA, and chromosomes so it received a correction to add material on the relationship between genes, DNA, and chromosomes because without material explaining the relationship between genes, DNA, and chromosomes, it would lead to misconceptions that each component of genetic material is each.

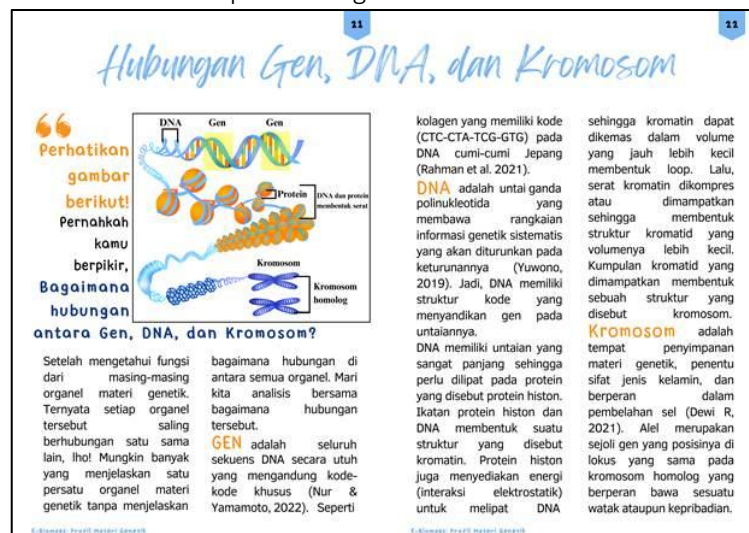


Figure 15. Results of the revision of curriculum aspect (KD demands).

Before the revision of E-BIOMAGZ, there was an incomplete evaluation of meeting the KD demands, E-BIOMAGZ received corrections to adjust the evaluation according to the KD demands so that the evaluation can measure the ability of students whether or not the KD demands are achieved in learning. The solution from the correction results is to design a learning evaluation according to the KD demands to assess students' abilities.

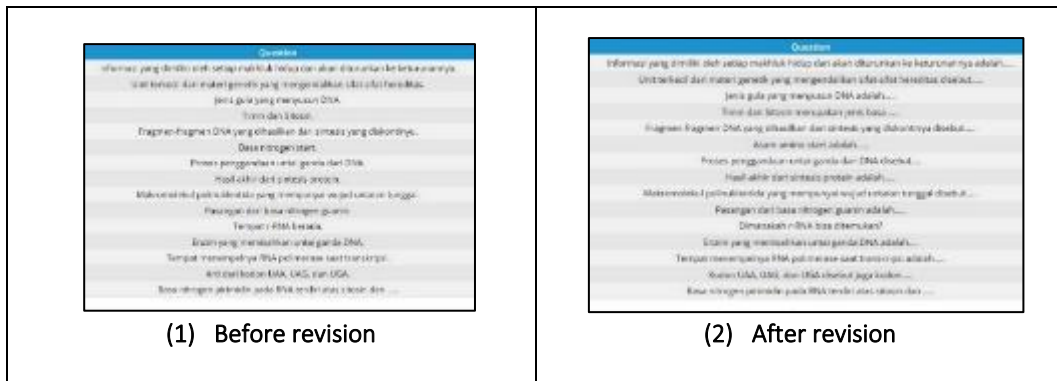


Figure 16. Results of curriculum aspect revision (Evaluation).

2. Content Eligibility Aspect

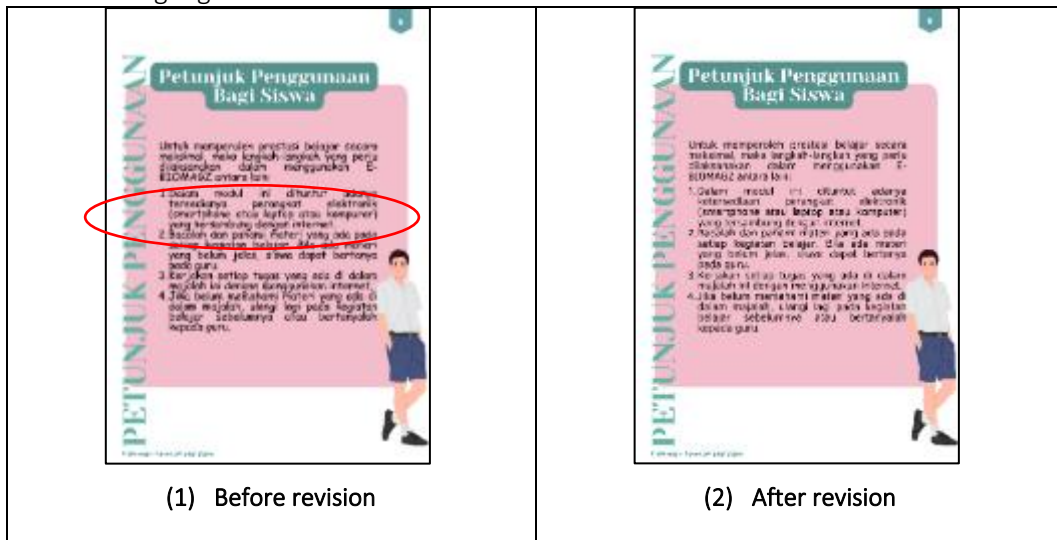
Before the revision, E-BIOMAGZ had learning videos that did not use Indonesian subtitles, which could cause students not to understand the material's content. Therefore, E-BIOMAGZ received corrections to add Indonesian subtitles as a tool to help students understand the content of the videos presented.



Figure 17. Results of the revision of the content eligibility aspect.

3. Language Aspect

Before the revision, the content presented in E-BIOMAGZ had a less communicative and effective language structure, so it was corrected to replace several less communicative sentences such as in the instructions for use for students and in the text bubble section in the biocomic, so improvements were needed to change these sentences into sentences that are following Indonesian language rules and communicative language.



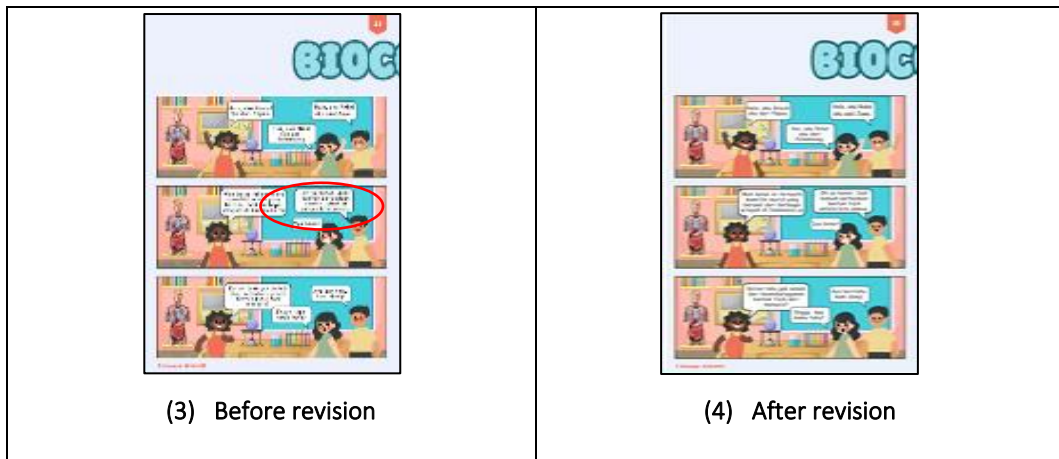


Figure 18. Results of the revision of the language aspect.

4. Cover Design Aspect

Before the revision of the content display of E-BIOMAGZ, several article designs were not quite right, so they were corrected to change the font on the chromosome article display. Changing the font type from Comic Sans MS to Clear Sans aims to make the article display more attractive and formal. The font changes aim to make the E-BIOMAGZ content display attractive and interactive to attract students' interest in reading when using E-BIOMAGZ in learning.

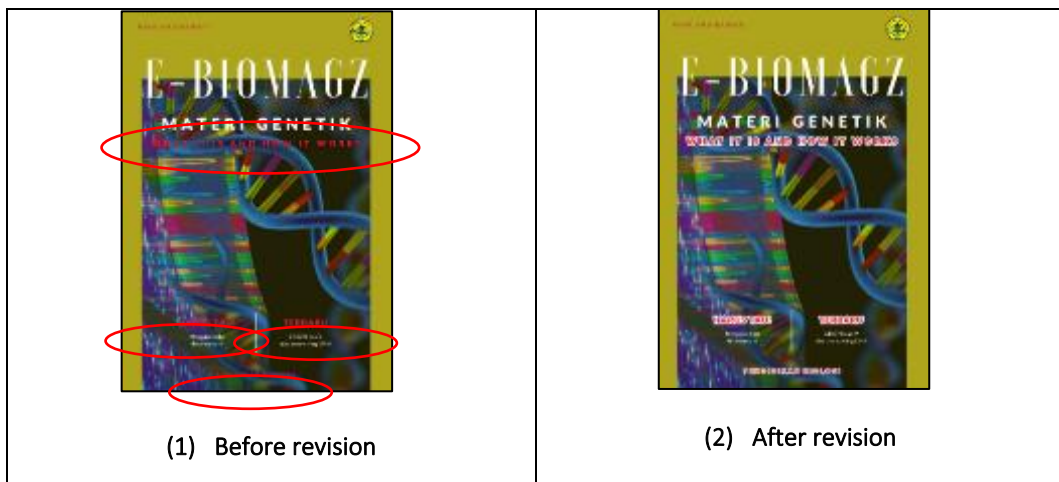


Figure 19. Results of revision of cover design aspects.

5. Content Design Aspect

Before the revision of the content display of E-BIOMAGZ, several article designs were not quite right, so they were corrected to change the font on the chromosome article display. Changing the font type from Comic Sans MS to Clear Sans aims to make the article display more attractive and formal. The font changes aim to make the E-BIOMAGZ content display attractive and interactive to attract students' interest in reading when using E-BIOMAGZ in learning.

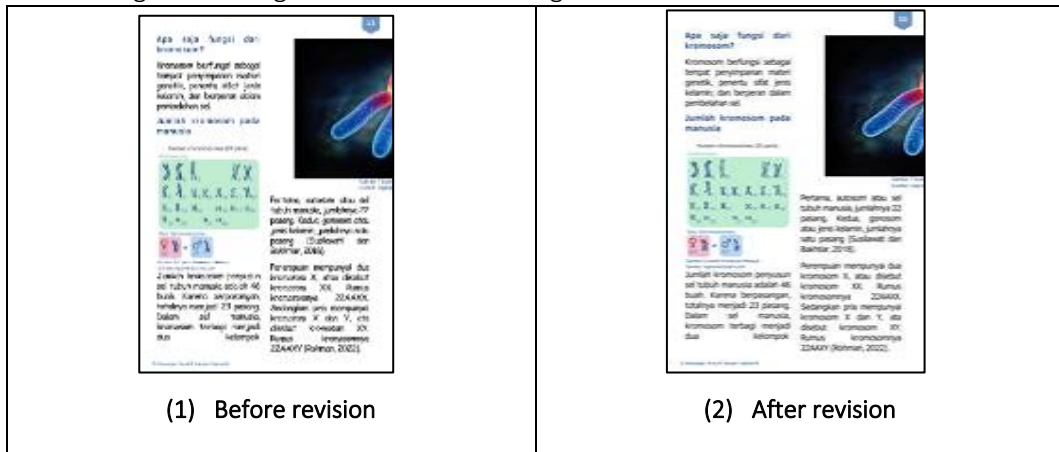


Figure 20. Results of revision of content design aspect

6. Multimedia Aspect

Before the revision of the multimedia display of E-BIOMAGZ, several elements such as images, videos, and audio were not appropriate to be presented in E-BIOMAGZ. The image element has a correction to add graphs illustrating the discoveries the scientists discussed. The video and audio elements get the same correction as the aspect of content suitability, namely to add Indonesian subtitles. Learning media equipped with the right multimedia will provide a clear learning experience because images, videos, and audio are presented to illustrate the material being explained. This improvements are made according to students' need because the use of interactive multimedia will attract students' attention in fulfilling learning material (Sholikah & Harsono, 2021).



Figure 21. Results of the revision of the multimedia aspects.

7. Product Anatomy Aspect

Before the revision of E-BIOMAGZ, the product's anatomy lacked material to meet the demands of KD regarding the relationship between genes, DNA, and chromosomes, so it was corrected to add content to complete the demands of the KD.

8. Programming Aspect

In the programming aspect, E-BIOMAGZ does not receive correction from experts because E-BIOMAGZ is easy to access and operate and does not require special specifications on the device used. To access E-BIOMAGZ, a stable internet connection is required so that it displays E-BIOMAGZ with good quality. The ease and practicality of E-BIOMAGZ are intended so that students can carry out the learning process anywhere and anytime.

3.6. . Product Trial

After going through the validation and design revision stages from the material and media expert teams, the next stage is that the product will be tested with a limited trial. During the product trial, several stages were carried out, namely students operating the learning media that was created, students were given a product trial questionnaire and asked to fill in and assess the product that had been operated. The trial process was carried out with the assistance and supervision of a biology subject teacher on January 30, 2024. The results of the limited trial obtained the highest value in the multimedia aspect of E-BIOMAGZ at 98.8%, which was categorized as very worthy. In assessing the usefulness aspect, a value of 94.64% was obtained, categorized as very worthy. Overall, the limited product trial on E-BIOMAGZ obtained a value of 96.5%, so Biology E-Magazine (E-BIOMAGZ) is a learning media that is very worth using in the learning process.

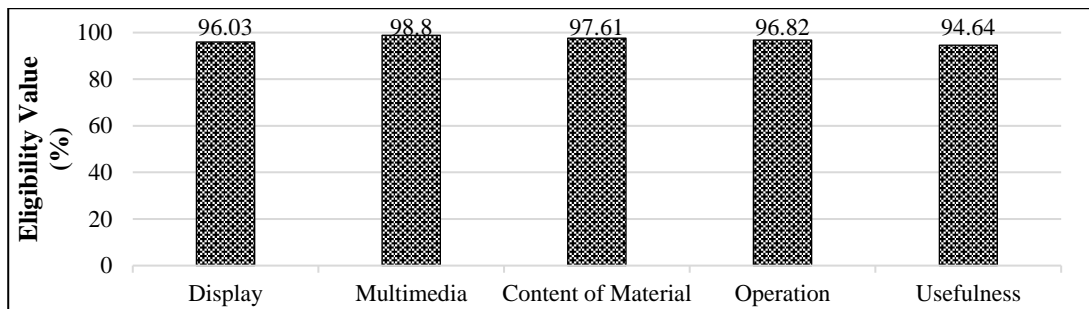


Figure 22. Limited trial results

4. CONCLUSION

The development of a multimedia-based Biology E-Magazine (E-BIOMAGZ) on genetic material was carried out through the Research and Development (R&D) process, which was divided into six stages: potential and problem analysis, data collection, product design, design validation, design revision, and product trial. The design validation stage was assessed by the material expert team, which received a score of 89.2%, and by the media expert team, which received a score of 93.5%. The limited product trial stage got a score of 96.5%. Based on the assessment results, the development of a multimedia-based Biology E-Magazine (E-BIOMAGZ) on genetic material is a worthy category for use in learning activities.

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