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WEIGHTING OF GREEN COMPETENCIES IN VOCATIONAL EDUCATION USING FUZZY ANALYTICAL HIERARCHY PROCESS (FAHP)

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Abstract

The urgency of integrating a green competency (GC) framework into vocational high school (VHS) education has become increasingly apparent, particularly to align with the Sustainable Development Goals (SDGs). This research aims to identify and prioritize the dimensions and sub-dimensions of GC, previously identified, to provide recommendations for a comprehensive GC framework in VHS. The study commenced with the development of a questionnaire comprising six sets of questions. The validated questionnaires were then disseminated via Google Forms to VHS students. The decision-making process employed the Multi-Criteria Decision Making (CDM) approach based on the Fuzzy Analytical Hierarchy Process (F-AHP). A total of 429 VHS students across various majors participated in the survey. The Geometric Mean Method (GMM) F-AHP revealed 45 priority GC rankings, all with a Consistency Ratio (CR) value of less than 0.1. The top eight competencies identified were: the ability to provide solutions to environmental problems, responsibility for environmental sustainability, environmental awareness, knowledge of legal compliance, a caring attitude towards the environment, communication skills, awareness of environmental issues, and proactive environmental protection actions. These prioritized competencies serve as critical recommendations for developing a GC framework in VHS, benefiting schools, the workforce, and policymakers. However, the study acknowledges certain limitations, such as the need for more specific competencies tailored to the distinct areas of expertise within Indonesian VHS, suggesting avenues for future research.

Keywords: Framework, Fuzzy analytical hierarchy process, Green competencies, Sustainability development goals, Vocational high school.

1. Introduction

Green Competence (GC) is increasingly recognized as a crucial skill set in the modern workforce, particularly due to its strong relationship with environmental sustainability [1]. GC encompasses a range of knowledge, skills, and socio-economic behaviors that enable individuals to act responsibly and effectively towards environmental conservation [2]. As economies shift towards sustainable practices, there is a corresponding need for changes in job structures and professional profiles, which necessitates new qualifications and competencies within the workforce. This shift significantly impacts the education sector, demanding a re-evaluation and integration of GC into educational curricula to prepare future professionals adequately [3-5].

The education sector has proactively responded to this need by incorporating Education for Sustainable Development (ESD) into curricula and teaching programs at all educational levels, including vocational education [6-9]. This integration marks a foundational step towards facilitating the transition to a green economy and industry, ultimately enhancing global competitiveness in a market increasingly driven by sustainability [10, 11]. In Indonesia, there is a pressing need for stakeholders to develop a GC framework that aligns with these global sustainability demands. Such a framework would support the education sector in producing graduates equipped with the competencies necessary to thrive in a sustainability-oriented job market.

An in-depth review of existing research on GC frameworks within vocational education is imperative to formulate strategic steps for the effective integration of GC into curricula. Previous studies have identified six primary dimensions of GC: green awareness, green knowledge, green skills, green abilities, green attitude, and green behaviour, each with several sub-dimensions totalling 45 different competencies [12, 13]. For these competencies to be effectively implemented, it is crucial to prioritize them according to workforce needs. Multi-Criteria Decision Making (MCDM) methods, such as the Fuzzy Analytical Hierarchy Process (F-AHP), have been identified as suitable approaches for determining these priorities [14]. Specifically, the Geometric Mean Method (GMM) of F-AHP and the Extent Analysis Method (EAM) of F-AHP are commonly used for calculating criteria weights [15]. Prior research has successfully applied EAM F-AHP to prioritize employability skills for vocational school graduates [16]. Building on these methodologies, this research aims to apply GMM F-AHP to identify and prioritize GC competencies in VHS, thus laying the groundwork for a robust GC framework that aligns vocational education with the evolving demands of a sustainable global economy.

2. Method

2.1. Fuzzy analytical hierarchy process (F-AHP)

F-AHP is an innovative aspect of the AHP model developed by Satty which has been applied in MCDM models in various research fields [17]. The fuzzy AHP technique uses fuzzy numbers to represent decision-making criteria to consider imprecise and uncertain information [18]. In this research, GMM F-AHP was used for priority selection. This decision was taken because GMM was suitable for use

in determining priorities from various options. The following are several stages in the decision-making process using GMM F-AHP [15]:

(1) Creation of the GC hierarchical structure (see Fig. 1);

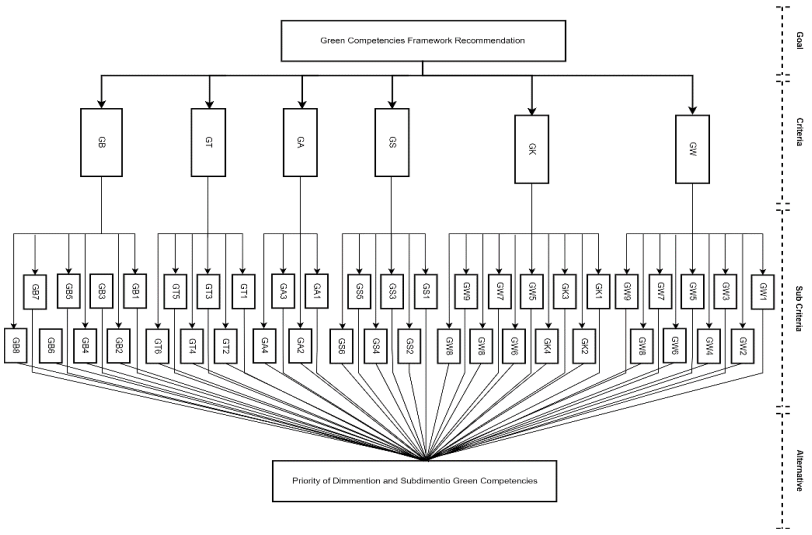

Fig. 1. GC hierarchical structure.

(2) Create a pair-wise comparison matrix.

(3) Construct Fuzzified Pairwise Comparison Matrix.

$$A = \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{a}_{nn} \end{bmatrix} \quad (1)$$

(4) Calculation of the Fuzzy Geometric Mean Value for each criterion.

$$\tilde{r}_i = \Big((r_{11} * r_{21} * \cdots * r_{n1})^{\frac{1}{n}}, (r_{12} * r_{22} * \cdots * r_{n2})^{\frac{1}{n}} \cdots \cdots (r_{1n} * r_{2n} * \cdots * r_{nn})^{\frac{1}{n}} \Big) = (r_{i1} * r_{i2} * \cdots * r_{in}) \quad (2)$$

(5) Calculate fuzzy weights.

$$\widetilde{w}_i = \tilde{r}_i \oplus \{\tilde{r}_i \oplus \tilde{r}_2 \oplus \ldots \ldots \oplus \tilde{r}_n\}^{-1} \quad (3)$$

(6) De-Fuzzification.

$$Centre\ of\ Area\ (COA) = w_i = \left(\frac{l+m+u}{3}\right) \quad (4)$$

$$BNP_{Ci} = \frac{[(U_{Wi} - L_{Wi}) + (M_{Wi} - L_{Wi})]}{3} + L_{Wi} \quad (5)$$

(7) Normalization of Weights.

(8) Consistency Check

$$Consistency\ Ratio = \frac{Consistency\ Index\ (C.I)}{Random\ Index\ (R.I)} \quad (6)$$

Determination of criteria and sub-criteria refers to the results of literature that adopts several articles that discuss GC dimensions and sub-dimensions. These dimensions and sub-dimensions are used as a reference for making instruments to gather information from experts to be used as material for making decisions from several options. This research began with creating a questionnaire, which refers to the results of identifying dimensions and sub-dimensions of green competency that have been determined previously. The questionnaire consists of 6 sets of questions from each of the variables green awareness, green knowledge, green skills, green abilities, green attitudes and green behavior (Table 1) where respondents fill in checklists according to their needs from several available options. Questionnaires were distributed randomly to vocational school students in Indonesia using an online survey using Google Form to reach all respondents.

Table 1. Criteria and sub-criteria of green competencies.

Dimensions (Code)	Sub-dimensions (Code)
Green Awareness (GW)	Awareness of the impact of air pollution (GW1); Awareness of carbon emissions (GW2); Energy production awareness (GW3); Energy consumption awareness (GW4); Awareness of energy reserves (GW5); Environmental awareness (GW6); Awareness of environmental problems (GW7); Sustainability awareness (GW8); Involvement in environmental protection (GW9)
Green Knowledge (GK)	Knowledge related to environmentally friendly issues (GK1); Knowledge related to compliance with law and order and environmental sustainability regulations (GK2); Knowledge related to environmental conservation (GK3); Knowledge related to energy conservation (GK4); Knowledge related to sustainable development (GK5); Knowledge related to recycling (GK6); Knowledge of renewable energy sources (GK7); Knowledge in the use of open space (GK8); Availability of access to ongoing services (GK9); Understanding of the natural environment (GK10)
Green Skills (GS)	Innovation skills (GS1); Design skills (GS2); Communication skills (GS3); Energy skills (GS4); Waste processing skills (GS5); Leadership skills (GS6); Adaptation skills (GS7); Analytical thinking skills (GS8)
Green Abilities (GA)	Able to provide solutions to environmental problems (GAI); Able to be responsible for environmental sustainability (GA2); Able to access the sustainability service system (GA3); Able to access waste processing facilities (GA4)
Green Attitude (GT)	Attitudes towards the importance of environmental education (GT1); Attitudes towards the importance of sustainable development (GT2); Attitudes towards the importance of environmental protection (GT3); Attitude of concern for the environment (GT4); A committed attitude towards solving environmental problems (GT5); Respectful attitude towards nature and society (GT6)
Green Behaviour (GB)	Actions to protect the environment (GB1); Energy saving behavior (GB2); Reuse and recycling behavior (GB3); Behavior for environmental preservation (GB4); Behavior to achieve sustainability (GB5); Behavior to produce environmentally friendly products (GB6); Buy products that are safe for the environment (GB7); Develop products that cause the least damage to the environment (GB8)

2.2. Respondent

A total number of 429 people serve as the respondents of the study. The specific data of them are presented in Table 2.

Table 2. Respondents of the study.

Item		%	Item		%
Gender	Male	70%	**Class**	Level 10	42%
	Female	30%		Level 11	41%
Field	Agribusiness and Agrotechnology	10%		Level 12	14%
	Business and management	1%		Level 13	3%
	Energy and Mining	4%	**Internship experience**	Not yet an intern	74%
	Health and Social Work	1%		Currently Internship	3%
	Arts and Creative Economy	5%		Already an Intern	23%
	Information Technology	22%			
	Construction and Property Technology	2%			
	Manufacturing and Engineering Technology	53%			
	Maritime	1%			

3. Result and Discussion

There are 429 respondent data that are ready to be processed. The total number of criteria is 6 criteria consisting of 45 sub-criteria. Geometric Mean Method of Fuzzy AHP (GMM F-AHP) is used to identify which sub-criteria are the most priority to be used as a GC framework recommendation for VHS. After using a variety of equations in the steps elaborated earlier, this study found the results of the weighted values for each criterion are then sorted based on the highest weight and the following ranking results are shown in Fig. 2.

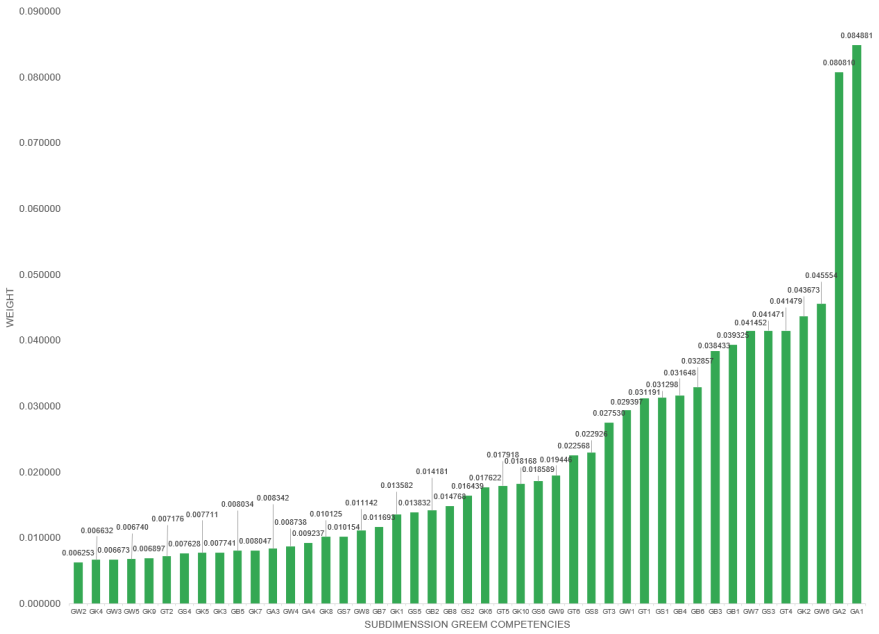

Fig. 2. GC priority order results.

Figure 2 presents the ranking results of 45 sub-criteria based on the GMM F-AHP calculation results. This ranking is derived from the weighted values obtained

by each sub-criterion, with a particular focus on the top eight rankings. The first and second positions pertain to the Abilities dimension, showcasing the most significant values compared to the other sub-criteria. The highest-ranked competencies are the ability to provide solutions to environmental problems and the ability to take responsibility for environmental sustainability. These competencies are essential for VHS graduates, aligning with the demands of 21st-century skills, where problem-solving and responsibility, including environmental responsibility, are paramount [19, 20]. The third position falls under the Green Awareness dimension, specifically environmental awareness. This competency is crucial for VHS graduates, resonating with industry perceptions, particularly in the IT sector, which emphasizes the importance of environmental awareness in supporting sustainability systems [21].

The fourth position is occupied by knowledge related to compliance with the law, categorized under Green Knowledge. Legal compliance is a critical area of study for prospective workers, encompassing rules and prohibitions essential for the workforce, particularly concerning environmental issues. However, some regions, such as Bangladesh, have yet to implement education on laws and regulations within sustainable systems, despite its necessity in the workplace [22]. The fifth position pertains to the Green Attitude dimension, specifically a caring attitude towards the environment. This competency is vital for prospective workers [23], as modern employees must possess not only skills but also a genuine concern for the environment. The sixth position is held by communication skills, part of Green Skills. Effective communication, including listening skills and oral expression, is indispensable for VHS graduates, forming the foundation of influential oral communication [16, 24].

The seventh position is occupied by awareness of environmental problems, a competency within the Green Awareness dimension. Understanding environmental issues is critical within the Green Human Resource Management (GHRM) framework, where employee involvement in environmental matters can influence their compensation [25]. The eighth position is held by the competency of taking actions to protect the environment, categorized under Green Behaviour. This competency is essential for prospective workers, as positive attitudes and habits towards the environment are integral to the ethos of a sustainable system, particularly in the workplace [26].

4. Conclusion

This study has identified a priority ranking of green competencies that must be mastered based on the perspectives of VHS students from various majors. Through GMM F-AHP 45 competency analysis, the weight is known, and the data can be used as a consideration because it has CR<0.1 (0.077854). Therefore, the 8 competencies with the greatest weight and occupying the top rankings and representing the 6 GC elements are discussed in this paper. These include being able to provide solutions to environmental problems and being able to be responsible for environmental sustainability which is part of green abilities, environmental awareness and awareness of environmental problems from green awareness, knowledge related to legal compliance from green knowledge, caring attitude towards the environment from green attitude, skills communication of green skills and actions to protect the environment from green behavior. The final ranking is from green awareness related to awareness of carbon emissions. This

research can be used as a recommendation for policy makers, the world of work and schools, especially VHS as a reference or recommendation in creating frameworks and curriculum updates as well as other parties or researchers in exploring this topic.

There are many shortcomings that are gaps in this research that must be perfected by other researchers, including the aspect of differences in ranking results from each group of various skills and not using or analyzing other F-AHP methods.

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