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# Microservices Scheduling Algorithms: A Survey Study

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**Abstract**: The development of many large and complex applications has led to the need to come up with a better solution to manage those applications from one large system into a combination of small services that work together in a cohesive way for a widely used application where it can be easy to deploy, configure, and scale. The popularity of microservices architecture in different fields has made it susceptible to development, especially in task scheduling. We report on the scheduling algorithms that have been used by many researchers and discuss their approaches. This report will help us ameliorate the flexibility of the system in future studies.

**Keywords**: Microservices architecture, Container, Performance Metrics, Microservices Scheduling Techniques.

## I. INTRODUCTION

The microservices architecture is the solution to go from large and complex applications to a combination of small services that can be deployed, configured, or even scaled [1]. Many organizations tried to solve the problem of complex applications that consume time, energy, and cost to deploy, configure, or scale. For this purpose, the concept of microservices can help us divide our application into smaller, interconnected services.

Microservices enable the user to build and maintain the application in the easiest way possible. Before microservice architecture, there was what we call monolithic architecture [2]. The code side of the monolithic architecture is implemented as one large system that shares the same database, which will lead to many problems in terms of management and the redeployment of the whole application.

To solve those problems, we moved from monolithic architecture into SOA architecture, which is an acronym for service-oriented architecture [3]. This architecture separates services into different modules that communicate with each other via a service bus to form the whole application. The problem in SOA architecture is the database storage that is shared with the whole application, as well as the increase in response time and machine load because of the interaction between services. Which leads us to microservices architecture, where the application is created using multiple microservices and each has its own database.

However, there are many tools that support microservices in building applications [4]. Docker, for instance, packages up code and all its dependencies and libraries so that applications can run from one computing environment to another, for instance, from a developer's laptop to another test environment. There are several benefits to containers, such as the fact that they could be lightweight because they share the same OS without the need for a full OS instance per application. Containers could also be portable and platform-independent; they can support modern development and architecture, as well as improve the utilization of application components in the microservices architecture, for instance.

The utilization of containers should be orchestrated by another tool. Kubernetes [4] helps containerized application to be deployed, managed and scaled. There are multiple benefits of orchestration, for instance preventing any unwanted access through using firewalls for example, as well as, having flexible operations and flexible data transfer. Furthermore, it can be economical especially for companies.

The use of microservice architecture has been increasing in the last few years. There are many large companies that have used this particular architecture, such as Netflix, LinkedIn, and Amazon [5]. The application of microservices architecture lies in the fact that it has various benefits in terms of deployment and scalability, as well as the fact that each microservice can be implemented in different languages and be more flexible.

However, the increase in cloud workload, such as Internet of Things (IoT) devices, machine learning applications, cloud storage, and streaming audio and video services, has led to extra demand for several cloud services. For that purpose, the deployment of the applications should meet performance requirements—the response time, for instance—and should also decrease the cost of cloud resources. Many researchers have tried to ameliorate microservices-based applications by working on two main problems: task scheduling and auto-scaling [1]. In the task scheduling context, tools like Docker Swarm and Kubernetes use scheduling strategies for containers and deploy those containers to the proper nodes. However, scheduling can get crucial in terms of cost-efficient operation in the cloud, which led the researchers to develop several scheduling algorithms to fulfill many targets, such as response time, load balancing, resource utilization, reliability, and energy consumption [6]. Therefore, we tried in this paper to highlight the existing scheduling algorithms as well as study their durability and limitations.

The rest of the paper is formulated as follows: Microservices scheduling techniques and performance metrics are introduced in Section 2. Microservices scheduling algorithms are being discussed in Section 3. Section 4 has a comparison of the algorithms referred to in the previous section. Section 5 will conclude the paper.

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## II. MICROSERVICES SCHEDULING TECHNIQUES AND PREFORMANCE METRICS

The microservices architecture is widely used nowadays to facilitate the work of many applications. However, it doesn't prevent the researchers from developing the microservices architecture to be more efficient and flexible. Many researchers tried to come up with new solutions for scheduling microservices and reaching optimal performance. As shown in Fig. 1, it is a generalization of how the scheduling of microservices works [7]. The incoming requests from users are treated by the scheduler to find the most suitable placement for those requests using various performance metrics. Each microservice has a specific number of container instances, which vary depending on the user's requests. The requests may be scheduled immediately into containers through physical machines (PM) or into virtual machines (VM) through PM.

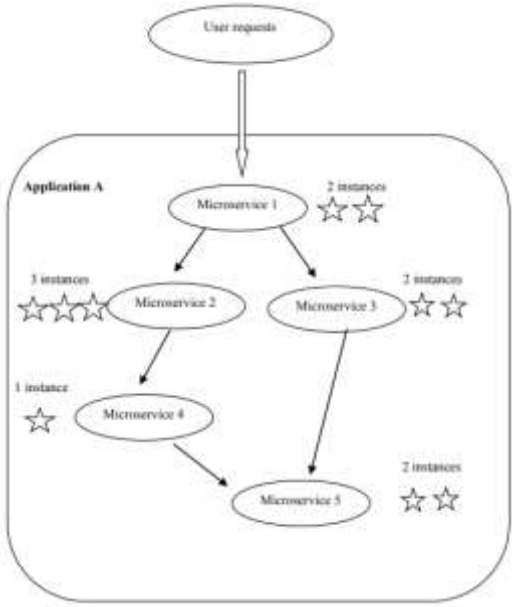


Figure 1 : Application example in the cluster

In this section, we first discuss the most common scheduling algorithm categories as well as the performance metrics used by the researchers to evaluate their algorithms.

### *A. Scheduling algorithms*

The scheduler uses various algorithms that are categorized into four different genres. Each one of those techniques works and operates differently than the others to solve multiple problems, such as scheduling problems [8].

#### *a. Mathematical modeling*

The first category finds an optimal solution using different techniques, such as integer linear programming (ILP), where it uses objective functions and equations that are linear as well as constrained variables that are integer. We can also have mixed-integer linear programming (MILP), where some variables are not discrete. Another technique is quadratic programming (QP), which is a technique that tries to find an objective quadratic function with the use of constraints that can be either linear inequality or equations. Quadratic-Constrained Programming (QCP) utilizes an objective quadratic function and quadratic constraints likewise [8].

#### *b. Heuristic techniques*

The next category came to solve container scheduling problems, where most of the time it uses the bin packing technique, which is an optimization problem that helps minimize the number of bins, particularly by assigning items of different weights to bins that have specific capacity and trying to minimize the total number of used bins. This category can also use a combination of different techniques in Docker Swarm and Kubernetes to schedule containers to the right nodes. The use of heuristic techniques may be fast and scalable, but optimal solutions are not ensured [8].

#### *c. Meta-heuristic techniques*

Meta-heuristic techniques are becoming more useful to solve optimization problems in several fields. Meta-heuristic techniques are categorized into evolutionary algorithms such as genetic algorithms, and swarm intelligence algorithms, such as Ant Colony Optimization, Particle Swarm Optimization, and many others.

As for the first category, genetic algorithms have become a focus of interest for many researchers because they are influenced by the theory of natural evolution. The individuals of the evolution process are being selected using their fitness to generate the next offspring for the following generation. Moreover, the Ant Colony Optimization algorithms are swarm-based search algorithms that are inspired by the behavior of ants in searching for food. The main goal of this type is to increase resource utilization using suitable load balancing. Concerning Particle Swarm optimization, it is one of the robust techniques that is influenced by the behavior of birds and helps improve the resource utilization and load balancing of the system [8].

#### *d. Machine learning techniques*

Machine learning algorithms allow you to build a model from data using algorithms that obtain a predictive analysis using this data. The use of machine learning allows computers to learn without being programmed, i.e., existing data can be used for future behaviors and trends. Many researchers have utilized machine learning techniques to enhance resource utilization by minimizing the number of computing nodes and reducing energy consumption [8].

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### *B. Performance metrics*

In this section, we are going to introduce the most common metrics used by researchers to evaluate the performance of the proposed algorithms for the purpose of formulating algorithms for more efficient container scheduling [8].

Energy efficiency: this type of metric tries to find an adequate scheduler that minimizes the energy consumption of the whole cluster in order to increase revenues as well as upgrade sustainability.

Cost: the communication cost indicates the telecommunication services rented with a variable to run the application. The more the communication are increased, the more the cost becomes greater.

Availability: This metric assures whether the scheduler is able to guarantee the application's availability to the user whenever he or she wants it.

Resource utilization: for this metric, it indicates how the resource utilization of a work node can affect resource efficiency in terms of memory, core, and network bandwidth.

Load balancing: this metric assures that the scheduler is able to evenly distribute the workload across nodes in a way that it won't be overloaded.

Scalability: the metric guarantees that the scheduler is in a position to provide the user with the intended service even though there is an increase in demand on the system.

Makespan/Latency: The scheduler should minimize the makespan or latency in such a way that the required time to run the application from the beginning to the end is reduced.

Throughput: is calculated by dividing the total number of tasks by the amount of time needed to execute the tasks.

Security: This metric tries to assure that the scheduler has the ability to protect data and services from attacks or software bugs.

## III. MICROSERVICE SCHEDULING ALGORITHMS

In this section, we introduce the latest scheduling algorithms proposed by researchers and discuss the strengths and limitations of those algorithms.

The authors in [9] proposed an approach called Least Waste, Fast First (LWFF). The concept of this model is to schedule microservices instances in the workload queue $S$ to nodes represented by $N$. The authors represented the scheduling using the mapping function $sched : S \rightarrow N$. The scheduling algorithm developed by the authors is formulated in the form of a complex variant of the knapsack problem.

The knapsack problem is a combinatorial optimization problem; the idea is to pack a set of items, that have a value and a weight, into a knapsack that has particular capacity under the condition of having a maximized value of the items inside the knapsack. In the scheduling algorithm proposed by the authors, the nodes are going to be packed by microservices instances. The nodes are associated with two computational resources, memory limitation $MEM_j$ and CPU limitation $CPU_j$, as well as 2-dimensional capacity vector that has memory and CPU capacity [9].

Afterwards, the authors tried to formulate the memory and CPU utilization of each node in a time interval by using equations (1) and (2), as well as define the average utilization of the cluster since each node has different resource capacities by using equations (3) and (4).

$$mem\_util(n_j, \Delta t) = \frac{\sum_{\{\forall s_i \rightarrow n_j\}} (mem_i.part(runtime_j^i, \Delta t))}{MEM_j.\Delta t} \quad (1)$$

$$cpu\_util(n_j, \Delta t) = \frac{\sum_{\{\forall s_i \rightarrow n_j\}} (cpu_i.part(runtime_j^i, \Delta t))}{CPU_j.\Delta t} \quad (2)$$

$$\overline{mem\_util(\Delta t)} = \frac{\sum_{j=1}^{p} MEM_j.mem\_util(n_j, \Delta t)}{\sum_{j=1}^{p} MEM_j} \quad (3)$$

$$\overline{cpu\_util(\Delta t)} = \frac{\sum_{j=1}^{p} CPU_j.cpu\_util(n_j, \Delta t)}{\sum_{j=1}^{p} CPU_j} \quad (4)$$

Thereafter, the authors attempted to introduce a profit function that will be used later as an objective function to be maximized. The equation (5) defines the profit function as a vector using equations (3) and (4).

$$profit(s_i, n_j) = (\overline{mem\_util(\Delta t)}, \overline{cpu\_util(\Delta t)}) \quad (5)$$

Eventually, the scheduling problem is being formulated by the authors using a bi-objective optimization problem as follows:

$$\forall s_j \in S \wedge \forall n_j \in N \; maximize \; profit(s_i, n_j)$$

$$Subject\ to\ \forall time\ t \wedge \forall n_j \in N \begin{cases} \sum_{\forall s_i \rightarrow n_j \; in \; t} mem_i \leq MEM_j \\ \sum_{\forall s_i \rightarrow n_j \; in \; t} cpu_i \leq CPU_j \end{cases}$$

At the beginning, to choose the microservices, the authors apply the approach first come, first served (FCFS), afterwards, the algorithm will allocate the service to the suitable node by achieving three phases: filtering, producing the Pareto set, and choosing the final solution. At first, the algorithm will generate a set of feasible nodes that meet the requirements of a specific service, and then it will runs a comparison based on a profit equation for all the nodes in the set of feasible nodes. Furthermore, to allocate each service to the proper node, the authors calculate the memory utilization and CPU utilization of the whole cluster. Next, the algorithm will calculate the profit vector of each decision that has been made to use it next in the Pareto set that has the non-dominated solutions after removing all the dominated solutions. In the next step, the solution that has the least execution time will be taken from the Pareto set to assign the service to the selected host as a final step [9].

To evaluate the efficiency of the proposed algorithm, the authors compared it with another two scheduling algorithms, which are Spread and Binpack. The spread approach tries to select the nodes with the least load, while Binpack maximizes the utilization of the nodes. At first, the authors compared the average utilization of memory and CPU in clusters between the three algorithms using nine different classes on six different nodes from AWS EC2, they concluded that the LWFF algorithm overcomes the two other algorithms by having the best memory and CPU utilization simultaneously.

The authors worked on different metrics to evaluate their algorithm. The first metric is scheduling latency and its effect on the execution time of services. The authors discovered that the latency of the other two algorithms is lower than the LWFF algorithm. On the other hand, the execution time of the LWFF algorithm is faster than the other two. The authors measured the throughput of the active nodes per second for the three

algorithms and concluded that LWFF has the highest throughput of the other algorithms. According to the metrics presented earlier, the authors concluded that their approach is the best choice for scheduling microservice instances into nodes [9].

Other researchers [10] suggest a model for multi-objective resource scheduling for vehicle-to-everything (V2X) microservices based on the edge container cloud architecture. The scheduling model that the authors worked on is the multiple fitness genetic algorithm (MFGA).

At first, the authors quantify three major factors: microservices calling distance, resource utilization, and resource utilization balancing. As for the microservices calling distance, the authors formulated an equation (6) that helps determine the calls between containers and measures how many calls have been made between containers. The calling distance generated between containers should be as short as possible than across physical hosts to meet the users' needs.

$$\begin{cases} d(k_i,k_j) = \begin{cases} 1, calls\ across\ physical\ hosts \\ between\ containers\ i\ and\ j \\ 0, else \end{cases} \\ D_{ij} = \sum_{j=1}^{m-1} d(k_i,k_j) \\ D_i = D_{ij} + D_{ji} \\ D = \sum_{i=1}^{m} D_i \end{cases} \quad (6)$$

The next factor, which is resource utilization, is being introduced by the authors using the first equation (7) that defines the total number of physical hosts held by deploying containers with microservices. Then comes formula (8), which indicates the overall resource utilization rate of physical hosts that are triggered to deploy container microservices. It is necessary to occupy the shortest number of physical hosts to successfully use the computing resource and minimize energy consumption.

$$Z = \sum_{i=1}^{n} P_i \quad (7)$$

$$U = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{l=1}^{s} p_i \times k_{ij} \times r_{jl}}{\sum_{i=1}^{n}\sum_{l=1}^{s} p_i \times c_{il}} \quad (8)$$

Where $k_{ij}$ indicates whether the container $j$ is placed in host $i$ or not, as for $p_i$ specify if the host is activated or not. For $r_{jl}$ and $c_{il}$ are respectively the resources requested by microservices container and the type of resources that the host can supply. The authors worked with four types of resources which are CPU, memory, disk, and bandwidth.

The resource utilization balancing for a server is defined using equation (9), as is the resource utilization balancing for the entire edge cloud, as denoted in equation (9). The authors claim that the smaller the values, the more load is balanced.

$$\begin{cases} N_i = \sqrt{\frac{1}{s}\sum_{l=1}^{s}(u_{i,l} - u_i)^2} \\ N = \sqrt{\frac{1}{z}\sum_{i=1}^{s} p_i \sum_{l=1}^{s}(u_{i,l} - u_i)} \end{cases} \quad (9)$$

Where $u_{i,l}$ is the utilization of type $l$ resources on host $i$, and $u_i$ is the average utilization of all resources on the physical host $i$.

Using those three factors, the authors introduced the goal of this study under the formula of an objective function, as shown in equation (10).

$$maxAim(aim_1, aim_2, aim_3) = \max\left(\frac{1}{D}, \frac{U}{Z}, \frac{1}{N}\right) \quad (10)$$

After introducing the three factors, the authors combined those factors to come up with a solution to the scheduling problem. The first step in the MFGA algorithm is chromosome coding, where the code divides the containers into H groups using resource utilization, and then each group is allocated to a particular host. Next, the authors defined a fitness function, which has a value that indicates if the solution to the problem is weak or not. The function is calculated using weight parameters, which are microservice dependencies, resource utilization, and resource utilization balancing [10].

Afterwards, the gene evaluation function is created to evaluate the load balance of hosts. The authors mentioned that the function accelerates the algorithm's convergence as well as improves the performance of each machine. The function uses the same parameters as the previous function.

Another operation is generated by the authors, which is a crossover operation. The crossover operation uses the gene evaluation function on each host to speed up the convergence of the algorithm and also reach the crossover efficiency of the task set. For that purpose, the authors determined three main steps for this operator. The first step is to select the initial solutions, then exchange the most adaptable genes. Afterwards, it will delete the same microservices container from the new chromosome. The final step is to re-add the containers that are missing because of gene exchange using the fitness function and the gene evaluation function. The authors have grouped all the steps mentioned above to formulate the MFGA algorithm [10].

To evaluate their algorithm, the author used the tool CloudSim as well as three other algorithms: the round-robin algorithm (RR), the most-utilization first algorithm (MF), and the first come, first served algorithm (FCFS). At first, the authors made a comparison concerning the number of hosts occupied by the four algorithms, and they concluded that MFGA is the algorithm that used fewer hosts compared to the others. As for resource utilization, MFGA has the highest values among the four algorithms. The authors also made a comparison of microservices calling distance and concluded that MFGA has the smallest calling distance among the four algorithms, and the same result goes for resource utilization balancing. The authors came to the conclusion that the MFGA algorithm has better performance than the RR algorithm, the MF algorithm, and the FCFS algorithm [10].

The authors in [11] used another approach, which also consists of an optimization problem. The authors in this article worked on two algorithms: the first is a scheduling algorithm, and the second is an auto-scaling algorithm. Our concern is the scheduling algorithm proposed by the authors under the name Urgency-based Workflow Scheduling (UWS).

At first, the authors tried to formulate the scheduling problem into a task scheduling scheme as defined in (11). Afterwards, the authors defined the optimization probing the execution time and finish time when a task is allocated to a microservice instance, as well as calculating the lease start time, the lease finish time caused by deploying containers into the VM, and the earliest start time for executing a task in the microservice instance at a timestamp. Then the authors introduced the optimization problem, which is defined as minimizing the cost of VMs by meeting the deadline constraints of all requests using the formula (12).

$$M = \left\{ m_{i,j,k,l} \mid m_{i,j,k,l} = (t_i, WF_l, ms_{j,k}, ST(t_i, ms_{j,k})) \right\} \quad (11)$$

Where $m_{i,j,k,l}$ denotes that task $t_i$ which belongs to the workflow $WF_l$ is allocated to the instance $ms_{j,k}$ starting from the start time $ST(t_i, ms_{j,k})$.

$$\min cost$$
$$s.t. \quad rt_l \le D_l, \forall WF_l \quad (12)$$

Where $cost = \sum_{vm_x \in VM} price_x * \left\lceil \frac{duration_x}{interval} \right\rceil$ and $rt_l = max_{t_i \in WF_l}\{AFT(t_i)\} - T$.

Eventually, the authors presented the algorithm by calculating in the first place the cost-effective configuration (CE) of each type of microservice using the statistical information of the computation workload of tasks. Then, the urgency-based workflow scheduling algorithm UWS is performed based on the CE. Moreover, in the algorithm, the deadline allocates a sub-deadline for each task according to the CE. The scheduling urgency is being calculated in the urgency calculation, and tasks are being prioritized according to their scheduling urgency. The task mapping will select the proper service instance for each task in the order of priority. As a final step, the set contains all newly created service instances [11].

The authors introduced another metric beside the objective function, which is the success ratio, which defines the ratio between the number of workflows that meet the deadline and the overall number of scheduled workflows. The success ratio is presented under the following formula (13).

$$ratio = \frac{\sum_{WF_l \in WF} succ_i}{|WF|} \quad (13)$$

Where $succ_i = \begin{cases} 1 & rt_l \leq D_l \\ 0 & rt_l > D_l \end{cases}$.

To observe the performance of the algorithm, the authors tried to work with four different workflow applications: Montage, LIGO, GENOME, and SIPHT. The number of tasks is about 50 per workflow. Regarding the information about the workflows, it is given in DAX format files that have the name, computation workload, data transfer amount, and dependencies between tasks, as well as using 8 different types of VMs with different prices. The authors picked two workflow scheduling algorithms which are ProLiS and IC-PCPD2 to make a comparison between their algorithm and the two algorithms. Afterwards, the authors implemented the three algorithms into the four workflows and observed the variation of each metric. As for the success ratio, the authors concluded that this metric is increasing for the three algorithms; however, the UWS has the highest rank among the other two for all the workflow applications. On the other hand, the authors confirm that their algorithm has the superior value of finding a number of feasible solutions with different workflows. Concerning the cost, the authors observed that it has a lower value compared to the other algorithms, which makes it the most appropriate algorithm for scheduling microservices [11].

Another algorithm has been proposed in [7]. The authors propose a multi-objective optimization model that aims to solve scheduling problems. The objective here is to improve the system by reducing the network transmission overhead through microservices, balancing the load of clusters, and ameliorating the reliability of cluster services. At first, to reduce the network transmission overhead among microservices, the authors introduced three factors: the network distance between nodes, the number of requests between microservices, and the quantity of data transmission. The authors utilized the equation (14) to calculate data transmission overhead.

$$COMM(X) = \sum_{j=1}^{n}\sum_{i=1}^{m}\frac{x_j}{Scale_i}\sum_{l=1\wedge l\neq j}^{n}\sum_{ms_k\in CON\_SET_l}\frac{x_{k,l}}{Scale_k}Link(ms_i, ms_k) * * Trans(ms_i, ms_k) * Dist(pm_j, pm_l) \quad (14)$$

The authors moved on to load balancing the system, where they presented equation (15) that helps in maximizing the resource utilization rate within the nodes, in which the resource utilization reflects the load balancing of the system. This means an unbalanced resource load with high resource utilization will lead to the worst load within the system.

$$RESRC_{CONS(X)} = \frac{1}{\sigma_1 + \sigma_2} max_{1\leq j\leq n} \max\left(\sum_{i=1}^{m} x_{i,j}\frac{Link_i \times Cal_{Reqst_i}}{Scale_i \times Cal_{Reqst_j}}\sigma_1, \sum_{i=1}^{m} x_{i,j}\frac{Link_i \times Cal_{Reqst_i}}{Scale_i \times Cal_{Reqst_j}}\sigma_2\right) \quad (15)$$

The other factor is request failure within the cluster, where the authors tried to calculate the average number of request failures to evaluate the cluster services using equation (16).

$$LINKFAIL(X) = \sum_{j=1}^{n}\sum_{i=1}^{m} Fail_j \times x_{i,j}\frac{Link_i}{Scale_i} \quad (16)$$

The authors used those three factors to present their multi-objective function under the constraints of resource capacity and microservice deployment requirements using the formula (17).

$$minimize\ COMM(X)$$

$$minimize\ RESRC\_CONS(X)$$

$$minimize\ LINK\_FAIL(X)$$

$$s.t. \quad \sum_{i=1}^{m} x_{i,j}\frac{Link_i}{Scale_i}Cal\_Rest_i \leq Cal\_Rest_j \quad \forall pm_j \quad (17)$$

$$\sum_{i=1}^{m} x_{i,j}\frac{Link_i}{Scale_i}Str_{Rest_i} \leq Str_{Rest_j} \quad \forall pm_j$$

$$x_{i,j} = \begin{cases} 1 & if\ ms_i \in alloc(mp_j) \\ 0 & if\ \ ms_i \notin alloc(mp_j) \end{cases}$$

$$\sum_{j=1}^{n} x_{i,j} = Scale_i, \quad \forall ms_i$$

$$\sum_{i=1}^{m} x_{i,j} = 1 \quad \forall pm_j$$

Afterwards, the authors explained how the ant colony optimization algorithm works. The latter is performing the feeding process of an ant to help schedule microservices, in which the algorithm applies several steps to reach the goal. The first step is placing a variable ant into the microservice, and then the ant chooses a path with a definite probability to attain the node that satisfy the constraints of the model. The allocation of microservices is linked to the number of containers in the cluster, and if the node that was selected is different each time, then the microservice will be put in the tabu list. As for the next step, the ant will return to the next microservice and perform the second step again. Eventually, the ants will complete allocating all the microservices, and the algorithm finishes when the maximum number of iterations is reached [7].

To compare the algorithms mentioned above, the authors took three related algorithms for scheduling: Multiopt, GA_MOCA, and Spread algorithm where each of those algorithms is a multi-objective container scheduling that considers different factors such as CPU usage, threshold distance, memory usage, balanced use of resource utilization, and so on. The authors made a comparison between the four algorithms using three factors: network transmission, cluster load balancing, and reliability of services. As for the network transmission overhead result with different numbers of user requests, the authors algorithm shows the best outcome took entire consideration of the network data transmission between microservices as well as network distance among nodes and optimized the scheduling using the ant colony algorithm. Concerning the result for resource load in the cluster, the algorithm proposed by the authors has the best performance in terms of resource utilization of nodes and load distribution of each resource. At last, the result of the reliability of the cluster

is being measured by the number of failures for microservices requests, where the algorithm made by the authors has the best performance among the other algorithms in view of the fact that the algorithm utilized the average number of failures to allocate the microservices with more requests to the nodes with lower for improving the reliability of the cluster [7].

## IV. MICROSERVICES SCHEDULING ALGORITHMS COMPARAISON

The container scheduling problem has become a major obstacle to effectively managing runtime cloud resources. The examination of microservice scheduling techniques has led to the conclusion that not all the algorithms can address the factor performance of the cluster; consequently, many challenges still remain to be solved as research opportunities. After introducing the scheduling algorithms in the previous section, we can observe that for each algorithm, it has its own scheduling factors that can vary from one algorithm to another, as well as each algorithm has its own parameter settings. However, the algorithms tried to solve a specific optimization problem using an objective function to properly improve the cluster. The first article tried to solve an optimization problem by maximizing the profit of using the memory and CPU of the resource, which leads to better throughput. As for the second article, they tried to maximize a multi-objective function in order to increase the chances of resource utilization, as well as adjust the load balancing of the cluster and the calling distance between microservices. The other multi-objective problem is concerned with the minimization of the cost and, on the other hand, the increment of the success ratio in the cluster. The last algorithm worked on minimizing three objective functions, which are network transmission, resource utilization, and the number of failures for microservice requests. As cited, each algorithm works with different multi-objective functions that have a different purpose in finding the ultimate solution.

## V. CONCLUSION

The utilization of containers has become the focus of attention lately, and for that reason, many researchers are trying to find an efficient solution to various problems that prevent the improvement of the application. In this article, we introduce a comprehensive survey concerning microservice scheduling techniques. At the beginning, we tried to classify the scheduling techniques into four categories, and then we examined the most common performance metrics used by researchers. Afterwards, we presented four different algorithms that work with a multi-objective optimization problem, yet each one of the algorithms has its own objective function to work with. Eventually, we made a comparison between the four algorithms to observe the similarities between them. We confirm that this survey is intended to provide a future perspective regarding ameliorating the usage of applications within the cloud computing community.

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# Interactive Multimedia Based on Contextual Children's Stories: Improving the Skills of Writing Fairy Tales for Elementary School Students

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**Abstract:** The purpose of this research is to (1) produce interactive multimedia based on contextual children's stories that are valid for students; (2) produce interactive multimedia based on contextual children's stories that are practical for students; and (3) produce interactive multimedia based on contextual children's stories that are effective for students. The research conducted is included in Development and Research. In this research, learning media using Adobe Flash will be developed. This research was conducted at Peureulak 2 Public Elementary School, East Aceh District, Aceh Province. The subjects of this research were class III A students at Peureulak 2 Elementary School, and the object of this research was contextual children's story-based learning media. research and development model, or R&D. Development research is a research process that has the aim of developing new products or updating old ones. With Thiagarajan's 4D development model. The results of research and development show that: (1) the results of contextual-based multimedia validity tests were obtained from 3 experts, namely 82% material experts, 78% multimedia experts, and 90% language experts, so that the average is valid; (2) the results of the practicality test were obtained from the results of the student response test and the teacher response test. In the results of the small-scale student response trial, the percentage score was 79%, and in the results of the large-scale student response trial, it was 76%. teacher response test (87%). Average trial: 87% Practical category; and (3) the results of the effectiveness test obtained Gain-Score, or improvement in students' writing skills, was seen from the pretest and protest. There was an increase in the classical average score of 0.56, and there was a "medium" increase in learning outcomes. The results of the gain score analysis were 0.60 in the medium category. It can be concluded that using multimedia learning can improve student learning outcomes and fulfill the criteria for effectiveness.

**Keywords:** multimedia media; contextual; children's stories; fairy tale writing skills

## 1. INTRODUCTION

One aspect that can influence students learning success is language skills. Even though many students and educators think this skill is easy, the fact is that our language skills are still behind those of several other countries. 13.11% of the Indonesian population aged over 10 years read newspapers or magazines; the remainder prefer watching television [1]. The lack of knowledge and language skills will have an impact on the lack of reading activities. Additionally, Indonesia's publication expansion, which continues to lag behind that of Malaysia, Thailand, and Egypt, points to the need to increase the country's writing productivity. Therefore, efforts need to be made to develop language skills aimed at school-aged children.

Some language skills that are important for elementary school students to master are writing and speaking skills [2]. Learning to write and speak is a big concern in the world of education. Because the instillation of concepts in writing and speaking will continue to be used continuously, from childhood to the end of life, Therefore, it requires persistence and accuracy in learning to write and speak for children, especially school-aged children.

Various aspects of student performance can be improved through their writing and speaking skills. But keep in mind that writing practice requires children who are mentally, physically, and emotionally ready. Children are better at speaking than writing. Therefore, don't be surprised if talking affects a child's writing ability [3].

The development of children's story media has the special ability to help students hone their writing skills. This is intended so that elementary school students can enjoy children's stories that have a unique appeal and are very similar in their features. As a result, students will be more motivated to learn.

Teachers must be able to innovate in their teaching, and one of the innovations in learning is the development of learning media. The number of teachers who have not been able to present a learning medium that is in accordance with the needs and periods of students [4] In addition, many educational practitioners realize that the use of interactive multimedia in learning actually helps learning activities both inside and outside the classroom. The use of interactive multimedia in Indonesian language learning, if developed and used well, can improve the quality and process of student learning, thereby enabling the teaching and learning process to be carried out in the classroom, anywhere, at any time. As expressed by Sriadhi [5]. Multimedia as a teaching aid as well as a learning resource will be more effective if the teaching material is built according to the rules. The learning sequence is carried out in a structured manner according to the objectives to be achieved. The selection of the order of materials is not a complete list, but it is the most necessary materials according to the curriculum.

To facilitate learning, teachers in the field of education are required to use and even create technological goods. Implementation of multimedia as a form of integration between media and technology where using various technical items, such as laptops or devices, allows students to access knowledge So that the use of technology in the field of education is a necessity for both teachers and students. Multimedia-assisted learning such as Adobe Flash makes students more involved

and active in learning, makes communication more effective, facilitates forums, and adds interest and motivation to learn [6]. Therefore, technological progress is very important for learning.

## 1.1 The Nature of Interactive Multimedia

Widodo & Wahyudin [7] stated that "learning media is a tool that can be used to convey the message to the students for the purpose of learning. This means that learning media is a tool that has been designed in such a way that it can be used to convey material in learning activities.

Indriana [8] argues that all real tools and resources that can be used to carry out learning and assist students in achieving learning goals or objectives are called learning media. Media is often associated with the actual tool or object. This is due to the role of the media as a facilitator of educational activities, which provides media in a physical form that students can see or use to assist learning.

Learning media offers variations so that learning does not take place in a monotonous manner. This also requires the participation of innovative teachers who are willing to provide meaningful learning for their students. Media is an alternative and effective step in providing effective learning for students through the main role of a teacher in designing learning [9].

Schramm [10] classifies media on the basis of their complexity. On that basis, Schramm divides the media into two groups, namely: large media (expensive and complex media) and small media (simple and cheap media). This includes large media, for example, film, television, and NCD video, while those that include small media, for example, slides, audio, transparencies, and text, Apart from that, Schramm also differentiates the media on the basis of their reach, namely mass media (whose coverage is broad and simultaneous), group media (whose coverage covers a certain room), and individual media (for individuals). Mass media include radio and television. Included in group media are audio tapes, videos, OHPs, and slides. Meanwhile, individual media included textbooks, telephones, and learning computer programs (CAI).

Meanwhile, of the many types of media that can be utilized in learning, Heinich, Molenda, and Russell [11] make a simpler media classification as follows: (1) non-projected media, (2) projected media, (3) media audio, (4) video media, (5) computer-based media, and (6) multimedia kits

Adobe Flash is software used to create animations, videos, and interactive multimedia. Adobe Flash is a product or software from Adobe (formerly known as Macromedia before being purchased by the Adobe company), which is used for the process of creating and managing animations or images that use vectors for small scale sizes. Adobe Flash is computer software used to create animations, videos, vector and bitmap images, and interactive multimedia. Animations or applications produced by Flash have the extension *.swf, which can be run using Adobe Flash Player.

## 1.2 Learning Media for Lower

Grade Elementary School Children. Elementary school-age children in the lower classes have experienced quite mature physical growth throughout their development. This is demonstrated by their ability to maintain and control their body balance. In addition, the ability of early elementary students to share with friends, be independent, have friends, and compete with each other is a sign of their social development.

In more detail, the developmental characteristics of elementary school students with an age range of 7–11 years are described by Santrock [12] in terms of physical, cognitive, language, and social-emotional development, which are described as follows: The physical development of children at this time is marked by their physical maturity; physical growth is quite stable and takes place slower than growth in the previous period. During this period, children's motor skills and growth are increasingly developing. Children become better able to control their bodies, so they can sit and be calm enough to focus for long periods of time.

The language development that children are going through at this time involves their ability to use language that is increasingly analytical and logical. The use of children's grammar and vocabulary is also increasingly complex, so it's not surprising that at this time children will have the ability to make up stories to share with others around them. It is important to pay attention to the social-emotional development of children at this stage because children will start school, so they will get a new environment, learn to adapt with friends, and start socializing with other people. It is not surprising that at this time children experience changes in their social and emotional abilities

## 1.3 Learning Multimedia

Interactive multimedia is a medium that can transmit information through presentations that can convey and distribute messages from various sources. The definition of media is anything that can be felt and used to plan how messages from sources are channeled to attract students' interests, ideas, and feelings and make learning more successful and efficient [13].

Interactive multimedia that is printed or in a form or model that is only inactive and cannot interact with its users Here, students can participate in two-way interactions through interactive multimedia.

According to Iswara [14], Adobe Flash is a product or software from Adobe (formerly known as Macromedia before it was purchased by the Adobe company), which is used for the process of creating and processing animations or images that use vectors for small scale sizes.

The tutorial model positions the computer as a teacher so that all interactions occur between the computer and students, while the teacher is only a facilitator and monitor. Learning in this model is presented through text or graphics displayed on a computer screen. Then the computer displays questions according to the material.

## 1.4 Fairy Tale Writing Skills

According to Raena [15], there are six pre-language skills of students, or what are known as the Six Early Literacy Skills, namely: print motivation, vocabulary, print awareness, narrative skills, letter knowledge, phonological awareness, and also learning Indonesian, which cannot be separated from the four language skills, namely: listening, speaking, reading, and writing. The four aspects of skills are interrelated [16]. However, language acquisition in the early grades places more emphasis on the early reading and writing sections [17].

The more often we write, the more vocabulary we will use, and that will also require us to read more. Reading a lot will add insight into literacy and vocabulary. And more writing will help someone convey what is on his mind. However, the fact is that there are still many students who think writing is difficult [18].

According to Langan [19], writing is the activity of expressing ideas offered to the reader, where each thought has a certain justification so that the idea can be accepted by the reader. This definition is in accordance with the opinion above. An article is broken up into paragraphs, each of which has one main idea and a number of supporting sentences. Therefore, an article includes a number of arguments that support the author's point of view, which the reader can then understand.

Tina Kogh states that a fairy tale is a story that has been used for centuries as a means of communication, in which there is an incident or events, the characters of the story, and messages taken from the characters in the story [20]. According to Anwar [21], simple essays are obtained from a process where existing ideas are involved in a word, and the words that are formed are then arranged into a sentence. Sentences are arranged to form an essay, and finally, the essays form a simple essay.

Fairy tales are a form of literary work whose stories do not actually happen or are fictional, are entertaining, and contain moral teachings. Based on these definitions, it can be concluded that fairy tales are fictional stories that aim to entertain and contain moral values [22]. Fables are children's stories whose characters are animals, but they carry out their roles like humans (personification). Basically, in the fable, the character values are included in the intrinsic elements. An intrinsic element is the building block of a work, which includes the plot, setting, and message contained in the story.


Figure 1. Interactive multimedia flash display of children's stories for elementary school students

The research problem is formulated as follows: (1) can interactive multimedia based on contextual children's stories be valid for use in learning; (2) whether interactive multimedia based on practical contextual children's stories can be used in learning; and (3) whether interactive multimedia based on contextual children's stories can effectively improve the learning outcomes of elementary school students.

## 2. METHOD

This type of research is a type of development research, commonly called development (research and development). In this research, learning media using Adobe Flash will be developed. The final product will be evaluated based on the specified product quality aspects. Thus, the product of this research is a medium that is valid, practical, and effective. This research was conducted at Peureulak 2 Public Elementary School, East Aceh District, Aceh Province. The subjects of this research were class III A students at Peureulak 2 Elementary School, and the object of this research was contextual children's story-based learning media.

Development research is a research process that has the goal of developing new products as well as updating old ones. With the 4D development model (Four D Models) from Thiagarajan. In developing interactive multimedia, the author carried out several procedures that refer to the development model proposed by Thiagarajan et al., namely 4D, where there are 4 stages: the definition stage, the design stage, the development stage, and the deployment stage (disseminate). There are two types of data used in this research and development: qualitative data and quantitative data.

Learning Outcome Test Data collection is carried out to determine improvements in student learning outcomes, namely by giving questions and students answering them, or student learning outcomes tests. The test was carried out before the learning treatment using interactive multimedia in the form of multiple choice questions consisting of 25 questions, and then the test results were used to analyze how much cognitive aspects of student learning outcomes improved after implementing contextually based interactive multimedia.

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Table 1. Learning achievement test grid

| No | Indicator | Level of Cognitive Ability | | | |
|---|---|---|---|---|---|
| | | C1 | C2 | C3 | C4 |
| 1 | Answer questions about the content of fairy tales, legends, experiences, and impressive events. | 5 | | | |
| 2 | Rewrite the contents of fairy tales, legends, experiences, and impressive events in a few sentences. | | 6 | | |
| 3 | Identify the characters in children's fairy tales or poetry. | 1 | | 1 | 1 |
| 4 | Answer questions about the content of fairy tales or children's poems. | | | 6 | |
| 5 | Play the characters in fairy tales or children's poetry according to their characteristics. | | | | 5 |
| Total | | 6 | 6 | 7 | 6 |
| The total number of questions is | | 25 | | | |

After being validated, the learning outcomes test was tested on students who were not part of the sample in the study. Test trials aim to obtain valid and reliable tests.

Further explanation regarding the writing test assessment format is as follows:

**Table 2. Writing Test Assessment Guidelines**

| No | Rated aspect | Criteria | Score | Maximum Score |
|---|---|---|---|---|
| 1 | Obedience to orders given | 1. The essay is very appropriate for the theme.<br>2. The essay is in accordance with the theme, even though there are things that are not appropriate, but they have no effect.<br>3. The essay is quite appropriate for the theme.<br>4. The essay does not match the theme.<br>5. The essay does not match the title or theme. | 2<br>1,4<br>1<br>0,5<br>0 | 2 |
| 2 | Organizational essay | 1. Everything is related to content and sentences.<br>2. One error that is not related to the content or sentence<br>3. Two or three unrelated errors between content and sentence<br>4. Four or more unrelated errors between content and sentences<br>5. There is nothing related to content or sentences.. | 2<br>1,5<br>1<br>0,5<br>0 | 2 |
| 3 | *Pertinence des informations données (accuracy of the information provided)* | 1. The narrative of the object is detailed and clear; the reader can experience the same experience as the author.<br>2. If the description of the object is unclear and lacking in detail, the reader may experience the same experience as the writer.<br>3. The description of the object is unclear and lacking in detail; the reader does not have the same experience as the writer.<br>4. The description of the object is not clear and not detailed; the reader does not feel the same experience as the writer.<br>5. The narrative of the object is unclear and not detailed; the reader cannot experience the same experience as the writer. | 2<br>1,5<br>1<br>0,5<br>0 | 2 |
| 4 | *Structures simples correctes, présences des temps du passé (use of correct simple sentence structures* | 1. There is not a single incorrect sentence structure.<br>2. There is a slight error in sentence structure, which occurs because you are not careful.<br>3. There are some mistakes in sentence structure, but it is still considered good.<br>4. There is a slight error in sentence structure, which indicates a lack of vocabulary mastery.<br>5. There are quite a number of sentence structure errors, which indicate a lack of vocabulary mastery.<br>6. There are many mistakes in sentence structure that indicate a lack of vocabulary mastery.<br>7. There are a lot of mistakes in sentence structure, either due to not mastering sentence structure (grammar) or not being careful. | 3<br>2,5<br>2<br>1,5<br>1<br>0,5<br>0 | 3 |

| No | Rated aspect | Criteria | Score | Maximum Score |
|---|---|---|---|---|
| 5 | *Léxique appropié (décrire) (vocabulary appropriateness)* | 1. The choice of words or terms is very precise and varied.<br>2. The use of appropriate and varied words or terms<br>3. The use of words or terms is very precise but not diverse.<br>4. Several uses of words or terms are appropriate but not diverse.<br>5. Some use of words or terms is inappropriate but does not interfere with understanding.<br>6. Some words or terms are used incorrectly but do not interfere with understanding.<br>7. Some use of words or terms is inappropriate and interferes with understanding.<br>8. The use of words or terms is inappropriate and interferes with understanding.<br>9. The author has a small vocabulary and does not use the terms that should be used; besides that, there is inappropriate vocabulary. | 4<br>3,5<br>3<br>2,5<br>2<br>1,5<br>1<br>0,5<br>0 | 4 |
| 6 | Présence d'articulateurs très simple, comme (et), (mais), (parce que), etc. (use of simple conjunctions such as (et), (mais), (parce que), etc.) | 1. There are no errors in the use of conjunctions, and the conjunctions used are varied.<br>2. There is a slight error in the use of conjunctions, and the conjunctions used vary.<br>3. There is a slight error in the use of conjunctions, and the conjunctions used vary.<br>4. There are many mistakes in the use of conjunctions.<br>5. Use of conjunctions incorrectly | 2<br>1,5<br>1<br>0,5<br>0 | 3 |

Data analysis technique The aim of the data analysis carried out in this research is to determine the level of validity, practicality, and effectiveness of the interactive multimedia being developed.

Media Due Diligence To determine the feasibility category of this comic using a Likert scale measurement scale. The Likert scale is a psychometric scale commonly used in questionnaires [23]. In order to obtain respondents' responses in choosing answers on the questionnaire sheet, four answer scales were used as codes in the assessment. Determine the Va value, or the total average value of the average value for all aspects, with the formula.

$$Va = \frac{Xv}{n} x100\%$$

with :
*Va* = is the total average value for all aspects
*Xv* = is the average value for the i-th aspect
*n* = is the number of aspects.

The results obtained are then written in the appropriate column of the table.
Furthermore, the value of Va, or the total mean value, is referred to in the interval for determining the validity level of interactive multimedia, as shown in the following Table 3:

Table.3. Validity criteria

| Score | Validity Criteria |
|---|---|
| 80,01% - 100% | Very valid |
| 50,01% - 80% | Valid |
| 40,01% - 60,00% | Valid enough |
| 20,01%-40,00% | Invalid |
| 0-20% | Very Inadequate |

Practicality Test. The student response questionnaire was given after the learning media trial. The questionnaire consists of positive and negative statements, each with a choice of answers: strongly disagree, disagree, agree, and strongly agree. According to Sukardjo, quoted by Maryono [24], the technique of analyzing student response questionnaires carried out in this study is as follows:

1) Make changes to the results of the response questionnaire assessment which are still in the form of letters converted into numbers with the scoring rules.
2) Calculating the practicality score percentage from the teacher's response questionnaire and each student with the formula: Likert scale formula:

$$Va = \frac{Xv}{n} x100\%$$

with :
*Va* = is the total average value for all aspects
*Xv* = is the average value for the ith aspect
*n* = is the number of aspects..

3) Make changes from the average score obtained to qualitative data that is adjusted to the following learning media practicality scale criteri.

Table 4. Practicality criteria

| Score | Practicality Criteria |
|---|---|
| 80,01% - 100% | Very Practical |
| 50,01% - 80% | Practical |
| 40,01% - 60,00% | Quite Practical |
| 20,01%-40,00% | Less Practical |
| 0-20% | Tid Impractical |

The practicality of interactive multimedia can be measured through a teacher response questionnaire, where the data obtained is analyzed based on the percentage of teachers who gave answers on the questionnaire sheet for each category asked. Then analyzed using Susanto's formula above.

Effectiveness Test. To find out the effectiveness of interactive multimedia that researchers have developed, N-Gain analysis can be used. N-Gain is the normalization of the gain obtained from the pretest and posttest results. The calculation of the

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average N-Gain value is carried out to see the increase in student learning outcomes. From the N-Gain value, we will see an increase in the use of interactive multimedia with the following formula:

$$\text{N Gain} = \frac{S_{postest} - S_{pretest}}{S_{maksimum} - S_{pretest}}$$

For the interpretation of the Gain value according to Sudjiono, you can refer to the table below:

Table 5. Interpretation of Gain Score

| Big Percentage | Interpretation |
|---|---|
| Gain > 0,7 | Height Gain |
| 0,3<Gain <0,7 | Increase is Moderate |
| Gain<0,3 | Increase is Low |

Test validity and reliability Before the pretest is carried out, the test used must go through a validity and reliability test by being tested on students outside the research sample.

Validity of Multiple Choice Tests Validity concerns the accuracy of the measuring instrument in mastering the concept being measured so that it actually measures what it should measure. The formula used to calculate validity is the product-moment correlation formula. Test the validity of multiple choice items using point biserial correlation as follows:

$$r_{pbis} = \frac{M_p - M_t}{S_t}\sqrt{\frac{p}{q}}$$

Information:
r*pbis* : Point biserial correlation coefficient
M*p* : Average total score for those who answered correctly on a question item
M*t* : Average total score
S*t* : Standard definition of total score
*p* : Proportion of students who answered correctly on each question item
*q* : Proportion of students who answered incorrectly on each question item

After calculating r, it is compared with the r table (r-point biserial) with a significance level of 5%. If r calculated > r table, then the question is said to be valid.

Reliability of multiple-choice tests. After the test in the form of multiple-choice questions is tested, its reliability is tested again.

The reliability of the test instrument is calculated to determine the reliability of the test results. The reliability of a measuring instrument is meant to be a tool that provides the same results. A measuring instrument is said to have high reliability if it has reliable consistency, even if it is carried out by anyone at the same level. To calculate the reliability coefficient for essay questions, the Alpha formula is used as follows:

$$r_{11} = \left(\frac{k}{(k-1)}\right)\left(1 - \frac{\sum \sigma_h^2}{\sigma_t^2}\right)$$

Information:

| | | |
|---|---|---|
| $r_{11}$ | : | The reliability coefficient of the test |
| k | : | Number of questions |
| $\sum \sigma_h^2$ | : | Total variance in scores for each test item |
| $\sigma_t^2$ | : | Total variance |

Se Meanwhile, to calculate the variance of each item, the formula is used:

$$\sigma^2 = \frac{\sum X^2 - \frac{(\sum X)^2}{n}}{n}$$

Information:
$\sigma^2$ : Variance of each item
$X$ : Value of each question item
$n$ : The number of students taking the test

To interpret the reliability coefficient of an evaluation tool (Arikunto, 2009) provides criteria such as table 6.

Table 6. Interpretation of Test Instrument Reliability

| No | Interpretation of Reliability test | Interpretation of Reliability test |
|---|---|---|
| 1 | $0,00 < r_{xy} \leq 0,20$ | Very low reliability |
| 2 | $0,20 < r_{xy} \leq 0,40$ | Low reliability |
| 3 | $0,40 < r_{xy} \leq 0,60$ | Medium reliability |
| 4 | $0,60 < r_{xy} \leq 0,80$ | High reliability |
| 5 | $0,80 < r_{xy} \leq 1,00$ | Very high reliability |

# 3. RESULTS AND DISCUSSION

## 3.1 RESULTS

Material expert validation includes aspects of the suitability of the material and the quality of the material used. There are three components of assessment indicators: guidance and information, accuracy of material, and evaluation. This aspect aims to determine the suitability of the material on the learning resources used and the material on the learning media that has been made.

Table 7. Material Expert Validation Results

| No | Assessment Indicator Components | Descriptor | Score |
|---|---|---|---|
| Content Domain/Multimedia Material | | | |
| 1 | Guide and Information | Description of multimedia products | 4 |
| 2 | | Guide to using multimedia software | 3 |
| 3 | | Statement of objectives | 5 |
| 4 | | Competency/learning achievement formulation (CP) | 4 |
| 5 | Accuracy of Material | Compatibility of objectives with the curriculum | 4 |
| 6 | | Suitability of material to objectives (CP) | 5 |
| 7 | | Material updates. | 4 |
| 8 | | Description of concepts or theories. | 3 |
| 9 | | Order (syntax) of presentation of material. | 5 |

| No | Assessment Indicator Components | Descriptor | Score |
|---|---|---|---|
| 10 | | Appropriateness of material coverage with objectives (CP) | 4 |
| 11 | | Appropriateness of material coverage with objectives (CP) | 5 |
| 12 | | Ease of understanding terms and formulations | 4 |
| 13 | | Conformity of examples or illustrations with the material. | 3 |
| 14 | | Giving a summary. | 4 |
| 15 | | Appropriateness of time duration with presentation material | 5 |
| 16 | | Use of spelling and presentation grammar | 3 |
| 17 | Evaluation | Practice/exam instructions.. | 4 |
| 18 | | Conformity of question coverage to objectives (CP) | 5 |
| 19 | | Suitability of the question domain to the objectives (CP) | 4 |
| 20 | | Suitability of the question domain to the objectives (CP) | 4 |
| 21 | | Distribution of items based on the domain of the question | 5 |
| 22 | | The suitability of the difficulty level of the questions for the objectives (CP) | 4 |
| 23 | | Appropriateness of exam questions with the time provided. | 3 |
| 24 | | Feedback (review) on the results of practice or exams | 4 |
| Score at Get | | | 98 |
| Maximum Score | | | 120 |
| Percentage | | | 82% |
| Category | | | Very Good |

The results of the material expert validation gave a score of 82%. This percentage result can be said to indicate that the Adobe Flash-based multimedia learning product is in a very valid category and can be applied directly to students. Multimedia validation for Adobe Flash learning media products includes the accuracy of the material, evaluation, and so on. In validation, media experts did not receive revisions from the validator, but the validator gave suggestions that further efforts should be made to use the media to make it bigger and more visible. The validation percentage value of 82% is categorized as a very valid product.

Table 8. Multimedia Expert Validation

| No | Assessment Indicator Components | Descriptor | Evaluation |
|---|---|---|---|
| Domain Konstruksi Multimedia | | | |
| 1 | Guide and Information | Description of multimedia products | 3 |
| 2 | | Guidelines for using multimedia software | 4 |
| 3 | | Assistance facilities | 3 |
| 4 | Performance and Programs | Ease of installation and configuration | 5 |
| 5 | | Accurate use of media navigation symbols | 4 |
| 6 | | Ease of use of navigation buttons (usability) | 4 |
| 7 | | Search accuracy and material links (hyperlinks) | 4 |
| 8 | | Interface quality | 4 |
| 9 | | Consistency of program operational quality | 4 |
| 10 | | Reliability of program operations from error free | 4 |
| 11 | | Operating system (software) support is required | 5 |
| 12 | | Required hardware support | 5 |
| 13 | | User stimulus-responsive interactivity with the system | 3 |
| 14 | Systematics, Aesthetics and Design Principles | Media display (screen) layout | 4 |
| 15 | | Menu facilities in media | 4 |
| 16 | | Acceleration of letters, numbers and symbols | 3 |
| 17 | | Visual quality (resolution) of graphics or images | 4 |
| 18 | | Color composition and resolution | 4 |
| 19 | | Compatibility of text color with background | 4 |
| 20 | | Acceleration of text, visuals, audio and animation | 3 |
| 21 | | Quality of narration and audio | 4 |
| 22 | | Use of language in narrative | 4 |

| No | Assessment Indicator Components | Descriptor | Evaluation |
|---|---|---|---|
| 23 | | Noise-free narration quality | 4 |
| 24 | | Communicative nature of narrative | 3 |
| 25 | | Suitability of background sound to material | 4 |
| 26 | | Background settings | 4 |
| 27 | | Interlaced and progressive scan quality | 4 |
| 28 | | Use of video/animation resolution (pixels) | 4 |
| 29 | | Suitability of objects/videos/animations with the material | 5 |
| 30 | | Visualization of objects based on concepts/abstract material | 3 |
| 31 | | Reducing misperceptions of media objects | 4 |
| 32 | | Application of spatial principles | 4 |
| 33 | | Use of temporal principles | 4 |
| 34 | | Use of clues and signaling | 4 |
| 35 | | Reduction of redundancy effects | 4 |
| 36 | | Application of the principle of coherence | 4 |
| 37 | | Use of modality principles | 4 |
| 38 | | Reducing cognitive load for users | 4 |
| Total Score | | | 149 |
| Average Score | | | 190 |
| Percentage | | | 78% |
| Category | | | Good |

The results of the validation by multimedia experts gave a value of 78%; from the results of this percentage, it can be said that the Adobe Flash-based learning multimedia product is in the very valid category and can be applied directly to students. Multimedia validation for Adobe Flash learning media products includes button application program performance, audio sound, video running, systematics, aesthetics, and design principles.

Table 9. Language Validation Results

| No | Component Rating Indicator | Descriptor | Assessment |
|---|---|---|---|
| Language Eligibility | | | |
| 1 | Accuracy | Accuracy of sentence structure | 4 |
| 2 | | Effectiveness of sentences | 5 |
| 3 | Communicative | Understanding of the message | 5 |
| 4 | Conformity to language rules | Grammatical accuracy | 5 |
| 5 | | Spelling accuracy | 5 |
| 6 | Suitability of student development | Suitability of students' intellectual development level | 4 |
| 7 | | Appropriate level of social emotional development | 4 |
| 8 | | Learning achievement test enrichment material | 4 |
| The score obtained was | | | 36 |
| Maximum Score | | | 40 |
| Percentage | | | 90% |
| Category | | | Very Good |

The validation results of linguists gave a value of 90%; based on the results of this percentage, it can be said that the Adobe Flash-based multimedia learning product is in a very valid category and can be applied directly to students. Multimedia validation for Adobe Flash learning media products includes accuracy, communication, appropriateness of language rules, and appropriateness of student development.

From the results of the practical analysis in the table above, 16 students got the good category and 14 students got the very good category. If seen from the score obtained as a whole, it gets a score of 415 out of a maximum score of 480. This result, if it is percentaged at 86%, is in a very good category.

From the results of the pretest and posttest scores carried out above, a gain score analysis is then carried out to determine the level of improvement in learning outcomes through students' storytelling skills. Following are the results of the gainscore analysis:

$$N\ Gain = \frac{S\ posttest - S\ pretest}{S\ maximum - S\ postets}$$

$$N\ Gain = \frac{415 - 332}{480 - 415}$$

$$N\ Gain = 0{,}56$$

Validity of contextual-based learning materials

From the results of the first material expert validation analysis, the total score obtained was 79, with a maximum score of 120 from 24 items. Material expert validation gave the first Adobe Flash-based learning medium a score of 66%. Obtaining a score of 66% requires a second stage of validation testing. For validation from the second material expert, a value of 82% was obtained. From the results of the validation of multimedia experts, 38 items were assessed; the score obtained was 110 with a maximum score of 190, and if it was percentaged, it obtained a value of 58%. These results need to be re-tested in the second stage, where the pretentiousness obtained from multimedia experts gives a value of 78%. From the validation results of linguists for the 8 items assessed, the score obtained

is 23, with a maximum score of 40. and if the percentage is calculated, it gets a value of 58%. These results require a second stage of language validation testing, where the results of the validity test from the second linguist give a value of 90%.

The practicality of contextual-based learning multimedia
There were 9 respondents who took part in the small-scale trial, and the overall score was 212 out of the maximum score that could be achieved of 270. If it is percentaged, the result is 79%. After the small-scale test was carried out, it was then entered into a large-scale test where 30 total respondents took part in the small-scale trial. Out of 6 indicators, the score was measured with a maximum score of 5 per indicator, and the results that were processed as a whole were 686 of the maximum score that could be achieved, amounting to 900. If calculated as a percentage, the result is 79%. The results of the practicality test were obtained by filling out the questionnaire given to the teacher or respondent. Of the six statement items with a maximum score of 30, the score obtained is only 14, and the percentage is only 47%. For the results of the practicality test of stage II, of the six aspects tested, the score obtained was 26 out of a maximum score of 30. If the percentage of the results above is 87%

Effectiveness of Contextual-Based Learning Multimedia
The results of student assignments are given through student worksheets. Of the 30 students who worked on the questions, there were 8 who got the fair category, and 28 other students got the good category. If the average score obtained by students as a whole is 332 out of a maximum score of 480, Or if the percentage is 69%. From the results of the practical analysis in the table above, 16 students got the good category and 14 students got the very good category. If you look at the score obtained as a whole, you get a score of 415 out of a maximum score of 480. The results are percentaged at 86%. And from the results of the gain score analysis above, the gain score can be obtained.

## 3.2 DISCUSSION

Based on the stages of developing the 4D model previously mentioned, the first stage in this development research is the stage of defining or analyzing problems related to the use of multimedia in research schools. Where student analysis finds problems that occur, such as in students in class III of SD Negeri 2 Peureulak, the average age is in the range of 9–10 years, where at that age they are at the concrete operational stage in accepting the learning process.

The concrete operational stage is in the range of 7 to 12 years, according to several theories of Piaget's cognitive development, which state that children are mature enough to use logical or operational thinking, but only for physical objects that currently exist.

In Piaget's theory, the third stage of mental development is the concrete operations stage. This stage is intended for children aged 7–12 years, when the transitional stage begins, where children can already be taught to think using logic but still with the help of concrete objects. While the learning process was carried out, there was no media that could be accessed at school to help early grade students with story writing and storytelling training, which was also confirmed by the class instructor during the interview. Various types of storybooks that lack training in writing and storytelling content are currently offered in schools. Apart from the problems that occur, students need media that can teach them how to tell stories both for fun and for practical purposes.

Based on the description of the problem and the analysis of meeting the needs of students, it is necessary to have learning media that are in accordance with the expectations of elementary school students and also in accordance with the capacity possessed by researchers as students, so that the findings of multimedia development are obtained. Interactive multimedia simulation models are part of the application of technology in an effort to solve problems in learning. The simulation model is basically one of the learning strategies that aims to provide a more concrete learning experience through the creation of imitations of experiences that are close to the real situation [25].

These practical criteria indicate that the developed multimedia can assist teachers and students in adjusting learning time according to their abilities. According to Jannah [26], the practicality of multimedia can be seen from two things: when experts and practitioners state that the media developed in reality can really be applied in the field. In addition to the student response test, the researcher also conducted an analysis of the teacher's response to determine the level of readiness of the product being developed. The results of the practicality test of the teacher's response obtained the results of the second phase of the practicality test, where out of the six aspects tested, the score obtained was 26 out of a maximum score of 30. If percentaged The results above are 87% in the very good category and have met practical criteria. These practical criteria indicate that the developed multimedia can assist teachers and students in adjusting learning time according to their abilities.

## 4. CONCLUSION

From the results of the research and data analysis obtained from the process of developing contextual-based multimedia products to improve story writing skills using the 4D model from Thiagarajan and Semmel, it can be concluded as follows:

1. From the results of the contextual-based multimedia validity test, obtained from 3 experts, namely material experts, multimedia experts, and linguists, obtained from the results of the analysis of material experts, the results of the analysis of multimedia experts, and the results of the analysis of linguists in the very good or decent category,
2. From the practicality test, it is obtained from the results of student response tests and teacher response tests. The results of small-scale student response trials, the results of large-scale student response trials, teacher response tests, student response tests, and teacher response tests indicate that the contextual-based multimedia developed has met the practical criteria.
3. From the results of the effectiveness test, it was obtained a gain score, or an increase in students' writing skills. As seen from the pretest and protest, there was an increase in the classical average score of 0.56. Referring to the gain score interpretation table, these results indicate an increase that is "moderate" in learning outcomes. And from the results of the gain score analysis above, the gain score obtained is 0.60, and if it is converted to the gain score category table, then it is already in the medium category. It can be concluded that using multimedia learning can improve

student learning outcomes and fulfill the criteria for effectiveness.

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