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Implementation of White Box Testing in Android Based Learning Media

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ABSTRACT *– This research is motivated by the fact that computer instruction at MTs Ishlahul Ummah remains conventional, which diminishes student motivation and comprehension. The research problem focuses on how to implement and test the logical structure of code within an Android-based learning tool. A qualitative descriptive approach was employed, utilizing observation, interviews, documentation, and a literature review. Additionally, White Box Testing specifically using 'flutter test'was applied to evaluate the application's core functions. The test results indicate that all testing phases successfully executed the sequences of source code statements across various program logic paths. Nevertheless, these findings require further evaluation to anticipate potential hidden logic errors that might arise under more complex conditions. The study concludes that the application of White Box Testing effectively verifies the validity of the program's internal code structure, rendering this Android-based learning tool a suitable resource for supporting interactive computer education for students.*

Keywords *- Learning Medium, Android, White Box Testing*

Implementasi White Box Testing Pada Media Pembelajaran Berbasis Android

ABSTRAK *–Penelitian ini dilatarbelakangi oleh proses pembelajaran komputer di MTs Ishlahul Ummah yang masih konvensional, sehingga menurunkan motivasi dan pemahaman siswa. Rumusan masalah dalam riset ini berfokus pada bagaimana mengimplementasikan dan menguji struktur logika kode pada media pembelajaran berbasis Android. Metode penelitian menggunakan pendekatan deskriptif kualitatif melalui observasi, wawancara, dokumentasi, dan studi literatur, serta teknik White Box Testing menggunakan flutter test untuk menguji fungsi-fungsi inti aplikasi. Hasil pengujian menunjukkan bahwa seluruh tahapan pengujian berhasil mengeksekusi rangkaian pernyataan kode sumber secara komprehensif pada berbagai jalur logika program. Meskipun demikian, hasil ini tetap memerlukan evaluasi lanjutan guna mengantisipasi potensi kesalahan logika tersembunyi pada kondisi yang lebih kompleks. Kesimpulan dari penelitian ini adalah penerapan White Box Testing mampu memverifikasi validitas struktur internal kode program, sehingga media pembelajaran berbasis Android ini layak digunakan sebagai sarana pendukung pembelajaran komputer yang interaktif bagi siswa.*

Kata Kunci *–Media Pembelajaran, Android, White Box Testing.*

1. INTRODUCTION

In the current digital era, the use of innovative media is essential to help students grasp learning materials more easily. At MTs Ishlahul Ummah, computer instruction currently relies on conventional methods—primarily lectures and direct explanations from teachers, supplemented by a blackboard and textbooks. This approach makes it difficult for students to understand fundamental computer concepts, such as hardware, software, operating system functions, and relevant practice exercises. Furthermore, the lack of visual and interactive learning media creates a monotonous classroom environment, which diminishes student motivation and participation.

As a solution, the development of Android-based learning media offers a promising alternative; such platforms are easily accessible, open-source, and already familiar to students. Android enables the creation of interactive applications that facilitate learning anytime and anywhere. However, for these learning tools to be reliable and function optimally, software quality is a critical factor. The developed application must be free from logical errors, bugs, or flaws in its internal code structure to ensure that the student's learning process is not hindered.

Consequently, quality assurance—achieved

through software testing—is an indispensable phase. One rigorous testing technique used to examine a program's internal structure and logical pathways is "White Box Testing." This method involves testing the source code, logic paths, branching conditions, and loops within the Android-based learning application [1]. Such testing is vital to ensure that every module, function, and algorithm in the application operates correctly according to the system design.

The application of White Box Testing to Android-based learning media is also supported by the need for valid, effective, and reliable digital systems in education [2]. By examining the application's internal structure, potential system failures—which might otherwise occur when students use the software—can be minimized early on. This ensures that the learning media is not only visually engaging but also possesses a high level of logical accuracy and reliability. Based on this background, this study focuses on the implementation of White Box Testing for an Android-based learning medium at MTs Ishlahul Ummah. Through this research, it is expected that the reliability of the program code structure of the developed application can be evaluated, ultimately resulting in a valid, high-quality computer-based learning medium capable of optimally enhancing student learning effectiveness.

2. LITERATURE REVIEW

1. Learning Media

Learning media encompasses any tools, materials, or resources used to convey messages and information during the teaching and learning process, helping students grasp subject matter more effectively [3]. Such media may take the form of text, images, audio, video, graphics, animations, or interactive elements accessed via technology-based applications or platforms. Utilizing these media makes learning activities more engaging and dynamic, fostering an enjoyable and meaningful educational environment. Furthermore, these media serve as a bridge between teachers and students, ensuring that instructional content is communicated with greater clarity, concreteness, and accessibility.

Learning media offer teachers the flexibility to innovate in the design of instructional materials, tailoring them to the specific characteristics of their students and the intended learning objectives [4]. Simultaneously, students gain the opportunity for independent learning, unconstrained by limitations of time or space. Through the implementation of digital learning, students can engage directly with the material, explore subjects in greater depth, and develop a contextual understanding. The use of interactive media has been shown to enhance both motivation and learning outcomes by integrating text, images, audio, and video into a cohesive experience.

Based on these perspectives, it can be concluded that learning media play a strategic role in improving the quality of the teaching and learning process in the age of technology. These media function not merely as aids for information delivery, but as instruments for shaping an active, creative, and autonomous learning experience. Through the use of e-learning and interactive media, the learning process becomes more flexible and communicative, while also cultivating the critical thinking and problem-solving skills essential for navigating the challenges of modern education.

2. Android

Android is an open-source, Linux-based operating system developed by Google for mobile devices such as smartphones and tablets [5]. It is designed with an open architecture that grants developers the freedom to create, modify, and develop applications tailored to user needs. Android also provides a wide range of supporting libraries and Application Programming Interfaces (APIs) that simplify the development of interactive applications across various fields, including education. With this support, Android has become one of the most popular and widely used platforms for developing modern, innovative, and engaging learning media for students.

One of Android's key advantages is its ability to run applications with a simple, user-friendly interface accessible to a broad range of users [6]. The system can also adapt its display to various screen sizes, ensuring an optimal user experience. In an educational context, Android offers significant potential for developing innovative learning media, as it supports diverse multimedia elements—such as videos, images, animations, and audio—that enhance the appeal and effectiveness of the teaching and learning process.

Based on these points, it can be concluded that Android is an ideal platform for developing digital learning media due to its open, flexible, and accessible nature. Its portability allows students to learn anytime and anywhere, free from the constraints of space or time. Furthermore, its support for multimedia features makes Android an effective and efficient tool for creating interactive and engaging learning experiences that are highly relevant to educational needs in the digital age.

3. Android-Based Learning Media

Android-based learning media are tools that integrate mobile technology into the teaching and learning process, helping students grasp subject matter in a more engaging and interactive way [7]. These media are developed as applications that run on Android-based smartphones or tablets, containing

learning materials systematically organized to align with educational objectives. Through mobile learning, students can engage in independent study by utilizing features such as animations, instructional videos, interactive quizzes, and simulations—all designed to suit the specific characteristics of the learners. Consequently, Android-based media play a vital role in fostering an innovative learning process that adapts to technological advancements.

Android-based learning media also facilitate the delivery of course content for teachers [8]. Educators can present material in an engaging format, update content in line with the curriculum, and tailor the presentation to meet the needs and learning styles of their students. Another key advantage is flexibility, as it allows students to learn anytime and anywhere, unconstrained by time or physical space.

Given these points, it can be concluded that Android-based learning media play a strategic role in enhancing the quality of education through the use of interactive digital technology. These media serve not merely as visual aids, but as tools capable of boosting learning motivation and creating an enjoyable, contextual learning environment that meets the demands of education in the digital age. Furthermore, such media promote a more efficient learning process that is highly relevant to the habits of a modern generation accustomed to digital devices.

4. Definition of Computer Lessons

A computer is a set of electronic devices used to input data, which is then processed according to specific instructions—dictated by the software being run—to produce output in the form of information that has been refined to be more meaningful to the user [9]. Based on this definition, computer studies can be understood as a subject aimed at equipping students with the ability to comprehend how computers function, operate hardware and software, and apply information technology in their daily lives. Furthermore, computer studies help students grasp the fundamental concepts of logic and algorithms, which serve as the foundation for data processing.

Computer studies play a vital role in enhancing students' digital literacy and fostering higher-order thinking skills [10]. In today's digital era, the subject goes beyond the technical aspects of device usage; it also contributes to the development of critical, creative, collaborative, and communicative thinking abilities. In this process, the teacher acts as a facilitator, helping students understand the contextual application of technology. This enables students to utilize computers not merely as learning aids, but also as tools for innovation and real-world problem-solving.

In light of this, it can be concluded that computer studies serve to build digital literacy and prepare students for the rapid evolution of information technology. Through computer-related coursework, students engage in learning that is both interactive and practical, allowing them to master the core principles of computer systems and networks. Consequently, computer studies not only enhance students' technical competence but also cultivate the logical, creative, and adaptive thinking skills necessary to navigate the challenges of the digital age.

3. RESEARCH METHODS

Qualitative research is a scientific approach used to understand and interpret the meaning of social events from the perspectives of the participants. This type of research emphasizes processes, contexts, and meanings that emerge naturally in the field, without manipulation by the researcher. Qualitative research seeks to describe phenomena in depth, utilizing the researcher as the primary instrument for data collection and analysis [11].

Given the research focus—which centers on software testing and analysis—a qualitative descriptive approach is employed. This approach provides a comprehensive overview of the entire process, ranging from the analysis of logic flows and the design of test scenarios to the outcomes of White Box Testing applied to an Android-based learning medium, all within its specific context. This methodology enables the researcher to gain an in-depth understanding of the quality of the internal code structure, the validity of decision paths (logic paths), and the overall reliability of the learning application.

1. Data Collection Technique

Data collection is a crucial stage in this research, as the quality of the data obtained significantly influences the accuracy and success of the system design being developed. To ensure the data is both accurate and relevant, this research employs several data collection methods: observation, interviews, documentation, and a literature review. Observations were conducted by directly monitoring the computer learning process at MTs Ishlahul Ummah. This activity aimed to assess the actual state of instruction, including the teaching methods employed by the instructor, the level of student engagement, and the available supporting facilities. Through these observations, the researcher was able to identify various challenges arising during the learning process, such as limited instructional media, a lack of variety in teaching methods, and low student interest in computer lessons. The findings from these observations serve as a crucial foundation for designing Android-based learning media, which is expected to enhance both the effectiveness of instruction and student motivation.

Interviews were conducted with the computer subject teacher, who served as the primary informant. This activity aimed to gather in-depth information regarding the ongoing instructional process, the challenges encountered in delivering course material, and the requirements for learning media tailored to the students' characteristics. Through these interviews, the researcher obtained data essential for understanding how Android-based learning media can assist the teacher in presenting computer-related content in a more interactive, engaging, and accessible manner for students. The findings from these interviews also served as a basis for determining the features and design of the learning media, ensuring they align with the specific instructional needs at MTs Ishlahul Ummah. Documentation was carried out by collecting various documents and supporting data related to the computer learning process at MTs Ishlahul Ummah. The collected materials include teaching resources, student learning assessment results, and records of relevant learning activities. This data was analyzed to understand the structure of the subject matter, the intended learning competencies, and the students' need for more engaging and interactive learning media. Furthermore, this documentation technique assisted the researcher in tailoring the content design and interface of the Android-based learning media to ensure alignment with the curriculum and the specific characteristics of the students in the computer subject.

A literature review was conducted by examining various academic and non academic source such as scholarly journals, books, conference proceedings, and prior research pertaining to Android based learning media, educational technology, and computer-related instruction. This process aimed to establish a robust theoretical foundation regarding the concepts of digital learning media, interactive instructional strategies, and effective approaches for enhancing student learning motivation. Through this literature review, the researcher was also able to gain insight into the latest technological developments and determine media development methods tailored to the needs of students in computer subjects at MTs Ishlahul Ummah. Consequently, this research is grounded in a relevant scientific basis that supports the implementation of innovative learning media within the *madrasah* (Islamic school) environment.

2. System Testing

System testing is conducted to ensure that the Android-based learning media for computer subjects functions according to its original design. The testing method employed in this study is White Box Testing. This approach focuses on the internal structure of the program—such as logic flow, branching, and code execution paths—to verify that every component operates correctly as intended [12]. In this study, White Box Testing is performed using the built-in tools provided by the Flutter framework, specifically `flutter test`, which is used to validate program functions and logic based on the application's source code.

White Box Testing was selected due to the complex logic inherent in the developed application. Through this method, the researchers can confirm that all core functions such as user login, access to learning materials, and the storage of evaluation results operate as expected, free from logical errors within the code. Furthermore, the use of `flutter test` ensures a more structured testing process, making it easier to detect errors within individual application modules.

The testing process involves executing each application module, tracing execution paths, and verifying that the outputs align with the provided inputs. The results are used to identify and rectify any errors that may arise before the application is fully implemented. Consequently, White Box Testing provides assurance that the developed learning media application possesses a high level of reliability, stability, and accuracy, effectively supporting computer-based learning within the school environment.

4. RESULTS AND DISCUSSION

In this study, system testing was conducted using the white-box testing method to analyze the program's logic flow within an Android-based educational application for computer-related subjects. The testing involved analyzing the source code for several core system processes, including user login, learning material management, practice exercises, assessment of exercise results, language settings, and the application logout process. The analysis began by identifying the source code used in each function, followed by the identification of statements that influence the system's execution flow. These statements served as the basis for creating flowcharts and flowgraphs, which provide a structured representation of the program's process flow. The study utilized 'flutter test' a built in tool within the Flutter framework to assist in testing program functions based on the application's source code.

Once the flowgraphs were established, the cyclomatic complexity was calculated to determine the minimum number of independent paths that must be tested for each program function. This complexity value was used to identify the independent paths, which represent the various execution routes within the system. Based on these independent paths, test cases were developed to ensure that all program logic flows operate as

expected covering aspects such as login validation, menu navigation, material selection, completion of practice exercises, and the storage of user performance results.

The final stage of testing employed statement coverage to evaluate whether every statement in the source code had been executed during the testing process, ensuring that the application functions correctly and meets user requirements.

Login Function Testing

a. Identification of Login Function Statements

Table 1. Identification of Login Function Statements

Statement	Source Code	information
S1	setState(() => *_error* = *False*)	Reset status *error*
S2	*password* = *_password*.text.trim()	Mengambil input *password*
S3	`if (*_User*name.text.isEmpty	
S4	setState(() => *_error* = *True*)	Menampilkan *error* input kosong
S5	if (*password*.length > 10)	Validasi panjang *password*
S6	SnackBar('*Password* maksimal 10 karakter')	Menampilkan pesan *password* terlalu panjang
S7	*regex* = *Regex*p(...)	Membuat validasi *regex password*
S8	if (!*regex*.hasMatch(*password*))	Validasi kombinasi huruf dan angka
S9	SnackBar('*Password* wajib mengandung huruf dan angka')	Menampilkan pesan validasi *password*
S10	setState(() => _loading = *True*)	Mengaktifkan loading
S11	*Firebase*Firestore.instance.collection()	Mengambil data *User Firebase*
S12	if (result.docs.isNotEmpty)	Memeriksa *User* ditemukan
S13	Session.uid = doc.id.toString()	Menyimpan session *User*
S14	Navigator.pushReplacement(...)	Navigasi ke halaman home
S15	setState(() => *_error* = *True*)	Menampilkan login gagal
S16	catch (e)	Menangkap *error* system
S17	_loading = *False*	Menghentikan loading
S18	*_error* = *True*	Menampilkan *error* sistem

b. Statement Coverage for the Login Function

Statement coverage is used to measure the extent to which all statements within the login function have been executed through the designed test cases. This testing aims to ensure that every statement in the program is executed at least once, allowing for a thorough verification of the program's logic.

The statements executed for each test case are as follows:

1. TC1: S1, S2, S3, S4
2. TC2: S1, S2, S3, S5, S6
3. TC3: S1, S2, S3, S5, S7, S8, S9
4. TC4: S1, S2, S3, S5, S7, S8, S10, S11, S12, S15
5. TC5: S1, S2, S3, S5, S7, S8, S10, S11, S12, S13, S14

Based on the test results, all statements in the login function—from S1 to S18—were successfully executed through the combination of test cases TC1, TC2, TC3, TC4, and TC5. Consequently, the statement coverage value is:

18/18 × 100% = 100%

This value indicates that every statement within the login function has been tested, and all possible program execution paths have been covered during the white-box testing process.

c. Identify the Logout Function Statement

Table 2. Identify the Logout Function Statement

Statement	Source Code	information
S1	void *_Logout*(BuildContext context)	Sistem menjalankan fungsi *Logout*
S2	final t = text[*widget*.language]!;	Sistem mengambil data bahasa sesuai pilihan pengguna
S3	showDialog(...)	Sistem menampilkan dialog konfirmasi *Logout*
S4	builder: (_) => AlertDialog(...)	Sistem menampilkan isi dialog *Logout*
S5	onPressed: () => Navigator.pop(context)	Pengguna memilih tombol batal
S6	Navigator.pop(context)	Sistem menutup dialog *Logout*
S7	onPressed: () { ... }	Pengguna memilih tombol *Logout*

Statement	Source Code	information
S8	Navigator.pop(context)	Sistem menutup dialog konfirmasi
S9	Navigator.pushAndRemoveUntil(...)	Sistem menghapus seluruh halaman sebelumnya
S10	builder: (_) => const LoginPage()	Sistem mengarahkan pengguna menuju halaman LoginPage
S11	(route) => *False*	Sistem mengakhiri seluruh halaman sebelumnya
S12	child: Text(t['yes']!)	Proses *Logout* selesai

d. Statement Coverage for the Logout Function

Statement coverage is used to measure the extent to which all statements within the Logout function have been executed through the designed test cases. This testing aims to ensure that every statement in the program is executed at least once, allowing for a thorough verification of the program's logic.

Executed Statements:

TC1: S1, S2, S3, S4, S5, S6

TC2: S1, S2, S3, S4, S7, S8, S9, S10, S11, S12

Based on the test results, all statements in the Logout function—from S1 to S12—were successfully executed using a combination of test cases TC1 and TC2. Consequently, the statement coverage is calculated as follows:

12/12 × 100% = 100%

This value indicates that every statement within the Logout function has been tested, and all possible program execution paths have been covered during the white-box testing process.

e. Identification of the Save Material Function Statement

Table 3. Identification of the Save Material Function Statement

Statement	Source Code	information
S1	_judulController.text.isEmpty	Memeriksa input judul kosong
S2	_isiController.text.isEmpty	Memeriksa input isi kosong
S3	Return	Menghentikan proses jika input kosong
S4	String? imageUrl;	Membuat variabel URL gambar
S5	if (_gambar != null)	Memeriksa apakah gambar dipilih
S6	uploadToCloudinary(_gambar!)	Upload gambar ke Cloudinary
S7	if (_editDocId == null)	Memeriksa proses tambah atau edit
S8	.add({...})	Menambahkan data materi baru
S9	.update({...})	Memperbarui data materi
S10	_resetForm()	Mengosongkan form
S11	if (!mounted) return	Memeriksa *widget* masih aktif
S12	Navigator.pop(context)	Menutup dialog
S13	catch (e)	Menangani *error* Firestore
S14	debugPrint(...)	Menampilkan log *error*

f. Statement Coverage for the "Save Material" Function

Statement Coverage is used to measure the extent to which all statements within the "save material" function have been executed via the designed test cases. This testing aims to ensure that every statement in the program is executed at least once, allowing for a thorough verification of the program's logic.

Executed Statements:

TC1:

S1, S2, S3

TC2:

S1, S2, S4, S5, S6, S7, S8, S10, S11, S12

TC3:

S1, S2, S4, S5, S7, S8, S10, S11, S12

TC4:

S1, S2, S4, S5, S6, S7, S9, S10, S11, S12

TC5:

S1, S2, S4, S5, S6, S7, S9, S10, S11

Based on the test results, all statements in the "save material" function—from S1 to S14—were successfully executed through the combination of test cases TC1, TC2, TC3, TC4, and TC5. Consequently, the Statement Coverage value is:

14/14 × 100% = 100%

This value indicates that every statement within the "save material" function has been tested, and all possible program execution paths have been covered during the white-box testing process.

g. Identification of the Statement for the Material Deletion Function

Table 4. Identification of the Statement for the Material Deletion Function

Statement	Source Code	information
S1	final t =text[*widget*.language] ?? text['ID']!;	Mengambil teks sesuai bahasa

Statement	Source Code	information
S2	showDialog(...)	Menampilkan dialog konfirmasi
S3	Navigator.pop(context)	Menutup dialog saat batal
S4	.collection('materi_hardware')	Mengakses collection Firestore
S5	.doc(docId)	Mengambil dokumen berdasarkan ID
S6	.delete()	Menghapus data materi
S7	Navigator.pop(context)	Menutup dialog setelah hapus berhasil

h. Statement Coverage for the 'Delete Material' Function

Statement coverage is used to ensure that every statement within the 'delete material' function is executed at least once during the testing process.

In test case TC1, the statements executed include displaying a confirmation dialog and canceling the data deletion. In test case TC2, the statements executed encompass accessing the Firestore collection, retrieving a document based on its `docId`, and performing the actual deletion of the material data.

Based on the test results, all statements within the 'delete material' function were successfully executed through the combination of test cases TC1 and TC2, resulting in a statement coverage value of:

$8/8 \times 100\% = 100\%$

This result indicates that every statement in the 'delete material' function has been successfully tested and that all program flows function correctly.

i. Identify the Statement for the Add Exercise Function

Table 5. Identify the Statement for the Add Exercise Function

Statement	Source Code	information
S1	titleController.text.trim()	Mengambil input nama latihan
S2	If(titleController.text.trim().isEmpty)	Memeriksa apakah input kosong
S3	return;	Menghentikan proses jika input kosong
S4	_firestore.collection('latihan_soal')	Mengakses collection latihan_soal
S5	.add({...})	Menambahkan data Latihan
S6	'title': titleController.text.trim()	Menyimpan nama Latihan
S7	'created': FieldValue.serverTimestamp()	Menyimpan waktu pembuatan
S8	if (!mounted)	Memeriksa status *widget*
S9	return;	Menghentikan proses jika *widget* tidak aktif
S10	Navigator.pop(context)	Menutup form tambah Latihan

j. Statement Coverage for the "Add Exercise" Function

Statement coverage is used to measure the extent to which all statements within the "add exercise" function have been executed through the designed test cases. This testing aims to ensure that every statement in the program is executed at least once, allowing for a thorough verification of the program's logic.

Executed statements:

TC1: S1, S2, S3
TC2: S1, S2, S4, S5, S6, S7, S8, S9
TC3: S1, S2, S4, S5, S6, S7, S8, S10

Based on the test results, all statements in the "add exercise" function—from S1 to S10—were successfully executed through the combination of test cases TC1, TC2, and TC3. Consequently, the statement coverage value is:

$10/10 \times 100\% = 100\%$

This value indicates that every statement in the "add exercise" function has been tested, and all possible program execution paths have been covered during the white-box testing process.

5. CONCLUSION

Based on the research, design, implementation, and system testing conducted, the following conclusions can be drawn: The Android-based learning application developed serves as an effective support tool for computer studies at MTs Ishlahul Ummah. It provides learning materials on hardware and software, practice exercises, and feedback on those exercises, helping both teachers and students engage in a more structured and effective learning process. The Android-based learning tool facilitates students' understanding of computer-related topics through an interactive, simple, and user-friendly interface. The inclusion of images, digital content, and practice exercises enhances student motivation and makes the learning process more engaging compared to conventional methods. The application is accessible via Android-based mobile devices,

allowing students to learn anytime and anywhere. By leveraging Android technology, the learning process becomes more flexible and aligned with current advancements in digital technology. The implementation of Firebase Firestore as a database storage solution enables the organized and integrated management of user data, learning materials, practice exercises, and exercise results. Furthermore, a role-based access control system (for teachers and students) ensures data security and facilitates more efficient application management.

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