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Inoculations against misinformation: The Effectiveness of Critical Thinking Training

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Abstract : This study aims to investigate critical thinking training effectiveness. Forty students (34 females and 6 males) participated in this study. A quasi experimental within subject design was employed in this study. Measurement was done by translated Scientific Reasoning Scale in the pre- and post-test. Data were analyzed using paired samples t-test. The results showed a significant difference in critical thinking skills before (M = 39, SD = 18.9) and after the intervention (M = 70.2 SD = 23.5); t(39) = 8.5 p < 0.01, d= 1.35. This result indicates that the intervention is effective to improve critical thinking skills

Keywords: critical thinking, cognitive skills, Scientific Reasoning

INTRODUCTION

Critical thinking is considered an important ability for everyone to have. This is because this ability is beneficial for all bida life. For example, critical thinking skills are associated with better academic achievement (2,3,4). Furthermore, critical thinking skills are also associated with better work performance (Elson et al., 2018; ŽivkoviL·, 2016). Not only that, the ability to think critically can also prevent individuals from making bad decisions in their lives. A study conducted by Butler, et al. (2017) showed that individuals who have critical thinking skills are less likely to make bad decisions in their lives (such as making bad financial investments). Even this critical thinking ability is a better predictor than intelligence. Furthermore, critical thinking skills are also associated with the ability to solve everyday problems such as making personal decisions during pandemics (Butler et al., 2017; Halpern & Dunn, 2021).

In today's information age, the need for critical thinking is increasing. With the development of information technology, information becomes very much and very quickly spread. Now, through social media, everyone can become a producer of information and also easily spread information. As a result, information spreads

very quickly, and this also applies to misinformation. The spread of misinformation can be bad for individuals as well as for society. In individuals, decisions based on misinformation become suboptimal. Because individuals are connected to others, these suboptimal decisions can also affect other individuals. This influence can occur in the form of the impact of individual decisions on other individuals, such as the individual's decision not to wear a mask at the time of a pandemic that can harm others, or it can also affect in the form of social pressures, for example, I do not wear a mask because others do not wear a mask.

The good news is that the impact of this misinformation can be prevented or at least marginalized by improving critical thinking skills. Previous research has shown that lessons on science and critical thinking lower students' vulnerability to trusting misinformation (McLean & Miller, 2010; Wilson, 2018). Even his intervention can prevent individuals from believing in misinformation (Lewandowsky & van der Linden, 2021; Linden et al., 2017). Based on the above description it can be concluded that although we face the danger of misinformation, with proper intervention, such dangers can be eliminated or at least minimized.

One of the challenges of the ability to improve critical thinking skills is its very broad definition. Critical thinking is defined as the ability to think reflectively to evaluate whether an information is reliable or not, and to assess what to do. This ability involves the ability to interpret, analyze, and make conclusions, and is also accompanied by personal characteristics that have high curiosity and open-mindedness (Facione, 1990). Based on this definition, critical thinking involves a very broad range of abilities, which are not only related to skills in processing information and making decisions, but also with individual predisposition.

The second challenge that makes critical thinking skills difficult is their association with the domain of knowledge. This related debate addresses whether critical thinking is an ability that can be transferred from one domain of knowledge to another. Halpern (1998) argues that critical thinking skills are abilities that can be transferred across a variety of knowledge domains. In other words, individuals who have critical thinking skills can apply it to various domains of knowledge. This opinion is supported by empirical evidence showing that individuals who have critical thinking skills can make optimal decisions for themselves (Halpern & Dunn, 2021). However, some experts argue that critical thinking is a skill that is domain specific. That is, an individual's ability to evaluate information depends largely on an individual's knowledge of the field, and is therefore difficult to transfer to another domain. For example, a doctor will be able to evaluate information about the effectiveness of a particular treatment, but not necessarily be able to evaluate the information equally well on information related to climate change (Moore*, 2004; Willingham, 2008).

The next challenge that makes this critical thinking ability difficult to teach is because the individual's ability to be able to evaluate information and make the

best decisions is greatly influenced by his physiological and psychological state. It is related to how individuals use two pathways in processing information and making decisions (Kahneman, 2011). The first process is called system 1 which is heuristic. The characteristics of this system are fast, automatic, and often influenced by emotions. Although not always accurate and make individuals often caught up in bias, the system is so efficient that it is often used. In contrast, system 2 involves careful and analytical thinking processes. Although considered more accurate, the system requires greater energy, time and cognitive resources, which makes it less efficient. Critical thinking skills are related to system two. Therefore, although individuals have the ability to think critically, individuals do not always do so because individuals do not always have the resources to do so. This makes thinking of the myth difficult to improve. Because even if individuals are able to do so, individuals are not always willing and/or able to do so.

Based on the description above it can be concluded that although critical thinking is an ability that is very important to be possessed by individuals, this ability is difficult to improve. We propose that one of the causes of the difficulty of developing critical thinking skills is its very broad definition. In line with those proposed by Schmaltz, et al. (Schmaltz et al., 2017) The definition proposed by Fascione (Facione, 1990) terminology is very broad, because it is related to the ability to process information, the ability to make decisions and individual characteristics. This definition is too broad that it is difficult to measure, the interventions designed become very complex and difficult to measure their effectiveness. Therefore, in this study, we will specify critical thinking as the ability to perform scientific reasoning.

The ability to perform scientific reasoning is the ability to perform complex processes involving investigation, experimentation, evaluation of evidence, and conclusions conducted to make conceptual understanding or scientific understanding (Zimmerman, 2000). This skill is related to the ability to be able to identify information that is worthy to be trusted and untrustworthy (Schmaltz et al., 2017). This definition is narrower than the definition of critical thinking proposed above. This definition is not related to individual decision-making or disposition, and focuses only on an individual's ability to validate information.

The ability to perform scientific reasoning is an important part of critical thinking skills that we believe are important to teach for some of the reasons we will lay out. First, the skill to perform scientific reasoning is an ability that individuals need to possess (Schmaltz et al., 2017). With the increasing flow of information, the need for individual skills to be able to evaluate information becomes very important. This very rapid flow of information provides an opportunity for the spread of misinformation and disinformation. The skill to perform ilimiah reasoning can be an inoculation against misinformation. Individuals who have the ability to perform scientific reasoning can validate claims based on arguments and available evidence.

Individuals can construct rival hypotheses, understand that correlation is different from causality, be able to recognize the fantasitic claims introduced as scientific breakthroughs, and use the precautionary principle.

The next reason is that scientific reasoning can be transferred on various domains of knowledge. In contrast to the definition of critical thinking related to an individual's ability to evaluate the truth of an information (Facione, 1990), scientific reasoning focuses on the ability to evaluate claims. In other words, scientific reasoning is not related to whether this information is true or false, but whether this information has strong evidence or not. An individual's ability to devalue whether an information is true or false is related to the knowledge it has related to that information (Moore*, 2004). In contrast, the ability to scientific reasoning is related to evaluating existing claims, which are less dependent on knowledge on a specific domain. For example, individuals do not need to have specific medical knowledge to know that cow pee cannot treat covid-19. Individuals can recognize this as pseudoscience because there is no solid scientific evidence to support this claim. Of course, if it turns out that in the future there is strong evidence to support this, individuals who have the ability to scientifically reason can change their opinions. Because as outlined above, scientific reasoning is not related to right or wrong, but to the availability of scientific support.

Furthermore, because it focuses on the evaluation of claims, scientific reasoning can protect individuals from excessive skepticism (Drummond &Fischhoff, 2017). In contrast to critical thinking that focuses on evaluating the truth of an information, scientific reasoning focuses on supporting evidence of scientific claims. Science very rarely provides certainty, because science is not related to truth itself, but rather the process of seeking the truth. Therefore, individuals who think critically without being equipped with the ability to perform scientifically can become prone to excessive skepticism. For example, with the number of KIPI (post-immunization follow-up incidence), which although rare, overly critical individuals may delay or refuse vaccination (Fischhoff & Davis, 2014). Another example is related to changes in the status of covid transmission that was once considered to be spread through droplets, into airborne (airborne). Individuals who are critical but lack the ability to perform scientific reasoning have the potential to become skeptical of health authorities because of these changes.

The next reason is to make the definition of critical thinking more specific then the scope becomes more specific, and allows for its effectiveness to be measured. By limiting it to the ability to evaluate claims, the effectiveness of these interventions can be measured by an increase in an individual's ability to evaluate claims. Metaanalysis results of the effectiveness of scientific reasoning interventions show a moderate effect (Engelmann et al., 2016).

The above description shows that narrowing the definition of critical thinking to scientific reasoning makes designed interventions more focused.

Although there are consequences that the definition becomes narrow, scientific reasoning remains needed by individuals especially in an information age where misinformation thrives. Based on that, it can be concluded that by specifying the definition of critical thinking into scientific reasoning does not understate its benefits.

This study was conducted to test the effectiveness of online training on the ability to perform scientific reasoning. The intervention was designed based on adaptations to the fine art of Baloney detection (Sagan, 2011) and Critical Thinker's Toolkit (Smith, 2011). Although many interventions have been made to develop the ability to perform scientific reasoning, as far as the authors know that interventions provided online are still rare. On the other hand, online training offers efficiency and flexibility that provides added value compared to training conducted.

METHOD

The study used quasi experimental within subject design. The variables of this study are the effectiveness of critical thinking training as a variable independent and the ability to perform scientific reasoning as a dependent variable.

Intervention

Intervention is provided in the form of online training for 4 hours. This intervention consists of 1) the importance of critical thinking and scientific reasoning 2) Steps to perform scientific reasoning 3) Cognitive errors that can affect scientific reasoning. Based on recommendations from Engelman, et al (2016) that scientific reasoning training will be more effective when training is designed interactively, then the intervention methods provided consist of online lectures, online group discussions, and online quizzes.

Scientific Reasoning

Scientific reasoning is measured using the Scientific Reasoning Scale (Drummond & Fischhoff, 2017) which has been translated and tested for readability. Scale is given before and after intervention.

P*artisipan*

Participants from this study were students of hasanuddin University Psychology Study Program who earned pulse rewards for their participation. There were 46 participants who participated in the study. However, six people were aborted for not completing pretests and post tests, so only 40 people (34 women and 6 men) participants whose data was analyzed.

Data Analysis

Data analysis is done by comparing the ability of scientific reasoning before and after intervention using a paired t sample test.

RESULTS AND DISCUSSION

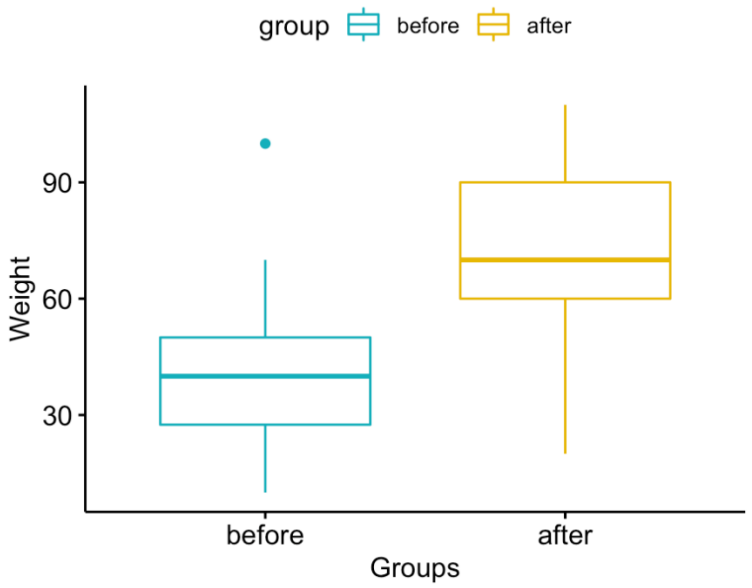
Illustrations

Table 1. Normality Test

Variable	N	Asymp Sig. (2-tailed)
Post-pretest	40	. 115

The table above shows the results of the normality test on the difference in score between post test and pretest using the Shaphiro Test normality test. The normality test results show a significance value of 0. 115 (>0.05) which means the data obtained in the study is normal distribution.

Figure 1. Graph of difference between pre- and post test scores



The image above shows the difference in scores before and after the intervention. To find out if the difference is significant, a paired t sample test is performed.

Tabel 2. Paired t-test statistics

		Mean	N	Std. Deviation
pair	Pre-test	39	40	18,9
	Post test	70.2	23,5	23.5

Tabel 3. Paired t-test

	Paired Differences						t	df	Itself
	Mean	Std. Deviation	Std. Error mean	d	95% Confiedence interval				
					Lower	Upper			
Pair Pre-post-test r	31.25	23.22548	3.672271	1,35	23.82	38.67	8,51	39	2,004 e-10

Table 2 and Table 3 show the results of the sample test paired on critical thinking variables. Based on the table above, there is a difference in critical thinking scores before intervention (M = 39, SD = 18.9) and scores after intervention (M = 70.2 SD = 23.5); The paired sample t test showed that this difference was significant t(39) = 8.5p <0.01. Furthermore, Table 3 shows that the effect size of the intervention is also large, d = 1.35. Based on this, it can be concluded that the interventions provided are effective to improve critical thinking skills.

Discussion

This study was conducted to test the effectiveness of online interventions on scientific reasoning skills. The results of this study showed significant differences in scientific reasoning ability in the before and after intervention. Therefore, it can be concluded that effective interventions improve the ability to perform scientific reasoning.

The results of this study are in line with previous research showing that scientific reasoning skills are skills that can be developed through appropriate interventions (Engelmann et al., 2016). The intervention in this study was conducted online, which added a choice of methods to the variety of interventions that have been done before.

The results of this study have scientific and practical implications. Scientifically, the study used a scientific reasoning scale (Drummond & Fischhoff, 2017) that measured an individual's ability to perform scientific reasoning on different domains of knowledge. The results showed positive effects of interventions that showed that individuals could develop the ability to evaluate scientific claims on a variety of domains of knowledge. In other words, scientific reasoning skills can be transferred in different domains. The results of this study support the opinion that considers critical thinking as a general skill that can be transferred (Halpern, 1998). Practically speaking, the study offers a choice of online intervention methods, which are also effective for improving the ability to perform scientific reasoning. The intervention is also only lasted in 4 hours, which makes it more efficient. With the increasing spread of misinformation and 'scientifically said' claims, the ability to perform scientific reasoning becomes very important. With the increasing choice of methods available to provide intervention, the opportunity to intervene can increase.

The empirical results reported here should take into account some of the limitations of this study. First, the study used a homogeneous sample of students, so generalizations from this study of different samples need to be done carefully. Second, the design of this study does not involve control groups, so it is not certain whether the effects obtained are actually caused by independent variables and not other variables such as maturity.

Researchers encourage to conduct further research related to this topic. Although the results of this study show positive and significant effects on the ability to perform scientific reasoning, it is not known until when such effects can survive, and the extent to which such effects can be seen in situations outside the research conditions. Therefore, researchers encourage further research to conduct longitudinal studies related to this. Furthermore, researchers also encourage research to investigate the relationship between the ability to perform scientific reasoning as measured by SRS and the ability to evaluate scientific claims in situations outside experimental conditions.

CONCLUSION

The study aims to test the effectiveness of online training on the ability to perform scientific reasoning. The intervention is carried out in the form of online training for 4 hours. The paired t-test showed significant differences in participants' critical thinking skills before (M= 39, SD=18.9) and after intervention (M = 70.2 SD = 23.5); $t(39) = 8.5$ $p < 0.01$, $d = 1.35$. These results suggest that interventions positively and significantly affect the ability to perform scientific reasoning. The results of this study show that the ability to perform scientific reasoning is a skill that can be learned and transferred in various domains of knowledge.

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