INTEGRATION OF AUGMENTED REALITY TECHNOLOGY FOR LEARNING: AN QUALITATIVE META-ANALYSIS STUDY

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ABSTRACT

Augmented Reality (AR) is one of the most popular technologies used in the field of education. AR technology is widely used as a learning medium or to develop engaging, innovative textbooks for students. However, there is still much debate regarding the use of AR at various levels of education, starting from elementary school to the higher education level. This qualitative meta-analysis research explores the urgency of implementing AR technology in schools and the readiness of the main subjects of learning (teachers and students) to use AR in the classroom. The synthesis method used is the narrative review model. This synthesis model is used to analyze 100 research results in non-numeric data by identifying the research results documents found. The study results show that teachers at the elementary to high school level and lecturers at the higher education level feel that AR technology is crucial to implement in the learning process. However, from all levels, teachers' and lecturers' readiness to make AR-based learning tools still needs to be improved. In addition, another finding in this study is that the percentage of teachers in elementary school (52%) readiness to use AR technology is higher than that of lecturers in higher education (21%).

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1. INTRODUCTION

Technology and information development are growing massively in every line of human life (Wahyudiyono, 2016). One aspect of human life that is starting to integrate with Technology and Information is Education (Radha et al., 2020). Undeniably, the COVID-19 pandemic that hit Indonesia in 2020 ultimately forced all education actors, from teachers and students to parents, to use technology in the learning process (Zirawaga et al., 2017). A pandemic situation that requires teachers to conduct online/online learning, in the end, makes teachers and students familiar with virtual learning aids such as Zoom Meeting, Edmodo, or Google Meet (Lidiawati & Helsa, 2021); (B. Klimova et al., 2022). Not only in the learning process, but many teachers also use the Quizziz website or the Google form feature to evaluate student learning outcomes during a pandemic (C. Yang, 2021); (Maulyda et al., 2020). From this explanation, the development of technology and information helped the education system run during the COVID-19 pandemic. This kind of situation may occur in the future. Because of that, the Government is starting to realize that it is crucial to involve technology and information in the education system in Indonesia.

This government awareness was eventually realized by adding the Augmented Reality (AR) feature to the Kemdikbud Learning House website. On this site, teachers can use AR technology as a free learning medium for teaching at school (Ashtari, 2020). The Augmented Reality system works based on digital image detection (Demitriadou et al., 2020); (Baran et al., 2020). The working principle of AR is quite simple; it only consists of a camera and a mobile monitoring device. Sometimes, it requires a particular device to interact with virtual objects such as images (Ibáñez, 2020). Based on the results of distributing online questionnaires to 35 teachers in schools (14 elementary schools, 12 junior high schools, and nine high schools) related to the use of AR in learning in schools, the following data was found.
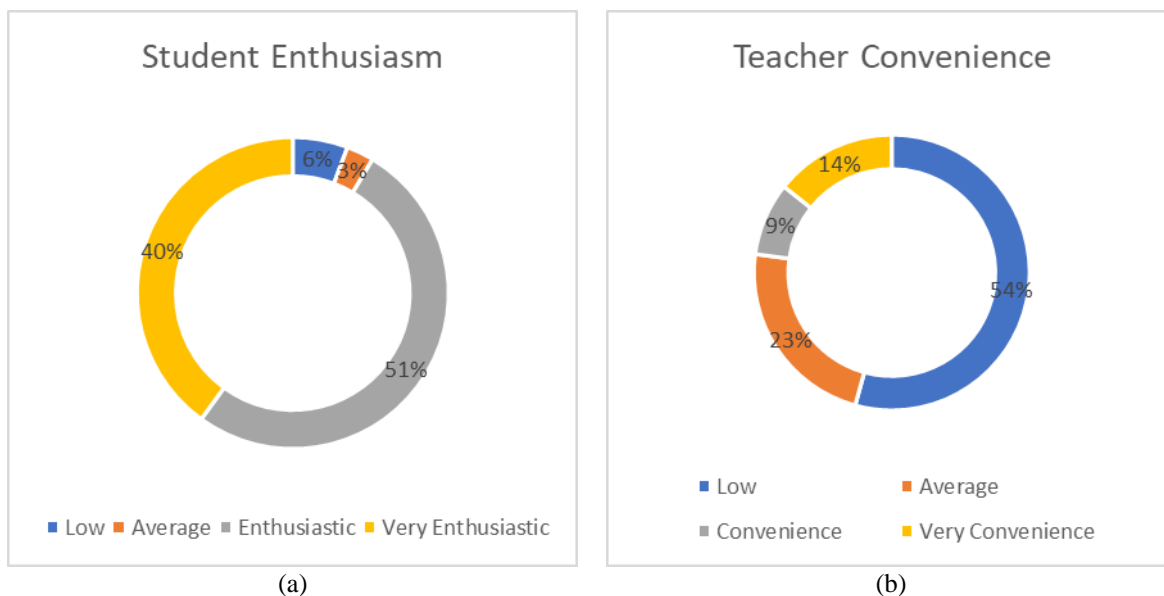

Figure 1. *Results of Interviews with Teachers*
(a) Student Enthusiasm, (b) Teacher Convenience

Referring to Figure 1, implementing the AR system in the learning process at school can arouse students' enthusiasm for learning. This can be seen from 51% of students considered very enthusiastic by the teacher when the learning process uses AR. In addition, 40% of students were considered enthusiastic by the teacher about using this AR. Conversely, 54% of teachers believe AR media still needs to be considered impractical and difficult to implement in schools. Thus, this AR system must still be entirely acceptable to school teachers. Not all teachers can adapt to technology and use AR as a tool or media for classroom learning.

Based on the results of the AR implementation questionnaire in schools that have been studied, several research questions were born, including; (1) Does the AR system need to be implemented in schools?; and (2) Are teachers and students ready to use the AR system in schools?

2.   METHOD

The research approach used in this study is Qualitative Meta-Analysis (Hoon, 2013). The type of research document used in this study is a scientific article related to the AR system. Research data was collected by searching for articles from the Scopus database, Web of Science, Crossref, and Google Scholar. The keywords used are "Augmented Reality" and "Innovative Learning".

The criteria for research results that researchers consider are: (1) Categories of National and International Journals; (2) Publications in the last five years; (3) The title contains the keywords AR and Learning; (4) Indexation of Sinta-indexed National Journals and Scopus-indexed International Journals or WoS. The researcher will select 100 research results documents that match the keywords and criteria determined. The synthesis process of 100 selected research documents uses the narrative review model. A narrative review is a synthesis model for non-numeric data, which is carried out by identifying the research results and documents found. The focus of the meta-analysis in this study was to answer the question of the need to use AR systems in schools. Moreover, the readiness of teachers and students to use AR systems in schools is presented in table 1 below.

Table 1. *Results of the AR Implementation Review in Schools*

No	Author	The Urgency of AR Systems in Schools	Readiness of Teachers and Students in using AR	The Role of AR in the Classroom	Educational stage
1	(Demitriadou et al., 2020)	Urgent	Ready	Learning Media	SD
2	(Ibáñez, 2020)	Not Urgent	Not Ready	Textbook	SMP
3	(Maas, 2020)	Urgent	Ready	Learning Media	SMA
4	(Iatsyshyn, 2020)	Not Urgent	Not Ready	Learning Application	PT
5	(Radianti, 2020)	Urgent	Not Ready	-	-
6	(Ibáñez, 2018)	Urgent	Not Ready	Learning Evaluation	SMP
7	(Garzón, 2019b)	Urgent	Not Ready	-	-
8	(Arici, 2019)	Urgent	Not Ready	Learning Application	PT
9	(Emanuel, 2020)	Urgent	Not Ready	Learning Application	PT
10	(Khan, 2019)	Urgent	Not Ready	Learning Media	SD
11	(Garzón, 2019a)	Urgent	Not Ready	-	-
12	(Fidan, 2019)	Urgent	Ready	Learning Evaluation	SD
13	(Pellas, 2019)	Not Urgent	Ready	Learning Evaluation	SMP
14	(Iwanaga, 2021)	Not Urgent	Not Ready	-	-
15	(Sahin, 2020)	Urgent	Ready	Learning Media	SD
16	(Elmqaddem, 2019)	Urgent	Ready	Learning Media	SD
17	(Grodotzki, 2018)	Urgent	Ready	Learning Application	PT
18	(Joda, 2019)	Not Urgent	Not Ready	-	-
19	(Ruiz-Ariza, 2018)	Not Urgent	Ready	Learning Media	SD
20	(Huang, 2019)	Urgent	Ready	Learning Media	SMA
21	(Yip, 2019)	Not Urgent	Not Ready	Learning Media	SMP
22	(Papanastasiou, 2019)	Urgent	Not Ready	Learning Media	SMA
23	(Syrovatskyi, 2018)	Not Urgent	Not Ready	Learning Media	PT
24	(Ozdemir, 2018)	Not Urgent	Not Ready	-	-
25	(Turan, 2018)	Not Urgent	Not Ready	Learning Application	PT
26	(Nechypurenko, 2018)	Urgent	Not Ready	Learning Media	SMA
27	(Gerup, 2020)	Urgent	Not Ready	Learning Media	PT
28	(Mota, 2018)	Urgent	Ready	Learning Media	SD
29	(Lai, 2019)	Urgent	Ready	Learning Media	SD
30	(Laine, 2018)	Urgent	Not Ready	-	-
31	(Aebersold, 2018)	Not Urgent	Not Ready	Learning Evaluation	SMP
32	(Kugelmann, 2018)	Urgent	Ready	Learning Evaluation	SD
33	(Y. Chen, 2019)	Urgent	Not Ready	Learning Media	SMP
34	(Ibrahim, 2018)	Urgent	Not Ready	Learning Media	SMP
35	(Soltani, 2020)	Urgent	Not Ready	Learning Evaluation	SD
36	(Cabero-Almenara, 2019b)	Urgent	Not Ready	Learning Evaluation	SMP
37	(Wang, 2018)	Urgent	Ready	Textbook	SD
38	(Kurniawan, 2018)	Urgent	Not Ready	Learning Media	PT
39	(Alalwan, 2020)	Urgent	Ready	Learning Media	SD
40	(Quintero, 2019)	Urgent	Not Ready	Learning Media	SD
41	(Cai, 2019)	Urgent	Ready	Learning Media	SD
42	(Garzón, 2020)	Not Urgent	Not Ready		-
43	(Bursali, 2019)	Not Urgent	Ready	Learning Evaluation	SMP
44	(S. Yang, 2018)	Urgent	Ready	Learning Evaluation	SMA
45	(Diao, 2019)	Not Urgent	Ready	-	-
46	(Tzima, 2019)	Not Urgent	Ready	Textbook	SD
47	(Cabero-Almenara, 2019a)	Urgent	Not Ready	Learning Application	PT
48	(Challenor, 2019)	Urgent	Not Ready	Textbook	SMA
49	(Lytridis, 2018)	Urgent	Not Ready	Learning Application	PT
50	(Scavarelli, 2021)	Not Urgent	Not Ready	-	-
51	(Moro, 2021)	Not Urgent	Not Ready	Learning Media	PT
52	ccc	Urgent	Ready	Learning Media	SD
53	(Kramarenko, 2020)	Not Urgent	Not Ready	Learning Media	SD
54	(Altmeyer, 2020)	Urgent	Not Ready	Learning Media	SMP
55	(Juraschek, 2018)	Urgent	Ready	Learning Evaluation	SMA
56	(Rau, 2018)	Urgent	Not Ready	Learning Evaluation	SMP
57	(da Silva, 2019)	Urgent	Not Ready	-	-
58	(Almenara, 2018)	Urgent	Ready	Textbook	SD
59	(Velázquez, 2018)	Not Urgent	Not Ready	Textbook	SD
60	(Lampropoulos, 2020)	Not Urgent	Not Ready	-	-
61	(Belmonte, 2019)	Urgent	Not Ready	Learning Media	SMA
62	(Barteit, 2021)	Urgent	Ready	Learning Media	PT
63	(Zafar, 2020)	Urgent	Not Ready	Learning Media	PT
64	(Bacca, 2019)	Urgent	Not Ready	Learning Media	SMA
65	(Radu, 2019)	Urgent	Not Ready	Learning Media	SMP
66	(Teng, 2018)	Urgent	Ready	Learning Application	PT
67	(Farronato, 2019)	Urgent	Not Ready	-	-
68	(R. Chen, 2019)	Urgent	Not Ready	-	-

69	(Uruthiralingam, 2020)	Urgent	Not Ready	Learning Media	SD
70	(Sırakaya, 2022)	Urgent	Ready	Learning Media	SMP
71	(Dalim, 2020)	Urgent	Not Ready	Learning Media	SMP
72	(Abad-Segura, 2020)	Urgent	Ready	Learning Media	SD
73	(Cai, 2020)	Urgent	Not Ready	Learning Media	SD
74	(Singh, 2019)	Urgent	Not Ready	Learning Media	SMA
75	(Garcia-Bonete, 2019)	Not Urgent	Not Ready	Learning Media	SMP
76	(Bacca, 2018)	Not Urgent	Ready	Textbook	SMA
77	(Jang, 2021)	Urgent	Not Ready	Learning Media	PT
78	(Jesionkowska, 2020)	Urgent	Not Ready	Learning Evaluation	SD
79	(Plunkett, 2019)	Urgent	Not Ready	Learning Evaluation	SMP
80	(Beck, 2019)	Urgent	Ready	Learning Media	SMP
81	(A. Klimova, 2018)	Urgent	Not Ready	Textbook	SMA
82	(Altinpulluk, 2019)	Urgent	Not Ready	Learning Application	PT
83	(Goff, 2018)	Urgent	Ready	-	-
84	(Nesenbergs, 2021)	Urgent	Not Ready	-	-
85	(Kerr, 2020)	Urgent	Not Ready	Learning Application	PT
86	(Moorhouse, 2019)	Urgent	Not Ready	Learning Media	SD
87	(Kobayashi, 2018)	Urgent	Not Ready	Learning Media	SMP
88	(Calvert, 2020)	Not Urgent	Not Ready	Learning Media	PT
89	(Sorko, 2019)	Urgent	Not Ready	Learning Media	SD
90	(Cai, 2021)	Urgent	Ready	Learning Media	SMP
91	(Petrov, 2020)	Urgent	Not Ready	Textbook	SD
92	(Vasilevski, 2020)	Urgent	Not Ready	Textbook	SD
93	(Karakus, 2019)	Urgent	Not Ready	-	-
94	(Syawaludin, 2019)	Urgent	Not Ready	Learning Media	SMP
95	(Karagozlu, 2018)	Urgent	Not Ready	Learning Media	SD
96	(Rossano, 2020)	Urgent	Ready	Learning Media	SD
97	(Catal, 2019)	Urgent	Ready	Learning Media	PT
98	(Redondo, 2020)	Urgent	Not Ready	Learning Media	SD
99	(Cabero-Almenara, 2019c)	Urgent	Ready	-	-
100	(Alhumaidan, 2018)	Urgent	Not Ready	Textbook	SD

In general, the results of a review of 100 research results related to the implementation of AR in schools show that it is important to develop Augmented Reality (AR) technology in the learning process in schools. However, teachers and students are still not ready to implement AR technology in schools. Details of the research results will be presented at the research results stage. Of the 100 research results analyzed, there were 18 literature study research results that could not be identified at the level of education studied. In addition, there are 82 empirical research results that can be identified as research focuses at each level of education, namely, elementary, middle school, high school and higher education which are explained in detail in the following research results.

3.   RESULT & DISCUSSION
3.1. Implementation of AR Technology at Elementary School Education Level

Of the 100 research data analyzed, there were 31 research results from the elementary school (SD) level. Data from research conducted at the elementary school level are as follows.
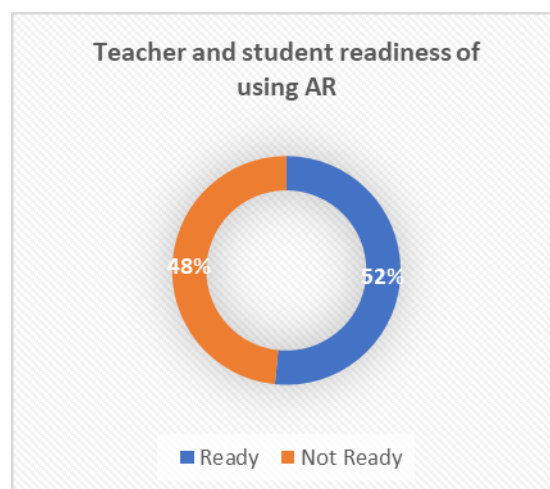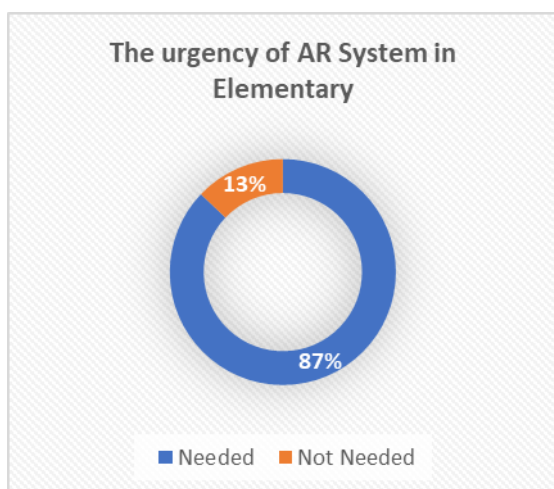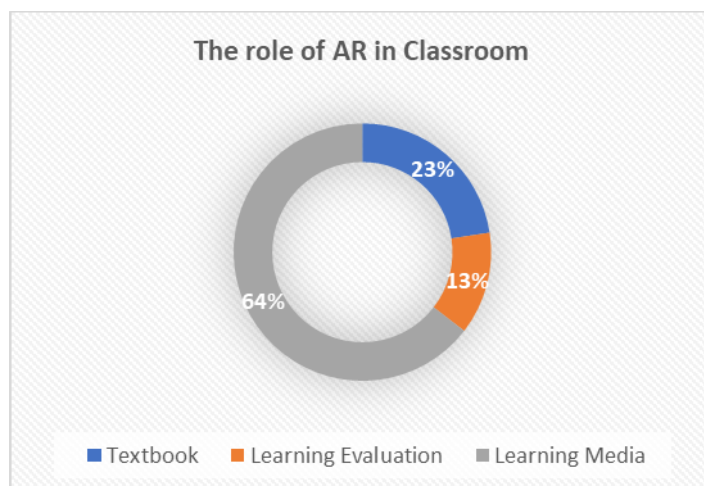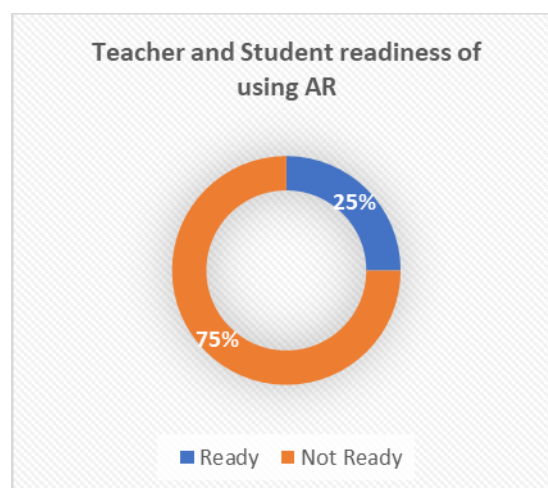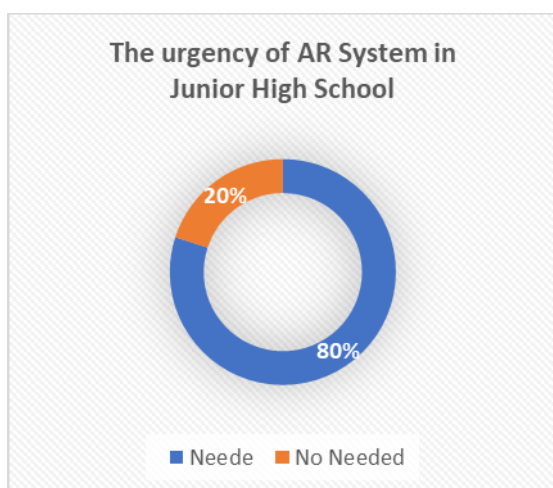
Figure 2. *Results of Meta Analysis of AR Implementation in Elementary Schools*

Based on the data in Figure 2, it can be seen that the urgency of implementing AR in elementary schools is considered very important. This can be seen from 87% or 27 research results stating that elementary school teachers consider the implementation of AR in schools to be very important. However, based on research results related to the readiness of teachers and students in implementing AR, it shows that the data is almost balanced between teachers and students who are Ready and Not Ready. The results of the analysis show that 52% (16 research results) stated that elementary school teachers and students were ready to carry out learning using AR, while 48% (15 research results) stated that elementary school teachers and students were still not ready to implement it. From these results, it is still difficult to conclude whether teachers and students in elementary schools are ready to carry out learning using AR technology. Apart from that, the research results also show the roles of AR in the classroom, including, 64% (20 research results) use AR as Learning Media, 23% (7 research results) use AR as a learning Text Book, and 13% (4 research results) using AR as Learning Evaluation in class.

3.2. Implementation of AR Technology at Junior High School Education Level

Of the 100 research data analyzed, there were 20 research results that came from the junior high school (SMP) level. Data from research conducted at the junior high school level are as follows.
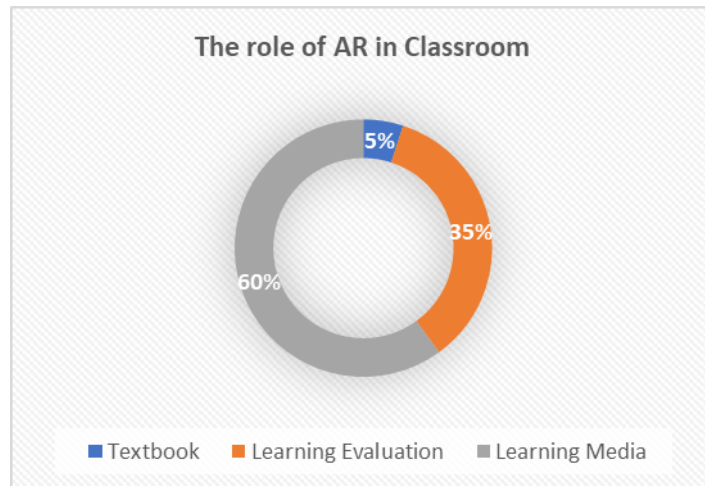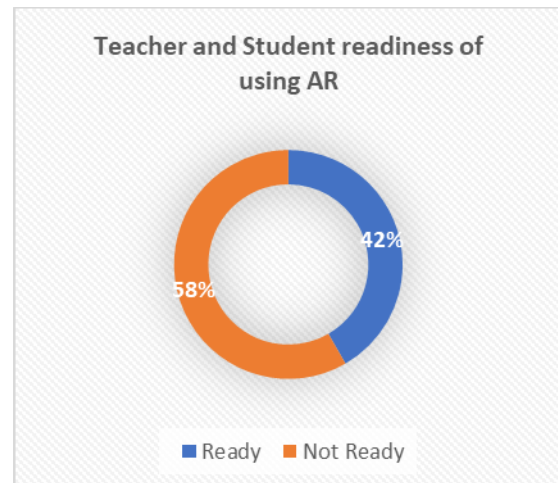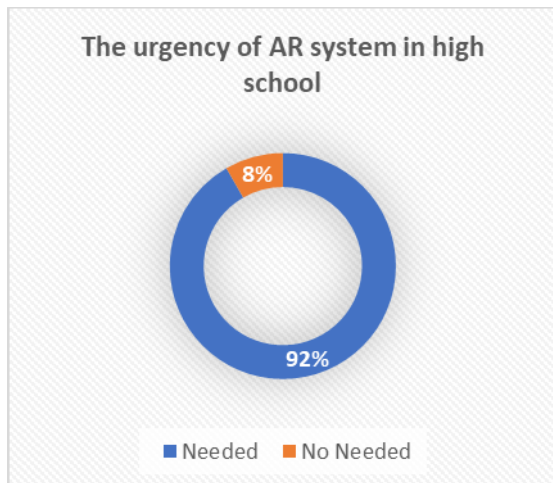
Figure 3. *Results of Meta Analysis of AR Implementation in Middle Schools*

Based on the data in Figure 3, it can be seen that the urgency of implementing AR in junior high schools is considered very important. This can be seen from 80% or 16 research results stating that junior high school teachers consider it necessary to implement AR in schools. However, based on research results related to the readiness of teachers and students to implement AR, the data shows that only 25% or 5 research results state that teachers and students are ready to use AR in learning. Meanwhile, 75% or 15 other research results stated that teachers and students were still not ready to use AR technology in learning. Based on these results, it can be said that the readiness of teachers and students at the junior high school level is still very lacking. For data on the use of AR that has been carried out, the research results show the roles of AR in the classroom, including, 60% (12 research results) use AR as Learning Media, 5% (1 research result) use AR as a learning Text Book, and 35% (7 research results) using AR as Learning Evaluation in the classroom.

3.3. Implementation of AR Technology at the High School Education Level

Of the 100 research data analyzed, there were 12 research results that came from the Senior High School (SMA) education level. Data from research conducted at the high school education level are as follows.
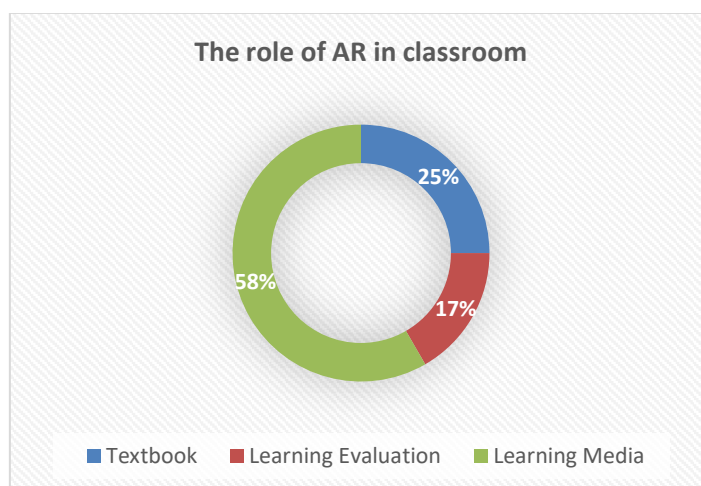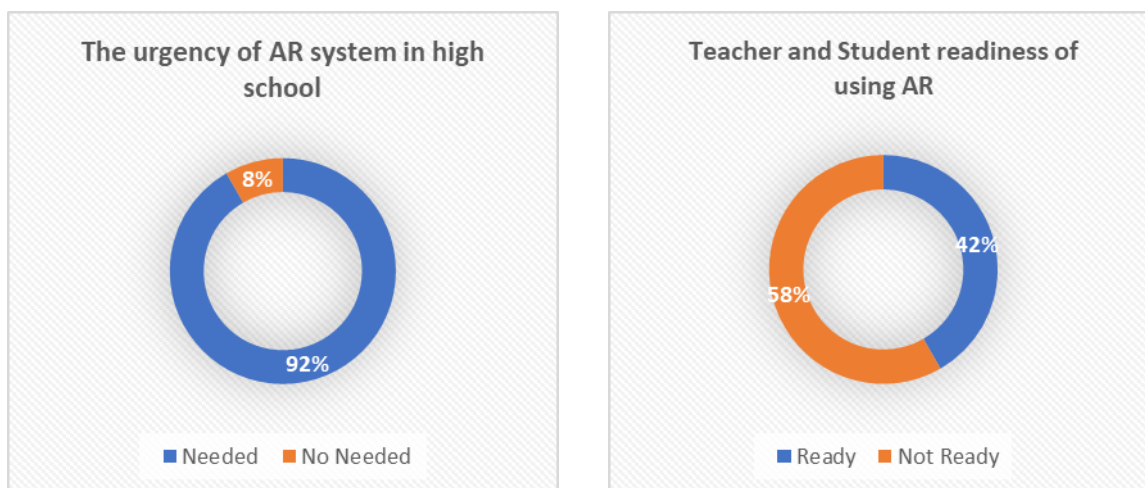
Figure 4. *Results of Meta Analysis of AR Implementation in High Schools*

Based on the data in Figure 4, it can be seen that the urgency of implementing AR in SMA is considered very important. This can be seen from 92% or 11 research results stating that high school teachers consider it necessary to implement AR in schools. Almost all high school teachers agree that AR technology needs to be used in classroom learning. Almost the same as the data from research at the elementary school level, the research results stating that teachers and students are ready to use AR technology are also quite balanced. It can be seen that 58% or 7 research results stated that teachers and students were still not ready to use AR technology, while 42% or 5 other research results stated that teachers and students were ready. Based on these results, it can be said that the readiness of teachers and students at the high school education level is still in doubt. For data on the use of AR that has been carried out, the research results show the roles of AR in the classroom, including, 58% (7 research results) use AR as Learning Media, 25% (3 research results) use AR as a learning Text Book, and 17% (2 research results) using AR as Learning Evaluation in the classroom

3.2. Implementation of AR Technology at University Education Level

Of the 100 research data analyzed, there were 19 research results that came from the Higher Education (PT) level. Data from research conducted at the PT education level are as follows.
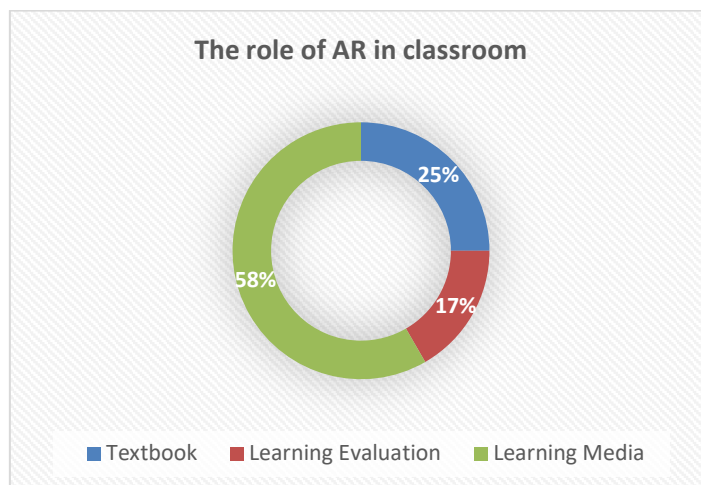
Figure 5. *Results of Meta Analysis of AR Implementation at University*

Based on the data in Figure 5, it can be seen that the urgency of implementing AR in PT is considered very important to do. This can be seen from 74% or 14 research results stating that lecturers think it is necessary to implement AR at the University. Meanwhile, the remaining 26% or 5 research results state that AR implementation is still not necessary. Regarding the readiness of AR technology integration at the HE level, it turned out to show quite surprising results. Of the 19 research results analyzed, 79% or 15 research results showed that lecturers and students were still not ready to use AR technology, while only 21% or 4 research results stated that lecturers and students were ready. This data is different from the existing stigma that the educational process involving technology at the tertiary level is more prepared than at lower educational levels. Based on these results, it can be said that the readiness of lecturers and students at the higher education level to use AR is still quite low. For data on the use of AR that has been carried out, the research results show the roles of AR in the classroom, including, 53% (10 research results) use AR as a Learning Media, and 47% (9 research results) use AR as an application to assist in learning.

Based on the results of the meta-analysis carried out, teaching staff at school (teacher) and higher education (lecturer) levels feel that AR technology is very necessary in the learning process. For elementary school education, AR technology can help students who are still at the concrete thinking stage understand abstract fields (Khan, 2019; Elmqaddem, 2019; & Alalwan, 2020). AR technology can visualize abstract objects into 3D, this makes objects more concrete and easier for elementary school students to understand (Mota, 2018); (Soltani, 2020). Teachers feel that it will be very helpful if this AR technology can be integrated optimally in several lesson materials in elementary school, such as flat planes in mathematics subjects, or body anatomy in science subjects (Quintero, 2019; Uruthiralingam, 2020; & Cai, 2020) . However, there are several research results which state that the integration of AR in elementary school learning is still not necessary. As according to Ruiz-Ariza (2018) & Tzima (2019) who explained that teachers in elementary schools still do not have the skills to create AR barcodes for learning. In creating AR, teachers must have adequate information technology skills, because it involves a lot of software and other computerized devices (Velázquez, 2018; Kramarenko, 2020).

For secondary school education levels, both junior high school (SMP) and senior high school (SMA), the research results show that teachers consider the integration of AR technology to be very important in the learning process. This is because students at the middle and high school education levels on average already have "dependence" on gadgets (Huang, 2019; Papanastasiou, 2019; & Sırakaya, 2022). Therefore, it is very important to involve gadgets in the learning process, so that students' learning motivation at school can increase and the learning process in class can run more actively and effectively (Bacca, 2019; Altmeyer, 2020; & Dalim, 2020). AR implementation has often been used as a Learning Media, where students will use their gadgets to scan barcodes that have been provided by the teacher (Ibrahim, 2018). Because it involves this gadget, students tend to like the learning process using AR-based Learning Media (Y. Chen, 2019; Huang, 2019). However, there are still several research results which consider that the integration of AR at the middle and high school education levels is still not necessary. As according to research results by Garcia-Bonete (2019) & Bursali (2019) which explains that integrating AR technology in learning in middle and high schools will make it difficult for students to develop the ability to abstract from an object. This is because students are still provided with concrete objects that should have been abandoned in the learning process at the junior and senior high school levels.

Finally, for higher education or university level, the results of meta analysis show that lecturers are very optimistic that AR technology can be implemented in the lecture process (Arici, 2019; Gerup, 2020). As

students, individuals should have experience in using technologies such as AR (Grodotzki, 2018). Especially for universities in the Teacher Education department as a forum for producing future teacher candidates. These prospective teachers must be prepared to be able to take advantage of developing technology in the learning process in their classrooms in the future (Kurniawan, 2018); (Cabero-Almenara, 2019b); & (Barteit, 2021). Just as AR technology is widely used in schools in developed countries, prospective teachers must be prepared to be able to use, create and even develop learning media based on AR technology (Zafar, 2020). Different from the role of AR in schools, the role of AR at the HE level is usually as a tool in creating learning media or as an application that students use to complete their assignments (Turan, 2018; Kerr, 2020).

Based on the results of the meta analysis conducted, teachers and students are still not ready to use AR technology in the learning process at school (Radianti, 2020; Iwanaga, 2021). This phenomenon occurs at almost all levels, from junior high school to PT. Meanwhile, teachers and students at the elementary school level are already ready to use AR, even though the percentage of research results that state this is not significantly different from research results that state that elementary school teachers and students are not ready to use AR (Mota, 2018; Lai, 2019 ; & Jesionkowska, 2020). There are several factors that are not ready for teachers and students based on the results of the meta analysis, namely, (1) The process of making AR devices for classroom learning is quite complicated for teachers to carry out (Garzón, 2019a). In creating AR, teachers must use several additional software such as Unity, Vuforia, ARCore, or ARKit. Teachers' proficiency in using this software is a problem for teachers who want to create AR-based media or other learning tools (Garzón, 2020). (2) There are limited gadgets owned by students, especially for students in elementary schools. The learning process using AR is very closely related to the use of gadgets as a means to display images of 3D objects. Therefore, if the availability of these gadgets is insufficient in the classroom, then AR-based learning will not run optimally (Papanastasiou, 2019; Kramarenko, 2020; & Scavarelli, 2021). (3) Teachers tend to be lazy about changing existing learning process methods (mostly lectures/conventional) with new methods. Moreover, when using additional devices such as AR technology in the classroom learning process, it is considered complicated and difficult. This is related to the teacher's ability to adapt to low technological developments (Rau, 2018; Altmeyer, 2020).

4. CONCLUSION

Based on the results of the synthesis carried out on 82 research results related to the Use of Augmented Reality Technology in Schools, it can be concluded that:

1. Of the 31 research results related to the implementation of AR at the elementary school level, 27 research results were found which stated that the implementation of AR technology in elementary schools was very important. Apart from that, 16 other research results stated that teachers and students were ready to use AR for classroom learning. The trend in using AR technology in schools is for Learning Media. The reason for using AR technology is to make it easier for teachers to explain abstract objects to students because AR can make 2D objects into 3D objects.

2. Of the 20 research results related to the implementation of AR at the junior high school level, 16 research results stated that the use of AR in learning is very important. However, 15 research results stated that teachers and students were still not ready to use AR in the classroom. This is because the process of creating AR learning devices tends to be difficult for teachers.

3. Of the 12 research results related to the implementation of AR at the high school level, there are 11 research results which state that implementing AR in the classroom is very important to do. However, in reality there are 7 research results that show that teachers and students are still not ready to use AR in the classroom. Just like before, the use of AR at the high school level is for learning media, but teachers still have difficulty designing and making AR devices for learning. This is because the material at high school level is increasingly complex, so it requires more complicated AR barcodes.

5. Of the 19 research results related to the implementation of AR at the Higher Education/University level, 14 research results were found which stated that the use of AR in the classroom was very possible. The use of AR at the HE level is usually for applications or tools to help students complete assignments, not as learning media like at the school level. However, 15 research results state that both lecturers and students are still not ready to use AR technology in the classroom. This is certainly surprising, because so far the stigma that has been built up is that universities are places

where innovative learning tools are developed before they are used in schools. With these findings, this stigma has been refuted and has become a reflection for all education stakeholders at the University.

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