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A Reliable Method for Innovative Lesson Improvement

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Abstract—Lesson improvement is becoming essential for adapting to the recent rapid changes in education. “Action research” is treated as a way to improve lessons. This paper reviews collaborative action research (CAR) to identify group decision-making for lesson improvement, providing methodologies based on the analytic hierarchy process, which is known as a method for successful group decision-making. In this study, we performed simulations to incorporate the analytic hierarchy process with CAR in the process of lesson improvement. Moreover, this work reviews how people from different fields discuss CAR and how diverse opinions are integrated into the process of revising plans. The difficulties of discussing in a group are also examined, focusing on the concept of groupthink.

Keywords: action research, collaborative action research, analytical hierarchy process, groupthink

1. Introduction

General lesson improvement training for in-service teachers is conducted with supervisors dispatched by the regional educational board in Japan. A dissemination format is used where the teacher teaches a lesson observed by the supervisor. Afterward, a general discussion between the teachers in the school and the supervisor is held, and the supervisor gives the teachers a lecture on improving teaching methods. However, it is questionable whether this lesson improvement training is beneficial for teachers [1]. Instead, schoolteachers feel that lesson improvement training has increased their workload. Therefore, teachers do not willingly regard such lesson improvement training as a personal issue that they should resolve.

In such a situation related to the improvement of lessons, two issues should receive focus. The first is that the lesson improvement perspective is limited to teachers in school. When the supervisor intervenes, the point of view is similar to that of the

teachers because supervisors also used to be teachers and have relevant experiences. The second is that a supervisor is an absolute leader in lesson improvement training and can become an advisory authority to teachers in school. The lesson topic for the training is prepared by the supervisor in advance, even though the supervisor has not seen the classroom environment beforehand. Furthermore, teachers become passive when a supervisor comments on lessons and provides teachers with educational theory. That is, the teacher's autonomy is deprived because a supervisor who ignores the class environment creates a theoretical framework for the curriculum and conveys it to the teachers, and the teachers only apply this theory [2].

As for the challenge of lesson improvement, although supervisors participate in lesson improvement, they convey a well-known theory without considering its adaptability to the class; therefore, teachers do not have a sense of ownership [3]. Therefore, whether the theory is adapted or the advice provided is applied depends on the choice of the teacher. Even if the in-school teacher spends significant time on the lesson improvement training, they conclude from the perspective of whether the theory is practical. The theory introduced undoubtedly does not apply directly to all classes, and the characteristics of the learner and the size of the class vary from school to school. Lesson improvement should not be a generally accepted improvement but a specific improvement for the class.

Based on the above two issues, this work focuses on perspectives of various experts and improvements to suit the characteristics of the class. To resolve these two issues, action research (AR) especially collaborative action research (CAR) are proposed. Moreover, the analytical hierarchy process (AHP) is adopted as a supportive tool for CAR.

This paper is structured as follows. Section 2 presents a brief description of each theoretical background, and Section 3 reviews the research questions and aims. Section 4 describes materials and methods used in the study, while Section 5 describes the simulation based on the difficulties of group discussion. Section 6 discusses the method, and Section 7 concludes.

2. Theoretical background

2.1 Action research for lesson improvement

One of the methods for improving lessons in the education field is action research (AR). The purpose of AR is not a general improvement but a specified improvement for a target.

Lesson improvement methods usually end with one cycle, for example, the plan-do-check-act (PDCA) cycle [3]. That is, the process of reflection is procedurally difficult to manage by the members of lesson improvement team in the next lesson planning phase. In contrast, AR conducts lesson improvements over several cycles (action-observe-reflect-revise plan) [4]. In AR, the reflection phase is more important than meticulous planning at first as it is a long-term relationship with targets conducted over several cycles. Therefore, lesson improvements can be aligned with the class environment.

The following section discusses reasons for bringing AR into the lesson improvement process. The first reason concerns the teachers. With the rapidly changing trends in education, the curriculum has been revised, and lessons are required to change. For teachers, it is therefore necessary to learn how to improve lessons. The second reason is related to researchers, who have undertaken empirical and developmental research with a specialized learning community as a conceptual model. In many cases, their targets are university students majoring in education within the researchers' institutions, and

the issue is that the studies do not extend to teachers in elementary and secondary schools [5].

Rowell *et al.* [6]reveal one of the challenges associated with action research is its limited contribution to quality and rigor. Nevertheless, the strength of qualitative studies employing action research is “triangulation” [7], which is a “multi-instrument approach” that gathers information in many ways rather than relying on just one. There are three categories of triangulation:

1. Experiencing (observation): Observation, fieldnotes;
2. Enquiring (researcher queries): Interviews, questionnaires, attitude scales;
3. Examining (making records): Archival documents, journals, maps, artifacts.

Therefore, it is recommended to have at least three types of members in AR.

Then, the typologies of people involved in action research are shown:

(1) Single teacher,

(2) Group of teachers in school,

(3) Teachers, university researchers, parents, and other people in various positions in the intervention.

At the level of in-school training, lesson improvement is usually conducted with a group of teachers. A method where each teacher in a group writes comments on a note and then passes around each note is often used. In this method, semi-understanding is emphasized, and each member’s own concept is based on daily life experience. It is developed or modified by expanding the interaction and creating a new concept. When action research and this method are compared, the common point is that they both are not perfect from the beginning but develop or improve through activities and the creation of new concepts. One significant difference between the two methods is that data is not collected in this method. Therefore, this method is a subjective assessment.

Even if there is time to share the interpretation of the activity, improvement plans are devised with the tacit knowledge buried.

2.2 Decision-making

The AR process includes a stage where a revised plan is produced. Therefore, decision-making is needed to select one plan from several. Various tools support decision-making. For example, “decision tree,” “operations research,” and “analytic hierarchy process (AHP)” are considered.

These models mainly support decision-making by quantifying the value of evaluation criteria or alternatives.

- Decision Tree: Risk analysis
- Operations Research: Choose the best, most efficient idea of many
- AHP: Comprehensive and rational decision-making by human subjectivity

Decision trees are used to visualize patterns and identify the causes of problems in system design. For example, in a study of detecting school dropouts [8], a trial was conducted to create a decision tree from learning log data to predict who would drop out. The study analyzed the behavioral patterns of learners with true or false choices and attempted to extract the characteristics of learners who tend to drop out of school. Decision trees have a high capacity for explaining the results of analysis, allowing us to predict and explain the causes of patterns in people’s behavior. Using decision trees to analyze and predict risks makes it possible to develop strategies to prevent poor outcomes.

“Operations research, in the most general sense, can be characterized as the application of scientific methods, techniques, and tools, to problems involving the operations of a system to provide those in control of the operations with optimum solutions to the

problems” [9]. For example, operations research is used to create a school timetable [10], which is a combination of various factors such as school grade, classroom, and teachers’ preferred schedule. Although there are many possible timetable patterns, operations research can be used to create an optimal timetable. Therefore, it is possible to find the optimal solution using combinatorial mathematics under various conditions. However, this approach uses mathematical models and is a scientific process, so it is challenging to include qualitative data.

AHP uses actual measurements or measurements from a fundamental scale that reflects the relative strength of preferences and feelings [11]. AHP is an appropriate method for the current study because it is used to draw a single conclusion from multiple criteria.

In addition, there are group decision-making support systems through computers, for example, “group DSS” (GDSS), which is defined as “a computer-based system that aims at supporting collective problem solving” [12]. The use of computers eliminates agility, which is a representative demerit of group decision-making.

2.3 Framework of AHP

AHP is a decision-making method advocated by T. L. Saaty [13]. When decision-making is conducted using quantitative data, it usually goes smoothly. However, far more cases arise where decisions cannot be made using only quantitative data or where it is challenging to use it. In such cases, the qualitative data provided by individuals play a significant role [14]. The most significant feature of AHP is the capability to measure human subjectivity using words, for example, those in TABLE I. Pairwise comparison is one by one compared with each criterion as to which one is more important [13].

TABLE I. Intensity of pairwise comparisons.

Intensity	Definition
9	Absolutely A
7	Very much A
5	Much more A
3	Somewhat A
1	Neutral
1/3	Somewhat B
1/5	Much more B
1/7	Very much B
1/9	Absolutely B

An approach based on the use of linguistic evaluations is considered more suitable for modeling human perceptions than that of conventional numbers [15]. By evaluating with words and replacing them with numbers, human subjectivity can be measured. That is, the AHP process provides members an opportunity to transfer their tacit knowledge gained from personal experience—which is more difficult to express—into explicit knowledge, which is easy to articulate, write down, and share [16]. In particular, many schoolteachers have tacit knowledge. The transferring of tacit knowledge into explicit knowledge can be recorded and visualized so that the explicit knowledge can be easily understood and shared by many people.

The criteria used in AHP allow for both qualitative and quantitative data. Teachers' tacit knowledge and researchers' data can be used together when making a decision so that it is possible to obtain results that can be agreed upon by members with different areas of expertise. In addition, AHP emphasizes the involvement of members and their subjective attendance by providing the activities of pairwise comparisons so that teachers can use them easily. Using AHP, various perspectives can be properly integrated, and revised plans can be generated. AHP can help various experts to examine a problem from each perspective and make a clear decision on what to do in the next cycle. AHP is effective for the reflection and revised plan steps of CAR.

AHP has two types [17]. One is a personal, dedicated type used when decisions are based on personal hobbies and tastes. This type is for improvements related to individuals. Another is a general type used when there is a problem that should be improved rationally and objectively. This type is used when a problem should be solved in a group. In the present study, the general type is adopted because lessons should be improved rationally and objectively.

Furthermore, AHP uses the geometric mean rather than the arithmetic mean. The geometric mean is closer to human intensity. According to Fechner [18], the Weber–Fechner law is explained whereby a subjective sensation is proportional to the logarithm of the stimulus intensity, that is, the relationship between stimulus and perception is logarithmic.

2.3.1 Consistency index

Two methods are used for calculating AHP: the eigenvalue method and the geometric mean method, which simplifies the eigenvalue method. The geometric mean method which is easy to calculate and understand is also useful for approximating the eigenvalue method solution [17].

During the AHP process, the consistency index (CI) is calculated [17]. When a pairwise comparison is performed, the results may show inconsistency. For example, suppose the following contradiction: A is better than B, B is better than C, and C is better than A. If the weight is calculated from the inconsistent answers, the reliability would be low. As pairwise comparisons are performed with human subjectivity, there is a risk of contradiction. The collective use of AHP is even more contradictory because several people are involved in the evaluations. The more consistent the pairwise comparison, the smaller the CI. The case where the consistency is higher than 0.1–0.15

is contradictory, so the pairwise comparison must be reconsidered [17]. For the eigenvalue method, CI is calculated using the following formula.

$$CI = \frac{Eigenvalue - Number\ of\ items}{Number\ of\ Items - 1} \quad (1)$$

For a perfect pairwise comparison, the eigenvalues must equal the number of items. Therefore, the numerator is set to the eigenvalue, where the number of items becomes 0 when consistent. The denominator is set to the number of items − 1 because the eigenvalue tends to increase as the number of items increases. However, the eigenvalue is not obtained with the geometric mean method, so we must estimate the eigenvalue if we want to know the consistency. The calculation procedure takes the total evaluation value and divides it by the weight to obtain the estimated eigenvalue.

$$total/weight = estimated\ eigenvalue. \quad (2)$$

2.3.2 Process of AHP

In this chapter, the use of AHP is explained in detail. The AHP procedure is shown in TABLE II [17].

TABLE II. Procedure of the analytic hierarchy process (AHP).

Phase	Description
1. Define the problem	Define the problem and determine the type of knowledge required.
2. Construct structure	Structure the decision hierarchy diagram from the top with the goal of the decision, the intermediate levels with criteria, and the lowest levels with alternatives.
3. Comparison and evaluation	Pairwise comparison of criteria for a goal and a pairwise comparison of alternatives regarding each criterion. Weight is calculated after each comparison.
4. Conduct the comprehensive evaluation	The sum of the product of the evaluation values of each alternative multiplied by the weights of the criteria is calculated.

For example, teachers were concerned about where to go on a school trip. Therefore, they used AHP.

The goal of AHP: To decide the best place for a school trip

Criteria:

C1: *Cost*
C2: *Educational facility*
C3: *Convenient transportation*

Alternatives:

A1: *Kyoto*
A2: *Hiroshima*
A3: *Okinawa*

In the following part, for the sake of brevity, each item is indicated by an initial symbol (for example, “cost” is indicated as C1).

A hierarchy diagram (see Fig. 1) is structured with the goal of the decision at the top, the criteria at the intermediate levels, and the alternatives at the lowest levels.

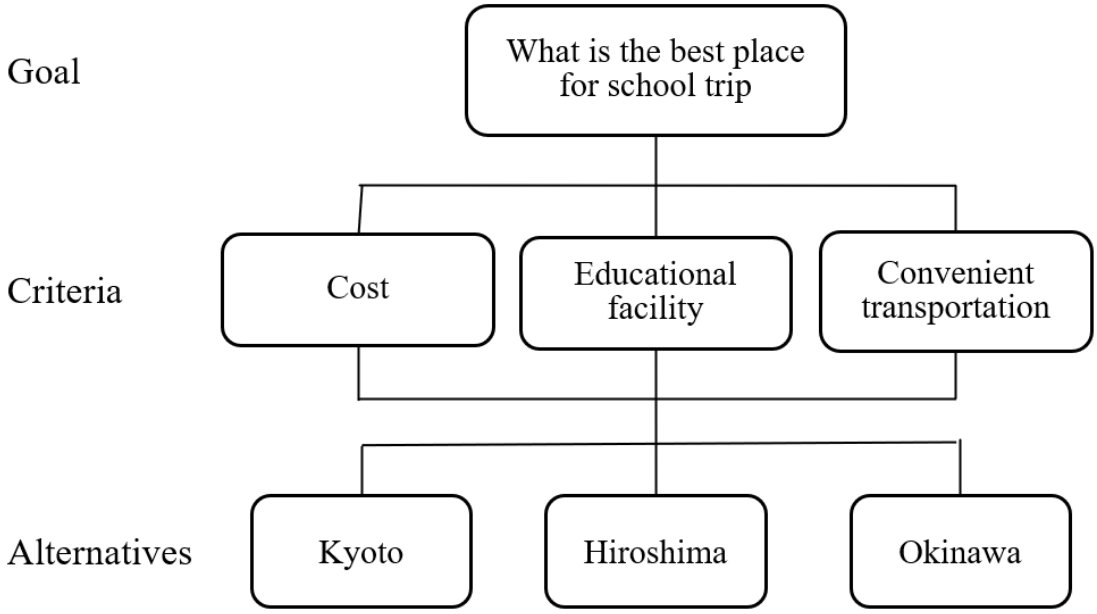

Fig. 1. Hierarchy diagram.

After the hierarchy diagram is established, the criteria are weighted, and the alternatives in terms of each criterion is evaluated. At that time, a pairwise comparison is used. The pairwise comparison begins with the selection of two variables, which are compared and evaluated to determine which one is recognized as more important or

preferable. According to the structure of the case simulation in Fig. 2, if there are three alternatives as variables, three comparisons are made. The number of comparisons needed for a particular matrix of order *n* and the number of elements being compared is $n(n-1)/2$ [17].

AHP is not an absolute evaluation, but two items are taken out and relatively evaluated. When a pairwise comparison between the criteria is performed, it is beneficial to use the questionnaire, as shown in TABLE III below.

TABLE III. Questionnaire of the weight of criteria.

criteria	Absolutely left	middle	Very much left	middle	Much more left	middle	Somewhat left	middle	Neutral	middle	Somewhat right	middle	Much more right	middle	Very much right	middle	Absolutely right	
	9	8	7	6	5	4	3	2	1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	
1													○					2
1							○											3
2			○															3

A pairwise comparison table is created from this questionnaire (see TABLE IV).

TABLE IV. Evaluation between criteria.

	Indicators					
	Criteria	**C1**	**C2**	**C3**	**Geometric mean**	**Normalized weight**
Indicators	C1	1	1/5	3	0.8434	0.1884
	C2	5	1	7	3.2711	0.7306
	C3	1/3	1/7	1	0.3625	0.0810
	total				4.4770	1.0000
	C.I.					0.0324

First, “1” should be placed in the diagonal column (for example, C1 vs. C1) of the pairwise comparison table (see TABLE IV) because a pairwise comparison of the same items must be of the same importance. Next, the results of the pairwise comparison are

entered. For example, in the comparison of C1 and C3 in TABLE V, the group decided that C1 is “somewhat” important, so the pairwise comparison value, 3 is entered in the C1 row and C3 column. Because the pairwise comparison value on the C3 is the reciprocal of this, 1/3, which is also the counter-score of 3, it is entered in the C3 row and C1 column. Subsequently, other pairwise comparison values are similarly entered in each table.

Next, pairwise comparisons between alternatives are shown in TABLE V–VII. A pairwise comparison is conducted between alternatives for C1. This is a pairwise comparison of how important each alternative is based on C1. The other criteria’s pairwise comparison values are similarly shown in TABLE VI and VII.

TABLE V. Pairwise judgment of alternatives for criteria 1 (C1).

	Alternatives				
C1	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	1/3	5	1.1856	0.2969
A2	3	1	5	2.4662	0.6175
A3	1/5	1/5	1	0.3420	0.0856
total				3.9938	1.0000
C.I.					0.0678

TABLE VI. Pairwise judgment of alternatives for criteria 2 (C2).

	Alternatives				
C2	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	1/3	5	1.1856	0.2790
A2	3	1	7	2.7589	0.6491
A3	1/5	1/7	1	0.3057	0.0719
total				4.2503	1.0000
C.I.					0.0324

TABLE VII. Pairwise judgment of alternatives for criteria 3 (C3).

	Alternatives				
C3	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	5	3	2.4662	0.6586
A2	1/5	1	1	0.5848	0.1562
A3	1/3	1	1	0.6934	0.1852
total				3.7444	1.0000
C.I.					0.0145

Next, the method of calculating the weights from the pairwise comparison table is explained. The product of the pairwise comparison values is obtained. For example, C1 in TABLE IV, $1 \times 1/5 \times 3 = 0.6$. Next, the geometric mean value is the third root of 0.6 (a number that becomes 0.6 when raised to the third power). This is calculated as 0.8434. Similarly, the other rows are calculated. Finally, the geometric mean value is divided by the sum to find the weight so that the sum is 1. This is called normalization (0–1). A summary of TABLE IV–VII is shown in TABLE VIII.

TABLE VIII. Comprehensive evaluation value of the alternatives for each criteria.

	C1	**C2**	**C3**	**Comprehensive evaluation value**
A1	0.0559	0.2038	0.0533	0.3131
A2	0.1163	0.4743	0.0126	0.6033
A3	0.0161	0.0526	0.0150	0.0837

The comprehensive evaluation is a weighted average value of the evaluation values of alternatives for criteria based on the priority. It is the sum of the product of the priority of the criteria (TABLE IV) and the evaluation value of the alternatives (TABLE V–VII).

The alternative with the highest overall performance will have the best score. Written as a formula, for example, Kyoto's comprehensive evaluation is $0.1884 \times 0.2969 + 0.7306 \times 0.2790 + 0.0810 \times 0.6586 = 0.3131$.

This result is shown in the graph (see Fig. 2).

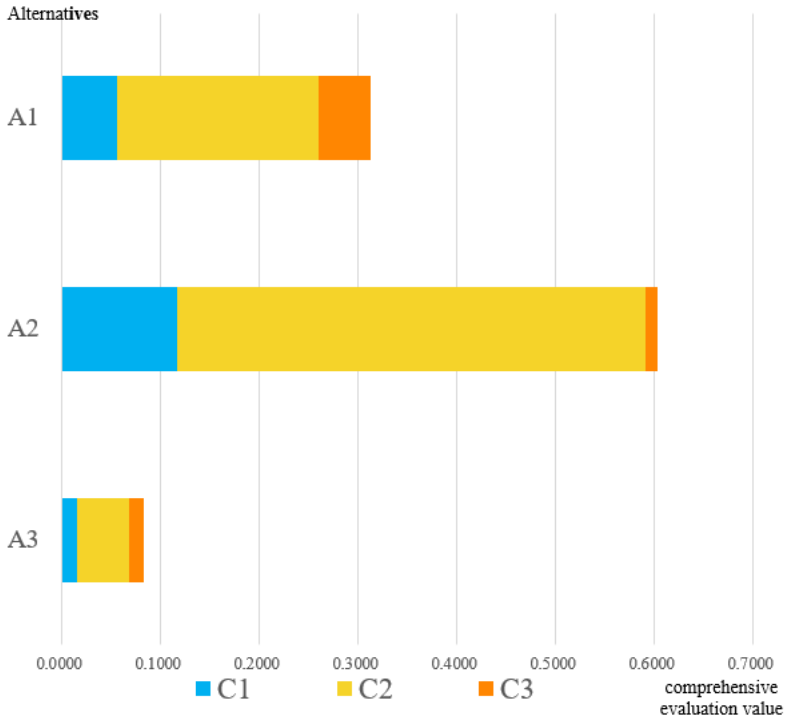

Fig. 2. Result in the graph.

2.4 Collaborative action research

As action research members described in Section 2.1, the intervention of several members through triangulation does more than guarantee the quality of the AR—collaborative activities can be a catalyst for improving lessons [7]. Wood and Gray state that collaboration is a "process through which parties who see different aspects of a problem can constructively explore their differences and search for solutions that go beyond their own limited vision of what is possible" [19]. Conducted by teams of practitioners, CAR is a process that enables teachers to (1) improve student learning, (2) improve their own practice, (3) contribute to the development of their profession, and (4) overcome the isolation commonly experienced by classroom teachers [20].

Regarding the benefits of researchers' participation in CAR, Ferrance states the following three effects [21]:

- Their presence in the project helps to legitimize the work;
- Consultants help to refine the question, establish an action plan and timetable, and reflect on data to find trends or patterns; and
- Consultants can offer a third-party perspective and ensure that the work and pace are on target.

AR type is shown in TABLE IX below.

TABLE IX. AR type for lesson improvement.

Members	Following the standard process of AR	Multiple perspectives	Evaluate to establish lesson goals	Collaborative evaluation	Include various fields of opinion	Update goals	A clear process for a revised plan
Stage	Overall	Observe	Reflection	Reflection	Reflection	Revised	Revised plan
A single teacher [7]			✓			✓	
Two teachers [7]	✓		✓				
Teachers and a university researcher working as the staff development coordinator [7]			✓	✓	✓		✓
A teacher, a mentor, university advisers, and fellow student teachers [22]	✓	✓	✓	✓	✓		✓
Two teachers and a researcher [23]	✓		✓	✓	✓		✓
A researcher, and various experts in the enterprises [3]	✓			✓	✓		
Three teachers, two researchers, and one ALT [22]	✓		✓	✓	✓	✓	✓

Note.

Following the standard process of AR: Is there a clear composition for the cycle (prediction, interpretation from the results) fixed?

Multiple perspectives: Are there different methods of observation, such as triangulation?

Evaluate to establish lesson goals: Are activities evaluated according to the goals?

Collaborative evaluation: Is there a perspective both as a practitioner and as a researcher?

Include various fields of opinion: Are there findings interpreted from multiple perspectives?

Updated goals: Are new goals set as a result of the action?

A clear process of a revised plan: Is there a revision plan for the next cycle?

Several findings were identified from the development of the AR type table (TABLE IX). Clearly, the intervention of various experts in the classroom results in a variety of perspectives and methods of observation [3]. By collaborating with various experts, it is easy to go through the cycle of AR, such as creating new questions and proposing revised plans. Regarding the number of members, when there are few members, it is difficult to create a multifaceted perspective. In addition, the intervention of researchers increases the reliability of data analysis. Selecting the most appropriate new plan is regarded as a critical decision that greatly influences the development of lessons. To improve the accuracy of selection, more experts should be involved to predict key indicators for revised plan selection [24].

2.5 Merit of using AHP in group lesson improvement

While there are many benefits to having various experts in the group, it is difficult to integrate the opinions of members who have different backgrounds and ideas. There are various perspectives, and it is often difficult to properly integrate them into one conclusion. AHP is used when the following conditions are met: (1) multiple experts exist, (2) multiple choices exist, (3) both qualitative and quantitative criteria are included, and (4) one conclusion must be determined.

AHP is used by multiple people to choose one option from multiple options, and therefore, can be used in group decision-making. The important points about group decision-making include “how to aggregate individual decisions for one representative decision in the whole group” and “how to make individual choices into group choices,” according to Saaty [25].

AHP is a convenient method that plays a vital role in enhancing CAR. It has the following three effects:

(1) Shows rationale and explains the decision-making process

(2) Obtains consensus

(3) Saves time

These effects are explained in detail below.

By using AHP, the decision-making process can be explained while providing rational evidence. AHP makes it possible to have discussions using pairwise comparisons while providing the rationale necessary to answer questions such as “Why do you think this is important?” and “Why did you choose this revised plan?” AHP makes information to communicate easily because the process of deciding which method to adopt for revised plans can be recorded and published [14]. Using AHP, it is possible to provide a transferable document to people who were not involved in the discussion and to show them the process of how a revised plan was selected. The essential purpose of conducting an AHP is not to decide which is the *best* idea, but rather to select which is the *appropriate* idea for the group and keep a record of why this idea was chosen. [13]

Moreover, it is possible to get a consensus rather than making a decision based on the opinion of one person. In discussions among members with different skill sets, it is often easier for them to transmit opinions since the irrelevant social authority of members is removed. For example, in a group of teachers and researchers, the researchers’ opinions often become strong, and the teachers concede to them.

However, using AHP, the criteria are anonymized and shaped, weighted, and compared during the discussion so that it is possible to reach a consensus rather than deciding based on the weight of the opinion of a particular individual. The most important merit of the AHP is that it enables us to reinforce what we do not know about each other. This is because discussions during the AHP process allow all members to understand what each member thinking are important.

In addition, it is difficult for teachers, university researchers, and parents to gather at the same time for frequent discussions. As an example, one may often get lost choosing between A, B, and C and go around in circles. This may be because each option may have its own inherent merits. Therefore, AHP is used to facilitate decision-making within the limited interaction time [26]. Furthermore, since the weightings are shown by using AHP, plans can be prioritized [17]. Therefore, AHP promotes effective interaction within a group.

2.6 Groupthink

In the previous chapter, although the merits of group lesson improvement have been discussed, some problems arise because of the group approach. One of the theories for tackling the difficulties of group discussions is "groupthink." Irving Janis, a Yale social psychologist, proposed the concept of groupthink. This is defined as " a mode of thinking that people engage in when they are deeply involved in a cohesive in-group when the members' strivings for unanimity override their motivation to realistically appraise alternative courses of action [27]." It can be said that this is the result of entrainment consciousness.

While discussing in a group, discussion members often reach unreasonable conclusions. Even though intelligent people gather together and discuss if building a consensus itself is given top priority, then it will not be possible to make accurate decisions. groupthink is whereby more unreasonable decisions are accepted when making decisions in groups than individuals. Janis describes the mechanism by which groupthink occurs in the following framework.

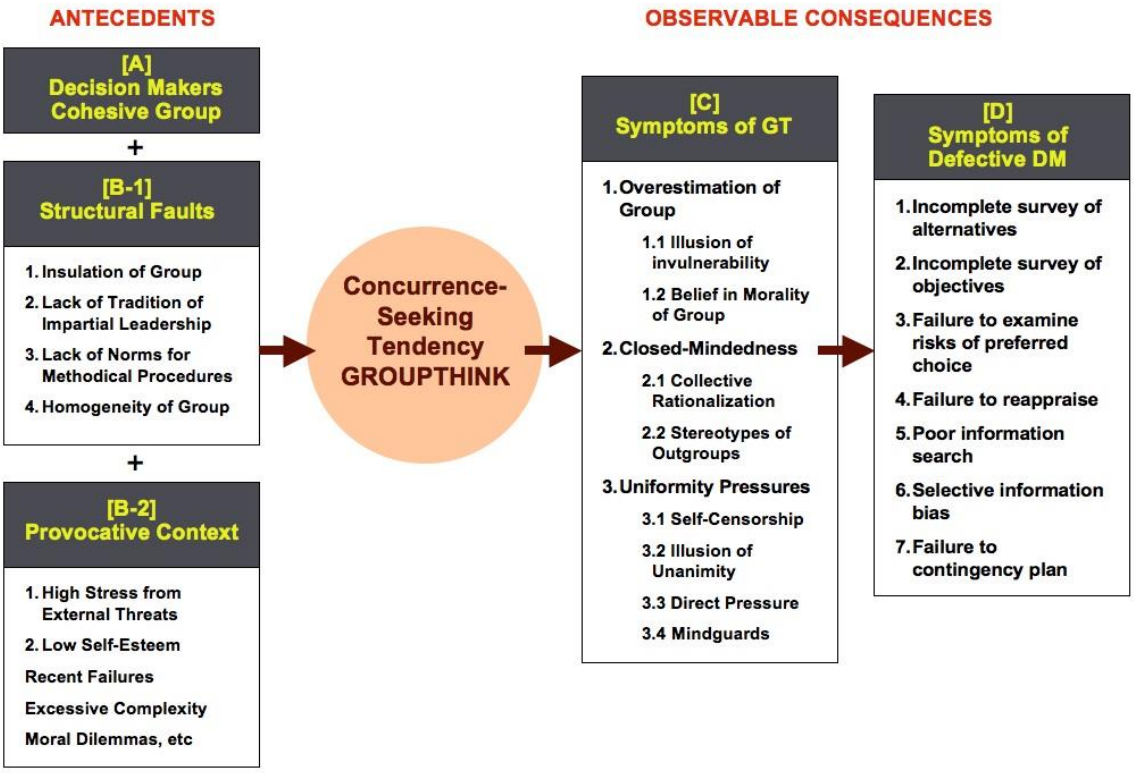

Fig. 3. Groupthink Theoretical Framework (Cited from Janis [1982], p. 244, Fig. 10-1).

These four antecedents (see Fig. 3 [B-1]) of the groupthink theoretical framework refer to “structural faults.” Although much research has been conducted on groupthink in practice, most of these studies have examined whether groupthink occurred by applying Janis’s groupthink mechanism to business and policy failures, and little attention has been paid to the development of comprehensive models of group problem solving [28]. In addition, research or discussions on groupthink in Japan [29], and few groupthink studies have been conducted on groups of teachers in education.

3. Research questions and aims

This study selected methods for CAR using AHP wherein the opinions of members can be integrated into a group decision. The following research questions were addressed:

(a) How are opinions integrated when there are diverse experts in a group?

(b) How is a diversity of perspectives generated?

(c) How is authority eliminated in group discussions?

(d) How is homogeneity in groups addressed? and

(e) What happens when there are no group norms?

This study framed the following aims to examine these research questions:

(a) Present a concrete model of AHP for lesson improvement

(b) Propose a method to generate ideas

(c) Provide solutions using CI of AHP

(d) Identify the vital role of CAR, and

(e) Provide solutions in the process of AHP

4. Materials and methods

We provide some simulations in the context of lesson improvement. To undertake these simulations, CAR and AHP are the methods used in this paper. This collaborative model is a new, modern approach which is unknown in the field of lesson improvement. These simulations were conducted from the perspective of a teacher (lesson practitioner). This study aims to suggest a suitable model for group lesson improvement.

5. Study environment and prerequisites for analysis

This chapter reveals a practical model that could integrate diverse evaluation opinions from various experts. The process chart in Fig. 4 illustrates the process of lesson improvement through CAR using AHP, which is designed to establish effective communication among members with different areas of expertise.

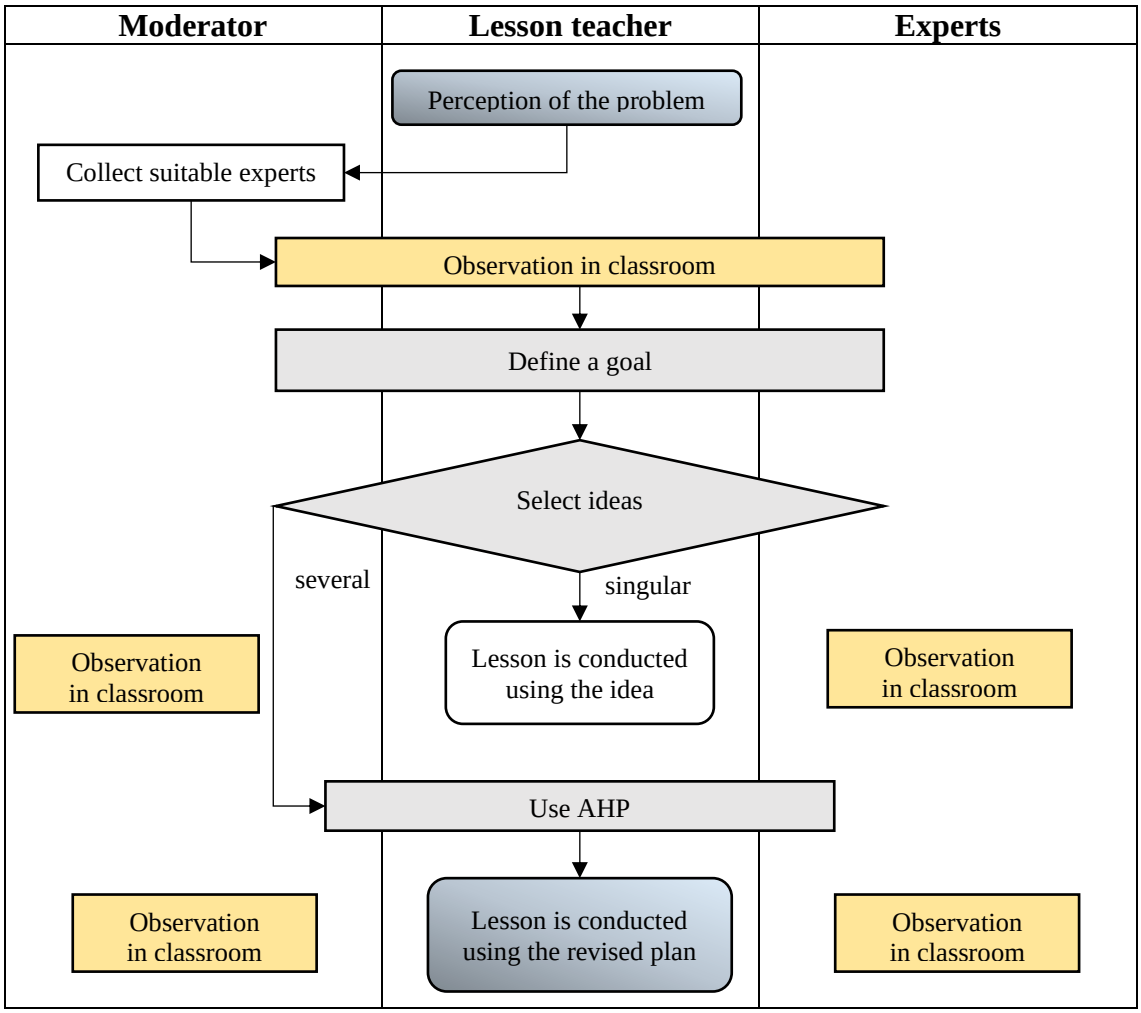

Fig. 4. Process chart.

It is useful to have a moderator when holding discussions. The moderator should be neutral during discussions and is responsible for promoting a common understanding among all discussion members.

5.1 Result

(1) Define the problem

In the process of AR, a teacher perceived a problem that learners found was challenging for class discussion. To conduct a more effective discussion, the lesson style should have been considered; however, the teacher could not select the best style. The teacher called upon experts to have a discussion. A mentor and a university researcher were invited and formed a group of CAR.

Members

- A teacher (lesson practitioner)
- A mentor
- A university researcher

(2) Construct structure

The members observed a class and defined a goal. Their goal was to decide the best lesson style for active class discussion. As each member had a different plan, they used AHP, discussing the criteria they felt had to be met to improve the lesson, and they listed four as the criteria:

The goal of AHP: to decide the best lesson style for active class discussion

Criteria:

C1: *Ease of changing opinions*
C2: *Deepening fundamental preferences*
C3: *Collective decision-making power*
C4: *Frequency of opportunities to speak*

Alternatives:

A1: *The whole class (raise their hand and answer one by one)*
A2: *Team (create a team of four with different opinions)*
A3: *Divide by camp (form groups of people with the same opinion and discuss)*

In the following section, for the sake of brevity, each item is indicated by an initial symbol (for example, “Ease of changing opinions” is indicated as C1). A hierarchy diagram is structured by goal, criteria, and alternatives (see Fig. 5).

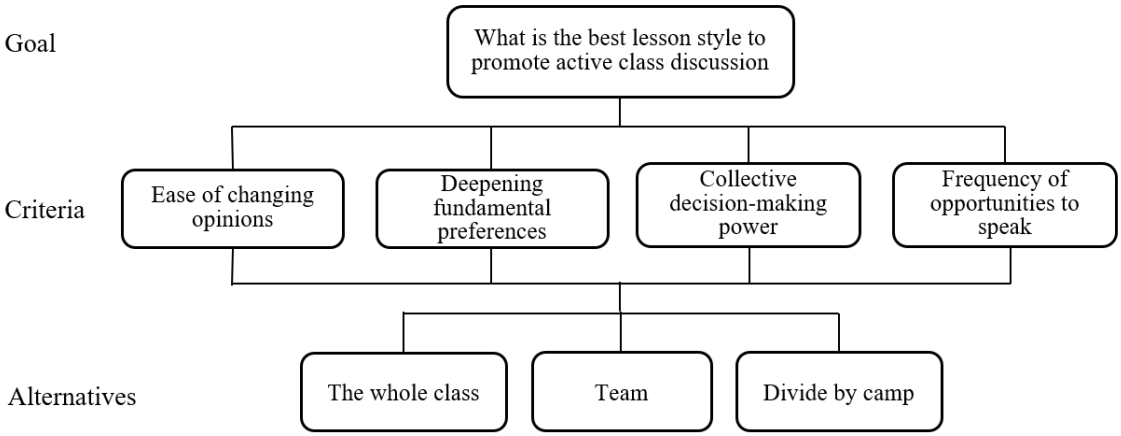

Fig. 5. Hierarchy diagram.

(3) Comparison and evaluation

Evaluation between criteria and pairwise comparisons between alternatives are shown in TABLE X–XIV.

TABLE X. Evaluation between criteria.

		Indicators					
	Criteria	**C1**	**C2**	**C3**	**C4**	**Geometric mean**	**Normalized weight**
Indicators	C1	1	1	5	1/5	1.0000	0.1715
	C2	1	1	3	1/5	0.8801	0.1510
	C3	1/5	1/3	1	1/7	0.3124	0.0536
	C4	5	5	7	1	3.6371	0.6239
	total					5.8296	1.0000
	C.I.						0.0526

TABLE XI. Pairwise judgment of alternatives for criteria 1 (C1).

Alternatives					
C1	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	1/5	3	0.8434	0.1884
A2	5	1	7	3.2711	0.7306
A3	1/3	1/7	1	0.3625	0.0810
total				4.4770	1.0000
C.I.					0.0324

TABLE XII. Pairwise judgment of alternatives for criteria 2 (C2).

	Alternatives				
C2	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	1/3	1/7	0.3625	0.0879
A2	3	1	1/3	1.0000	0.2426
A3	7	3	1	2.7589	0.6694
total				4.1214	1.0000
C.I.					0.0035

TABLE XIII. Pairwise judgment of alternatives for criteria 3 (C3).

	Alternatives				
C3	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	1/5	5	1.0000	0.2185
A2	5	1	7	3.2711	0.7147
A3	1/5	1/7	1	0.3057	0.0668
total				4.5768	1.0000
C.I.					0.0914

TABLE XIV. Pairwise judgment of alternatives for criteria 4 (C4).

	Alternatives				
C4	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	1/7	1/3	0.3625	0.0810
A2	7	1	5	3.2711	0.7306
A3	3	1/5	1	0.8434	0.1884
total				4.4770	1.0000
C.I.					0.0324

(4) Conduct comprehensive evaluation

A summary of TABLE X– XIV is shown in TABLE XV.

TABLE XV. Comprehensive evaluation value of the alternatives for each criteria.

	C1	**C2**	**C3**	**C4**	**Comprehensive evaluation value**
A1	0.0323	0.0133	0.0117	0.0505	0.1078
A2	0.1253	0.0366	0.0383	0.4559	0.6561
A3	0.0139	0.1011	0.0036	0.1175	0.2361

If the CI is less than 0.1, then the weights are reliable (see Fig. 6).

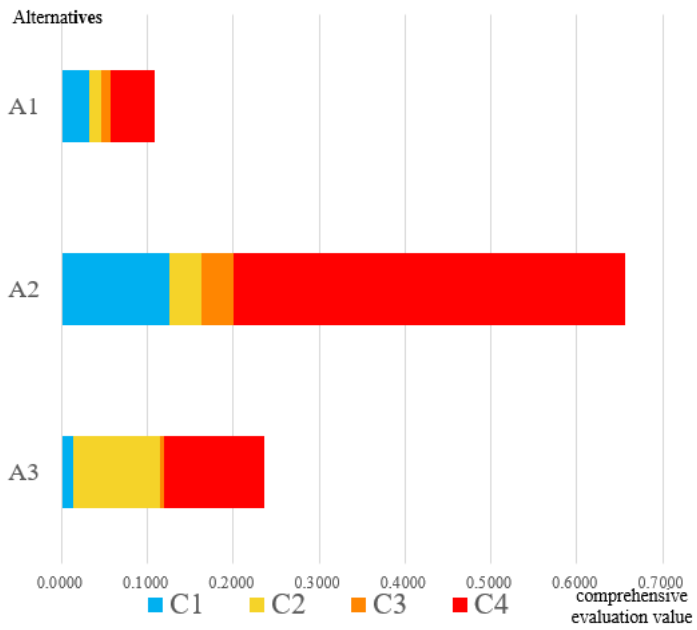

Fig. 6. Summary result.

The weight shows a high percentage would like to have more frequent opportunities to speak (red area in Fig. 6). The percentage is high (A2), influencing the final decision. Examining the comprehensive evaluation value, *Team* is the best way for active class discussion.

5.2 Simulation for difficulties of discussion in cases

From the concept of groupthink(see chapter 2.6) [27], the four structural faults of organizations (5.2.1-5.2.4) and how they can be addressed are described. The faults can be overcome by the combined model of CAR and AHP. The model of lesson improvement is an effective method to overcome the structural faults of organization in schools.

5.2.1 Insulation of the group

The group is isolated from external information.

An example of choosing suitable learning material is given below. A teacher was considering a lesson to make the learners more interested in mathematics. The group for improving the lesson included a supervisor. However, the group felt isolated from information outside of school because few new perspectives were presented. Thus, the moderator thought that the group should have access to outside information, and in the middle of the meeting, he/she brought a university researcher into the group of CAR. Members

- A teacher
- A supervisor
- A university researcher

The researcher then introduced the group to the latest applications of computer-based math games. The members decided to adopt the math game. The group all discussed the idea again and, with consensus, designed the lesson. As a result, the teachers could implement a lesson model that they had never tried before.

5.2.2 Lack of tradition of impartial leadership

The group has a leader who has high authority.

A teacher in charge was tasked with improving a lesson on Goal 4 of the United Nations Sustainable Development Goals (SDG-G4) [30]. However, the teacher, who could not determine the best pedagogical principle, called on experts to hold a discussion. The teacher invited a university researcher, a teacher mentor, an information and communication technology (ICT) teacher, and an English teacher to form a group of CAR. They observed a class and provided suggestions on the criteria that they deemed should be met to improve the lesson on SDG-G4. In addition, they discussed

which competencies students should develop through the improved lesson plan. Through the discussion, they listed four competencies as criteria (Fig. 7).

Members

- A teacher
- A university researcher
- A teacher mentor
- An information and communication technology (ICT) teacher
- An English teacher

The goal of AHP: To decide the best pedagogical principle to teach SDG-G4

Criteria:

C1: *Education for sustainable development (ESD) competencies*
C2: *Communication skills*
C3: *ICT competencies*
C4: *English proficiency*

Alternatives:

A1: *Self-regulated learning*
A2: *Computer-mediated communication (CMC)*
A3: *Problem-based learning (PBL)*

In the following part, for the sake of brevity, each item is indicated by an initial symbol (For example, “ESD competencies” is indicated as C1).

In the middle of the CAR, an AHP was performed, and the CI was shown to be 1.1428 (see TABLE XVI).

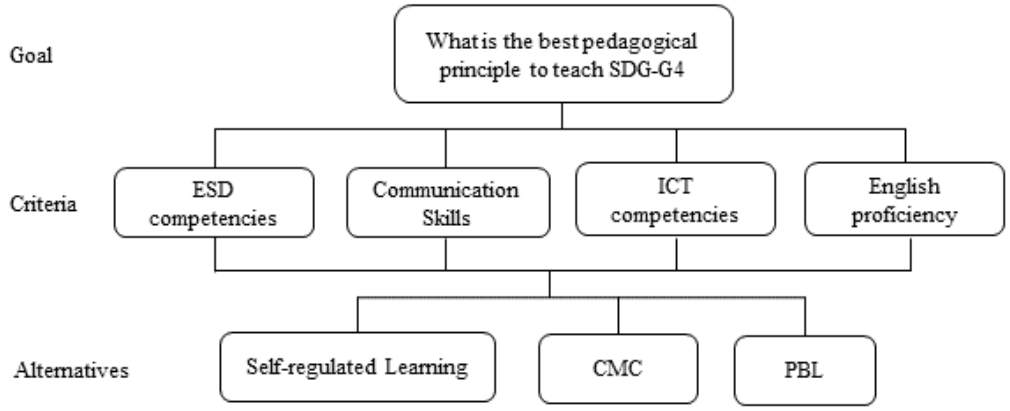

Fig 7. Hierarchy diagram.

TABLE XVI. Evaluation between criteria.

		Indicators					
	Criteria	**C1**	**C2**	**C3**	**C4**	**Geometric mean**	**Normalized weight**
Indicators	C1	1	7	1/7	3	1.3161	0.2810
	C2	1/7	1	1/9	3	0.4671	0.0997
	C3	7	9	1	1/3	2.1407	0.4570
	C4	1/3	1/3	3	1	0.7598	0.1622
	total					4.6837	1.0000
	C.I.						1.1428

TABLE XVII. Pairwise judgment of alternatives for criteria 1 (C1).

	Alternatives				
C1	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	1/3	3	1.0000	0.2583
A2	3	1	5	2.4662	0.6370
A3	1/3	1/5	1	0.4055	0.1047
total				3.8717	1.0000
C.I.					0.0193

TABLE XVIII. Pairwise judgment of alternatives for criteria 2 (C2).

	Alternatives				
C2	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	1/3	1/5	0.4055	0.1047
A2	3	1	1/3	1.0000	0.2583
A3	5	3	1	2.4662	0.6370
total				3.8717	1.0000
C.I.					0.0193

TABLE XIX. Pairwise judgment of alternatives for criteria 3 (C3).

	Alternatives				
C3	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	5	1	1.7100	0.4353
A2	1/5	1	1/7	0.3057	0.0778
A3	1	7	1	1.9129	0.4869
total				3.9286	1.0000
C.I.					0.0063

TABLE XX. Pairwise judgment of alternatives for criteria 4 (C4).

	Alternatives				
C4	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	1/7	1	0.5228	0.1194
A2	7	1	5	3.2711	0.7471
A3	1	1/5	1	0.5848	0.1336
total				4.3786	1.0000
C.I.					0.0063

A summary of TABLE XVI – XX is shown in TABLE XXI.

TABLE XXI. Comprehensive evaluation value of the alternatives for each criteria.

	C1	**C2**	**C3**	**C4**	**Comprehensive evaluation value**
A1	0.0726	0.0104	0.1989	0.0194	0.3013
A2	0.1790	0.0258	0.0356	0.1212	0.3615
A3	0.0294	0.0635	0.2225	0.0217	0.3372

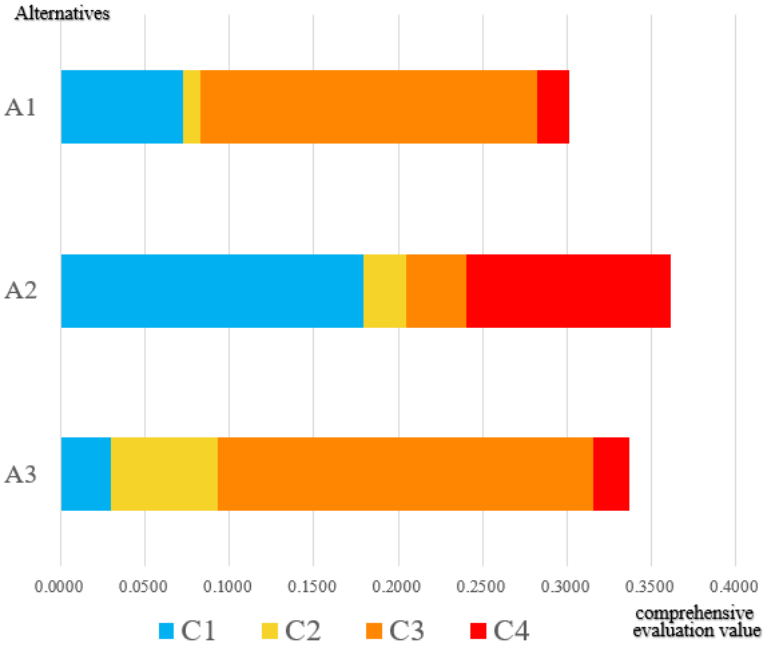

Fig. 8. Summary result.

Suppose that one person insists during the discussion that a computer should be introduced and thinks that having a computer will improve their lessons. In such a case, the CI would be high. Contradictions can be revealed when ill-structured consistency is revealed (Fig. 8).

If the consistency index is higher than 0.15, it is necessary to clarify the goal again and check the criteria. By discovering where the contradictions lie, the discussion process can be reflected on, and a more consensual discussion can be held.

5.2.3 Lack of norms requiring methodical procedures

High group cohesiveness was observed.

Teachers were tasked with improving a lesson on writing an essay. However, they could not determine the best learning method for the instruction of drafting an essay. Through their observation and discussions, they listed four criteria and three alternatives (Fig. 9).

Members

- Teachers

The goal of AHP: To decide the best learning method for the instruction of writing an essay

Criteria:

C1: *Deepening written content*
C2: *Obtaining various ideas*
C3: *Clarifying sentence structure*
C4: *Learning written expression*

Alternatives:

A1: *Read seniors' writing*
A2: *Discuss with friends*
A3: *Make a mind map*

In the following section, for the sake of brevity, each item is indicated by an initial symbol (For example, "Deepening written contents" is indicated as C1).

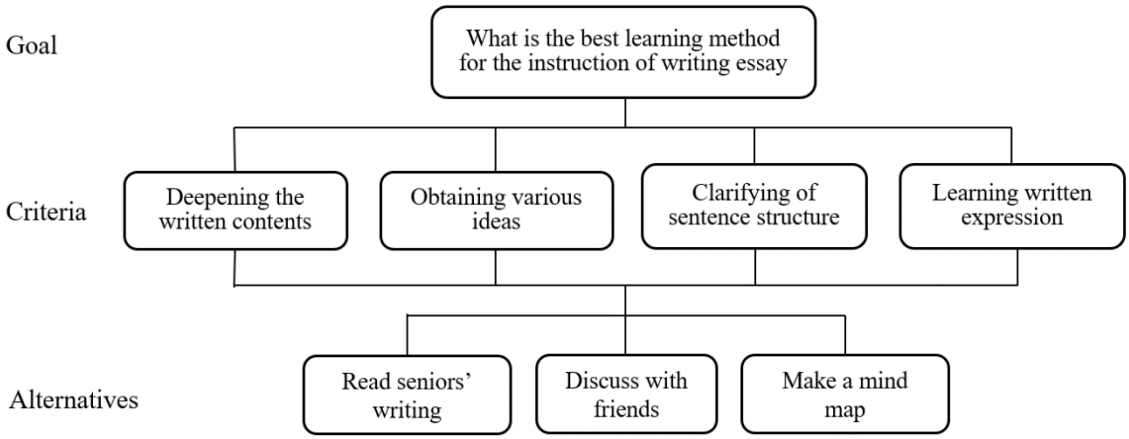

Fig. 9. Hierarchy diagram.

TABLE XXII. Evaluation between criteria.

		Indicators					
	Criteria	**C1**	**C2**	**C3**	**C4**	**Geometric mean**	**Normalized weight**
Indicators	C1	1	1	2	1	1.1892	0.2818
	C2	1	1	1	2	1.1892	0.2818
	C3	1/2	1	1	2	1.0000	0.2370
	C4	2	1/2	1/2	1	0.8409	0.1993
	total					4.2193	1.0000
	C.I.						0.0618

TABLE XXIII. Pairwise judgment of alternatives for criteria 1 (C1).

	Alternatives				
C1	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	2	1	1.2599	0.4126
A2	1/2	1	1	0.7937	0.2599
A3	1	1	1	1.0000	0.3275
total				3.0536	1.0000
C.I.					0.0268

TABLE XXIV. Pairwise judgment of alternatives for criteria 2 (C2).

	Alternatives				
C2	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	2	1	1.2599	0.4000
A2	1/2	1	1/2	0.6300	0.2000
A3	1	2	1	1.2599	0.4000
total				3.1498	1.0000
C.I.					0.0000

TABLE XXV. Pairwise judgment of alternatives for criteria 3 (C3).

	Alternatives				
C3	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	1/3	1	0.6934	0.2098
A2	3	1	2	1.8171	0.5499
A3	1	1/2	1	0.7937	0.2402
total				3.3042	1.0000
C.I.					0.0091

TABLE XXVI. Pairwise judgment of alternatives for criteria 4 (C4).

	Alternatives				
C4	**A1**	**A2**	**A3**	**Geometric mean**	**Normalized weight**
A1	1	1/2	2	1.0000	0.2958
A2	2	1	2	1.5874	0.4695
A3	1/2	1	1	0.7937	0.2347
total				3.3811	1.0000
C.I.					0.0268

TABLE XXVII. Comprehensive evaluation value of the alternatives for each criteria.

	C1	**C2**	**C3**	**C4**	**Comprehensive evaluation value**
A1	0.1163	0.1127	0.0497	0.0589	0.3377
A2	0.0733	0.0564	0.1303	0.0936	0.3535
A3	0.0923	0.1127	0.0569	0.0468	0.3088

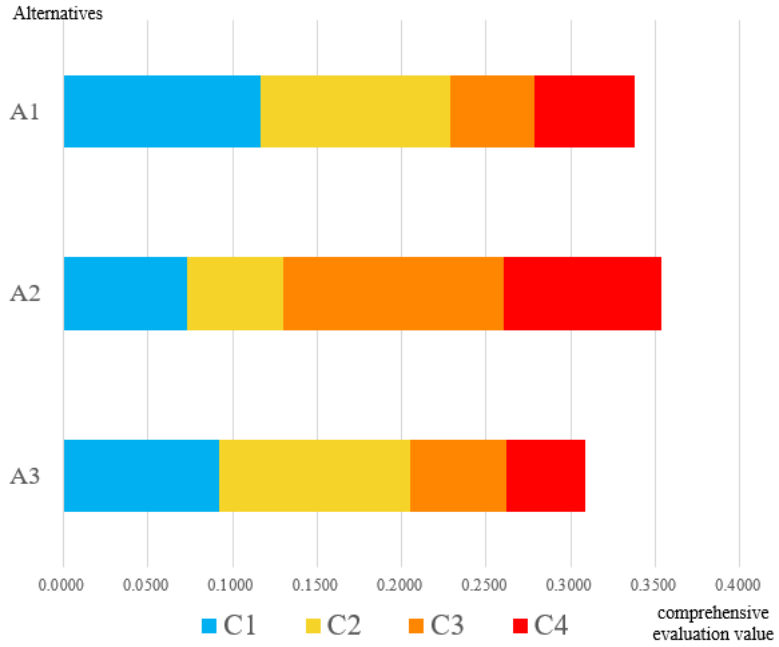

Fig. 10. Summary result.

If the members offer only evaluations close to neutral (see Tables XXII – XXVII), the CI will be low, but the decision will not be made gracefully. The results may be difficult to interpret. By representing the results in a graph, it is possible to check the state of the discussion. In this example, the sizes of the items in the graph are all similar (see Fig. 10). This result does not mean that it is a bad discussion, but it can be a chance to reconsider the environment of the discussion to see if everyone can express their opinions.

5.2.4 Homogeneity of members' social backgrounds and ideologies

The group consists of people with similar circumstances and environments.

For a lesson on work experience for learners, an action research group of only teachers was formed. However, the moderator was concerned about the homogeneity of the group. Therefore, a CAR was set up to involve professionals from various backgrounds, including the following members as participants in the group.

Members

- Educational and non-educational companies
- A museum curator
- A university researcher
- Parents
- Local school coordinators

The diversity of backgrounds was a strength, and many ideas were suggested. The teachers were able to consider a variety of ideas and put them into practice. The AHP was not used this time as there was no need to decide upon one idea.

6. Discussion

The simulations revealed the function of the CAR and AHP collaboration models as well as various problems that could arise during the group discussions.

Furthermore, in the process of the model, it is necessary to describe what to do when no ideas are generated or when more than eight criteria and alternatives are generated. This is described in detail in two chapters. The first is brainwriting and the second is the Kawakita Jiro method.

6.1 Brainwriting

If no alternatives or criteria were suggested, the group should discuss the ideas before conducting the AHP. As one method of group discussion, brainstorming is often used. However, in the current study, brainstorming is not adopted.

According to Garold Stacer and William Titus's study [31], in terms of the number and quality of ideas, it is far better to silently write down members' thoughts on paper than discuss each other's ideas. This discussion gap widens the more people attend the meeting.

There are three reasons for this result. One is that there is no “speech blocking.” In cases such as meetings, only one person can talk at a time. As a result, an attendee may forget an idea that came to them while they were silent because someone else was talking. Also, even if it comes to their turn to speak, one may feel uncomfortable to comment if their opinion does not align with the group. In addition, the more people in a group, the harder it is to find an opportunity to speak. In traditional brainstorming, a few attendees dominate 60%–75% of the opportunity to speak [32]. Therefore, other attendees are unlikely to have a chance to speak.

The second reason is that the act of “silently writing their thoughts on paper” is not embarrassing in public. Particularly when attendees can be anonymous, they feel quite free to write down their opinion. Attendees do not lose confidence by hearing the opinions of others or change their opinions considering the atmosphere.

The third reason is that the form in which everyone fills in silently is an “all-participation meeting.” If they have a piece of paper and a pencil in front of them, they would feel pressured to write something and cannot hide behind others.

For the above reasons, brain-writing, which is a method of silently writing one’s opinions and ideas within a group, is an alternative to brainstorming [33]. It is particularly useful with a group of people who are somewhat reticent and would be unlikely to offer many ideas in an open group session, such as brainstorming. Relative to brainstorming, brain-writing potentially minimizes the effect of status differentials, dysfunctional interpersonal conflicts, domination by one or two group members, pressure to conform to group norms, and digressions from the focal topic. Indeed, brain-writing is more effective (20% more total ideas and 42% more original ideas) than a meeting using ordinary brainstorming [34].

6.2 Kawakita Jiro Method (KJ Method)

To introduce CAR in the AHP session because multiple experts intervene, many criteria and alternatives will be possible to arise. However, Takahagi and Nakajima [17] indicate that AHP sessions require a limited number of criteria and alternatives of 2~7. It is better to choose essential elements and a smaller number of criteria because the contents of the criteria might fluctuate inconsistently when compared with a large number of criteria.

If more than eight alternatives or criteria have been provided, three steps of the KJ method [35] are recommended [36] to reduce the number. First, the ideas that the members create are written on a card. Second, the cards are classified by issues. Once a conceptually similar card group is formed, a label is created with a sentence that represents the entire group. Finally, the grouped cards are placed on a large piece of paper to create a diagram.

(1) Write down what you came up with about the theme on the card. This time, write only one thing on one card.
(2) The collected cards are classified. It is better to form a group for each card that you want to put in the same group. Once a group is formed, make a label card with a sentence of the theme of the group. After that, the group will be represented by this label card.
(3) The grouped cards are placed on a large piece of paper to create an illustration. At this time, place the cards that you feel are close to each other. Moreover, when you want to show the relationships between groups, draw a relationship line between them.
(4) Select one starting card from the completed card arrangement, and write the contents written on all the cards.

The KJ method has two advantages. The first is that it can keep a record that can be shared with people who were not present at the meeting, and it can show how the criteria and alternatives were chosen in the same way as the AHP. The second is that the KJ method is anonymous at the stage of suggesting ideas. Thus, the discussion is not disturbed by authority [35].

7. Conclusion

This study has revealed two main findings. The first is that action research, particularly with the involvement of several experts, is effective in improving lessons. Second, the use of AHP encourages more effective discussions. The starting point of this study was the opinion of schoolteachers: they do not embrace the meaning of lesson improvement training, which only increases the workload and makes them feel like a burden. From there, a method of lesson improvement known as action research was discussed, highlighting the significance of a spiral process of improvement. In addition, collaborative action research was proposed as it is more effective when the number of members in the action research is multiple and heterogeneous. At that time, the difficulty of improving lessons in groups was thought to be in integrating multiple opinions into one in discussions. As a solution to this difficulty, the model combining collaborative action research and AHP was developed. Furthermore, the difficulty of discussing in a group was mentioned, and this model was proposed as one of the ways to overcome the challenge.

Therefore, this study is proposed as one of the methods to promote lesson improvement training and organize the discussion among several people with different specialties. In the past, few studies have approached lesson improvement training from the perspective of social psychology, such as decision-making or groupthink. This lack of studies is due to schools being closed spaces—the involvement of outsiders, such as

university researchers and educationists who are invited to give lectures, has become a form of authoritative training. This research will also impact the way teachers approach lesson study, namely that the study proposes a concrete and implementable method in the field of lesson improvement training.

8. Final remark

This study is regarded not as a case study but as a method development study. Therefore, there is no description of the practice or data on which it is based. The limitation of this paper concerns the fact that the estimations are based on individual preferences. The purpose of these simulations is not to prove the significance of lesson improvement but to show the validity of the discussion.

Thus, it is necessary to implement this model and to test its effectiveness. Moreover, many new issues could be considered, such as the extent to which AHP can uncover teachers' tacit knowledge. The goal of a future study is to help to make lesson improvement training more meaningful for teachers.

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T. Kubota and M. Yoshida, "Innovative Approach for Lesson Improvement through Collaboration", preprint. *Int. J. of Inf. and Educ. Technol.*, 2021.

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10. Declaration

The author declares no conflicts of interest and no competing interests.

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