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Expert Validation: A Critical Phase in the Development of ARIPSA

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ABSTRACT
The study aims to create an evaluative examination for problem-solving skills that incorporates Augmented Reality (AR) technology as a means of enhancing 21st-century education, with a specific focus on the domain of physics education. The tool, referred to as ARIPSA (Augmented Reality Integrated on Problem Solving Assessment), has been developed utilising the Borg and Gall research and development methodology. This research encompasses various significant stages, including an analysis of educational needs, the design of applications, as well as the development, dissemination, and deployment of those applications. The process of validation involves the participation of individuals with expertise in physics and technology, who evaluate the application to ascertain its efficacy and dependability. Additionally, they assess the quality of the physics-related information offered within the application. The validation findings suggest that ARIPSA demonstrates appropriateness and efficacy in an educational setting, particularly in enhancing students' problem-solving abilities.

INTRODUCTION

In anticipation of the multifaceted challenges intrinsic to the 21st century, society must cultivate foundational competencies encompassing critical thinking, creativity, problem-solving, collaboration, and communication [1] [2] [3]. These skills are particularly needed for students to compete globally [3] [4]. The ability to solve complex problems is considered a crucial skill in today's information technology society [3] [5]. The global development of communication and technology requires the ability to adapt to changing conditions through flexible use of information [1] [5] [6]. An American survey institution identified thinking skills as fundamental for building a high-quality workforce, including creativity, decision-making, problem-solving, visualization, learning skills, and reasoning [1] [7] [8]. This aligns with the government's policy in the implementation of the 'Kurikulum Merdeka' which encompasses the Pancasila profile covering all students' thinking skills.

In response to these demands, problem-solving is often acknowledged as a crucial objective in bachelor's level education, especially in the field of education for future educators, particularly in preparing students to be competitive. Problem-solving skills are consistently rated as "important" to possess, above knowledge content (science), and laboratory skills [1] [5]. Therefore, science education plays a significant role in training problem-solving skills.

Science learning is expected to integrate science content in solving everyday problems. Physics is one part of science, where it doesn't only look at the quantitative aspects of solving mathematical equations, but also qualitative analysis to make valid, correct choices [9] [10]. Problem-solving skills are crucial in physics learning and are a central topic in physics education research. Students who possess problem-solving skills can solve physics problems by combining knowledge, skills, and understanding to obtain the best solution for complex problems. Through problem-solving, students will gain new knowledge [4] [10] [11] [12]. Student achievement can be evaluated based on the accuracy of their answers and to what extent the students have problem-solving skills [9] [10] [11] [12]. Problem-solving can also help students understand physics concepts in a real-world context [13] [14]. This certainly becomes a demand for educators to assess students' problem-solving abilities as an effort to improve lecture activities, and this assessment is also used to determine student competence performance.

One way to achieve meaningful learning is through problem-solving [9] [10] [11] [12] [14]. By consistently practicing problem-solving, students are likely to acquire skills for gathering information, analyzing it, and reevaluating what they have learned [14] [15]. Furthermore, problem-solving is crucial in independent learning and helps to add meaning to what is learned [9] [10] [12] [13]. Problem-solving skills can assist students in thinking more effectively. In the process of measuring problem-solving skills, a suitable and high-quality measurement tool is needed. Currently, the development of assessments has become a priority in the educational world, particularly for measuring thinking skills, one of which is problem-solving skills.

Over the past two decades, several researchers have conducted studies on assessment development to measure problem-solving skills. For instance, Docktor [9] developed an assessment in the form of a rubric for essay questions to measure problem-solving skills. Likewise, Gok [10] conducted research on development to measure the learning process based on problem-solving and metacognition. Permatasari, Istiyono, and Nadapdap [12] [13] [14] developed an instrument in the form of multiple-choice reasoned questions to measure problem-solving skills, while Burkholder [15] not only developed tests and assessment rubrics for problem-solving skills but also developed learning guidelines that support problem-solving skills.

Based on the background that has been conveyed and the analysis of several studies on problem-solving assessment development, it was found that the developed test assessments are limited to the development of instruments with information in the form of writing and one-dimensional images, and are still paper-based tests with types of multiple-choice reasoned tests and essay tests. Meanwhile, current learning is leaning towards digital learning with technology and the digitization of real-world concepts. Thus, the solution to this problem lies in the development of a problem-solving assessment that can be accessed by students without restrictions, which is a digital, internet-based test assessment with varied types of questions.

After the COVID-19 pandemic, we've become increasingly aware that digital learning should be a crucial part of learning activities. By integrating technology into the existing curriculum, not just using it as a crisis management tool, educators can utilize technology as an effort to increase student engagement. Virtual classrooms, videos, robots, augmented reality (AR), and other technological tools can not only enliven the class but also create a more inclusive learning environment that encourages collaboration and curiosity, and allows educators to gather data about student performance [16] [17]. The use of technology, especially AR, has become highly desirable and inseparable in physics learning activities, particularly to facilitate the visualization of abstract physics concepts. The use of AR in learning, especially in experimental activities, has been widely conducted and proven to support physics learning activities, both in classroom learning processes, laboratory practice, and independent tasks [16] [17] [18] [19].

However, there has not been any research that uses AR as part of learning assessment. Based on the background presented, the state of art of this research is the use of AR in problem-solving assessment. The use of AR in the assessment serves to provide a real-life depiction of the phenomena related to the problem presented in the three-dimensional test, thereby helping to more accurately measure problem-solving skills in physics material. In brief, the objective of this research is to develop an assessment to measure problem-solving skills by integrating augmented reality into physics learning. Therefore, this research aims to develop ARIPSA (Augmented Reality Integrated on Problem-solving Assessment) in Physics Material".

METHOD

The method used in this research is a development research method. The model used in this development research is the Borg and Gall development model [20]. The Borg and Gall development model is a development process that serves to develop and validate educational products. The stages of this model include analyzing previous research results related to the product to be developed, developing the product based on findings, expert validation, product testing, and the product is ready to be used [21] [22]. The research and development framework by Borg and Gall is depicted in Figure 1.

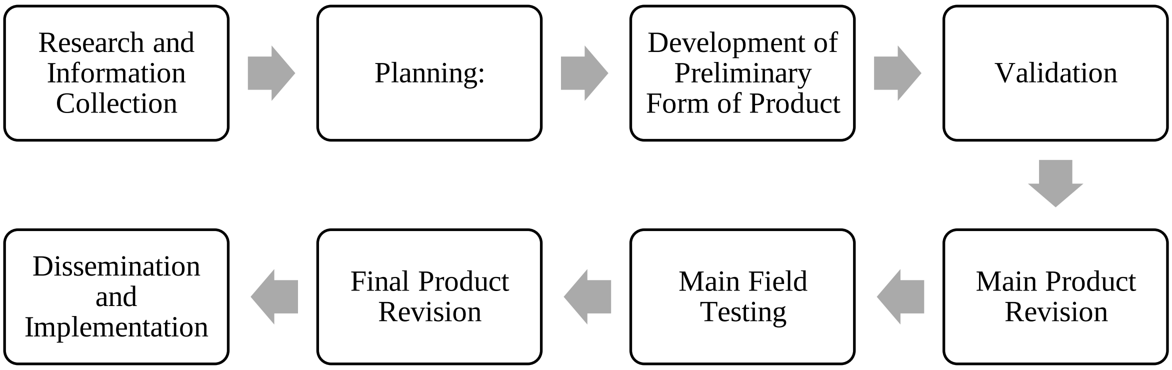

Fig 1. *Borg and Gall Development Procedure Scheme (1989)*

The development product in this research is an assessment to measure problem-solving skills integrated into AR (augmented reality) as support in solving problems in the context of physics material, entitled Augmented Reality Integrated of Problem Solving Assessment, further abbreviated as ARIPSA. This assessment product will be created and arranged according to Heller's problem-solving indicators, namely (1) visualizing the problem, (2) describing the problem in a physics description, (3) planning a solution, (4) implementing the plan, and (5) checking and evaluating each item [9]. ARIPSA is structured as an alternative digital test and will go through several stages of feasibility validation that must be carried out. The aspects of validation feasibility include language aspects, display design, material content, and conformity with problem-solving indicators.

The instruments used in this research include expert validation sheets. In this development research, the research data is in the form of the percentage of product feasibility obtained from the results of validation by validators. The appropriateness of the ARIPSA product data is obtained from the results of expert validation as well as users. The expert validation aspect is presented in Table 1 as follows:

Table 1. Indicators for Validation Assessment

Aspect	Indicators
Content	• Congruence between instructional materials and learning objectives is observed. • The alignment of instructional materials with students' needs and capabilities is evident. • Consistency with Heller's problem-solving indicators is evident. • Alignment between Augmented Reality (AR) elements and the core content is apparent. • Contextual presentation characterizes the offered problem scenarios. • The presented problems effectively stimulate students to engage in problem-solving endeavors. • Problem scenarios are presented in the form of plausible narrative inquiries, closely mirroring real-world magnitudes and values. • The presented problems are characterized by their solvability. • Precision is maintained in terms of the correspondence between posed questions and expected solutions. • Answer options are coherent with the respective questions and exhibit logical viability. • Plausible yet erroneous answer choices (distractors) are notably reasonable, prompting students to cogitate deeply and apply their acquired knowledge. • The number of questions correlates appropriately with the designated time frame.
Language	• The application of language adheres rigorously to the principles of the EYD framework. • The avoidance of lexicon bearing profane connotations, hate speech, or extraneous and incongruous sensitive issues is evident. • Test inquiries are crafted with readability and student comprehension in mind, ensuring a lack of duplicity. • Questions are phrased in a manner that leverages linguistic efficacy. • Each question epitomizes a comprehensive and singular concept, thereby eschewing any semblance of partiality.
Design	• Explicit directives governing the effective utilization of the Assessment are incorporated. • Visual representations within the Augmented Reality realm manifest with a conspicuous level of visual acuity and precision. • Augmented Reality elements seamlessly materialize following the activation of the camera scanning process. • The textual components and typographical elements maintain an optimal level of clarity and legibility. • The Assessment interface is meticulously engineered to ensure intuitive navigability and comprehension ease.

RESULTS AND DISCUSSIONS

This study is a research endeavor with a developmental focus, aiming to design and build an integrated Augmented Reality (AR) evaluation tool. The project was launched in the month of June. The study employed Borg and Gall's Research and Development (R&D) paradigm, encompassing a series of eight distinct stages. The eight stages of the research process include: 1) Data collection, which involves gathering relevant information; 2) Planning, which entails developing a comprehensive research plan; 3) Initial product development, where the initial version of the product is created; 4)

Validation, which involves assessing the accuracy and reliability of the product; 5) Preliminary field test and revision, where the product is tested in a controlled environment and necessary adjustments are made; 6) Main field every stage of the process had a significant role in both the advancement and verification of the augmented reality (AR) assessment tool.

After doing pilot testing on the questions, the ones that were considered suitable were combined to create an assessment instrument called Augmented Reality Integrated Performance and Skills Assessment (ARIPSA). The formulation of the inquiries followed the organized framework of problem-solving, as outlined by Heller [23]. The initial interface of the system includes a gateway that provides access to the ARIPSA platform. Additionally, it presents clear and concise instructions on how to successfully navigate and complete the ARIPSA process. Subsequently, a subsequent window presents an animated student avatar that serves as a navigational aid. The subsequent interfaces encompass the inquiries that necessitate the attention and response of the students.

In order to participate in ARIPSA, it is necessary for students to download the MAKAR application from the Play Store. The instructor will subsequently distribute an access code to facilitate student entry into the ARIPSA interface. It is important to notice that each question offered in the different windows is accompanied by a predetermined time limit, which promotes the practice of effective time management. Before its implementation, ARIPSA received thorough validation that covered several aspects such as content, linguistic precision, and design aesthetics. The results of the validation for aspect content procedure are methodically depicted in Figure 2.

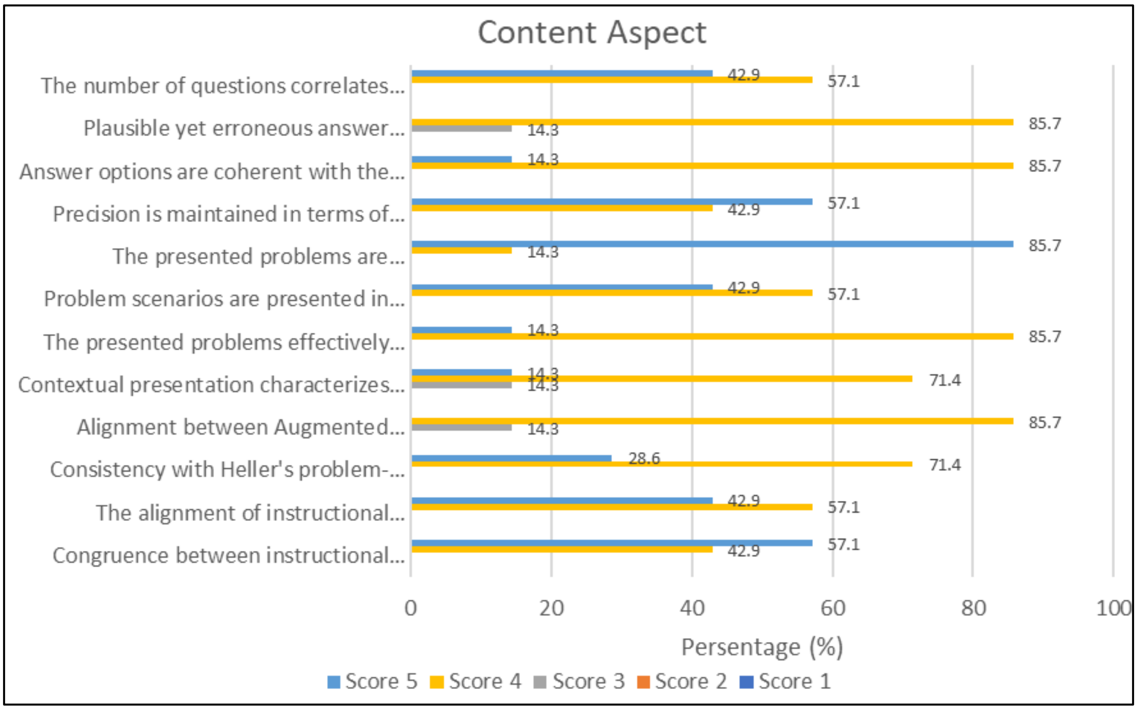

Fig 2. *Results of the validation pertaining to content aspects*

Figure 2 delineates the validation of an assessment instrument via twelve evaluative statements on content quality, quantified on a 1-to-5 scale. Observably, no statements garnered a score below 3. Predominantly, indicators clustered around scale 4, with a few approaching scale 5, particularly in the realm of "Material Relevance to Learner Needs" and "Number of Questions and Time," underscoring the alignment of instructional content with learner objectives and temporal considerations. Conversely, the indicator "Plausible Distractors" approached a scale of 5 rating, attesting to the instrument's cognitive rigor.

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Two statements related to Augmented Reality (AR) in ARIPSA scored at point 3, presumably owing to technological limitations and connectivity issues. Cumulatively, the data suggest the instrument's content quality is commendable, albeit with opportunities for refinement to achieve universal scale-5 ratings. These findings substantiate the hypothesis of systematic design in the assessment, with indicators revealing meticulous content alignment and temporal balancing [2] [24]. However, the AR-related metrics indicate technological constraints that merit further scrutiny [24] [25]. Overall, the instrument manifests commendable quality, while acknowledging the necessity for continual refinement, particularly in technological domains [24]. The results of the validation pertaining to linguistic aspects are delineated in Figure 3, as follows:

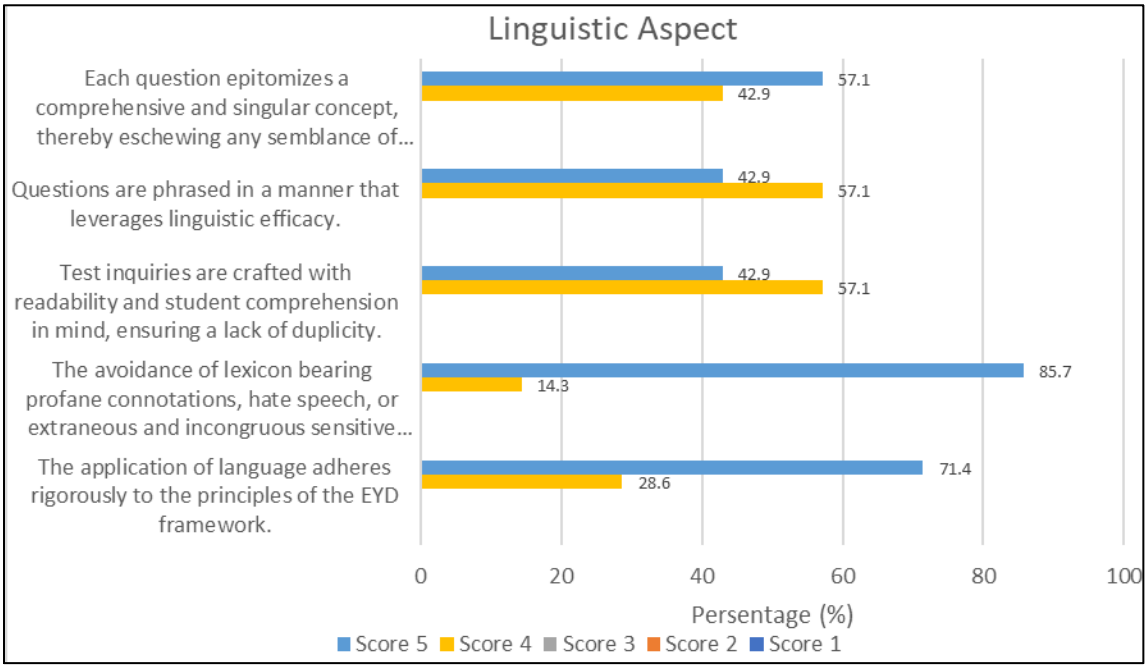

***Fig 3**. Results of the validation pertaining to linguistic aspects*

The empirical evaluation of ARIPSA's linguistic content is presented in Figure 3 through a bar chart. This evaluation is conducted based on five criteria that are specifically relevant to linguistic features. The assessment of each criterion is conducted using a metric scale that spans from 3 to 5. After doing a preliminary analysis, it becomes apparent that the majority of the criteria have received the highest grade of 5. However, there are anomalies present in the form of two specific criteria that have not attained the highest possible rating. These criteria, namely "*Legibility and Comprehensibility of Questions*" and "*Efficacy of Language Utilized in Questions*," have not attained the zenith of the evaluation scale. This observation implies that while ARIPSA demonstrates overall excellence in linguistic quality, there are discrete domains, particularly clarity and language efficacy, that necessitate further refinement [2] [26] [27]. In contrast, the criteria such as "*Conformity to EYD (Enhanced Standard Indonesian) Guidelines*," "*Absence of Inflammatory, Sensitive, or Irrelevant Language*," and "*Incorporation of a Singular*, Unbiased Idea in Test Questions," each received a perfect score of 5. This serves as a testament to ARIPSA's optimization in these particular linguistic domains.

In relation to the developmental process of ARIPSA, there has been a conscious focus on adhering to the requirements set by EYD and the deliberate elimination of anything that may be deemed problematic. The aforementioned emphasis is supported by the highest ratings obtained in these specific areas [28]. Notwithstanding the commendable performance, it is worth noting that the use of certain phrase or terminology may lead to confusion among a specific group of students. Although the majority of learners may find this language clear, there is a subset of individuals who may encounter difficulties in interpreting it [29] [30]. Moreover, the inherent subjectivity of language efficacy and lucidity, particularly when assessed by educational professionals, underscores the imperative for continuous improvements. Therefore, despite undergoing several iterations of refining, there are still aspects inside ARIPSA that require enhancements in terms of language clarity and efficacy [26] [29]. The design aspect validation results are displayed in Figure 4.

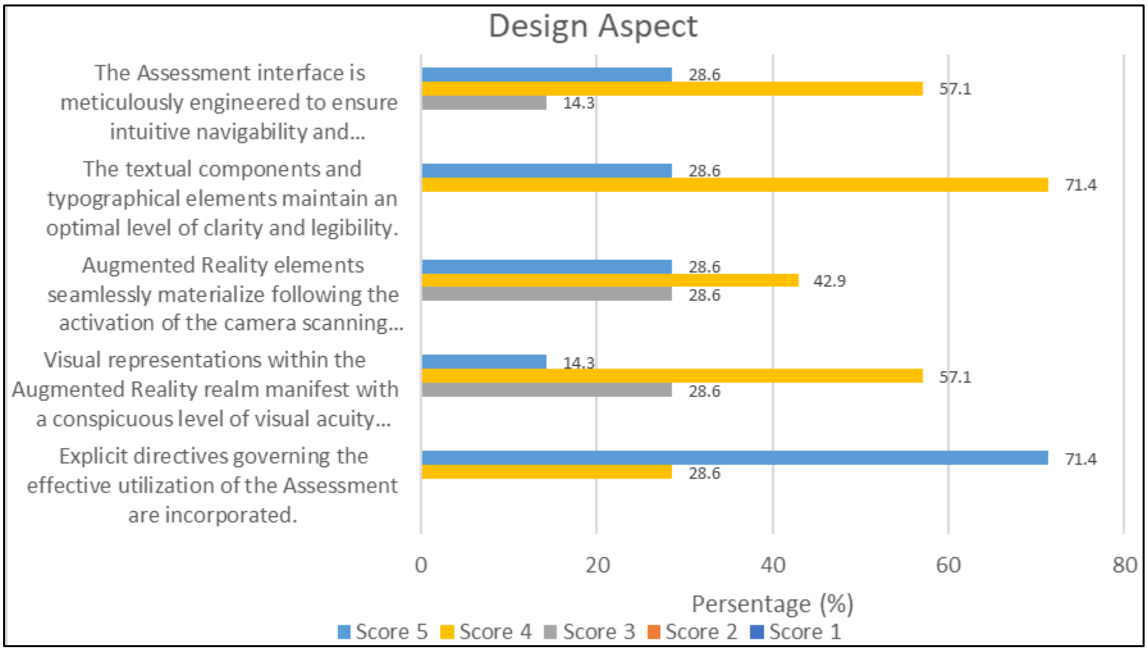

***Fig 4**. Results of the validation pertaining to design aspects*

Figure 4 displays a bar chart that provides a quantitative evaluation of the media design characteristics of the test instrument. The aforementioned traits were assessed using a numerical scale that spanned from 1 to 5, and were quantified across a set of five distinct indicators. A considerable number of the criteria received a rating of 4, with an average percentage above 40%. However, the criterion referred to as "Clarity of Assessment Instructions" received a maximum score of 5.

Four distinct indications, namely "Image Clarity in Augmented Reality (AR)," "Effectiveness of AR Camera Scanning," "Readability of Text," and "User-Friendliness of the Assessment," received evaluations on a scale of 4. This implies satisfactory performance in these areas, but also highlights the possibility of additional improvement [24] [31] [32]. In contrast, the criterion pertaining to the clarity of assessment instructions was awarded a flawless rating, underscoring the instrument's exceptional ability to provide users with lucid and comprehensible recommendations [33].

Possible opportunities for enhancement within the suboptimal domains could be to the improvement of resolution, optimization of software, and ensuring compatibility with various devices [34] [35]. Various situations may have an impact on the visual aspects, scanning accuracy, and readability of a given subject. The ARIPSA product can be accessed via the MAKAR application. Once the program is downloaded, students have the ability to search for "ARIPSA" and then proceed to interact with the assessment by choosing the "experience" option.

CONCLUSION AND SUGGESTION

After undergoing thorough validation methods that encompassed content, linguistic articulation, and design, it has been determined that the ARIPSA is academically robust and pedagogically impactful in improving students' problem-solving skills. The utilization of comprehensive evaluation metrics provides support for the assertion that the assessment material possesses both relevance and empirical validity and reliability. Consequently, this ensures the integrity and quality of the resulting data. Moreover, the linguistic selections included in the evaluation are clear and readily understandable, therefore making this tool suitable for use across various academic populations.

In terms of recommendations for future study, it is advised to enhance the graphical quality and resolution in order to offer a more authentic and engaging augmented reality (AR) encounter. Furthermore, the integration of additional interactive components within the augmented reality (AR) encounter, such as gesture-based control or voice-activated instructions, will effectively enhance the process of navigating through the content and thereby elevate student involvement and participation. Although the duration may be extended, the anticipated results are projected to be more favourable.

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