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Merging Science Education into Communication: Developing and Validating a Scale for Science Edu-Communication Utilizing Awareness, Enjoyment, Interest, Opinion formation, and Understanding Dimensions (SEC-AEIOU)

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Received: 16 July 2019; Accepted: 12 August 2019; Published: 22 August 2019

Abstract: For better understanding of how the public perceive the information in science communication; this study sought to develop the scale of Science Edu-Communication (SEC), an instrument to measure AEIOU: *Awareness; Enjoyment; Interest; Opinion formation;* and *Understanding*. The AEIOU framework was adopted for use as the major component of SEC to depict participants' general perceptions of science communication from their daily life experiences. Responses from 121 participants were analysed using exploratory factor analysis; item discrimination; and qualitative coding analysis. Results support SEC-AEIOU as a valid and reliable instrument to measure the effectiveness of science communication experiences. Additionally; SEC-AEIOU can serve as a framework for research and practice to bridge science communication and science education. In particular; science communicators; educators; and institutions that engage in science communication and educational activities may benefit from such a metric. This scale seeks to assist in building a robust framework to facilitate the trend of bridging science communication and science education: Science Edu-Communication.

Keywords: science education; science communication; science edu-communication; AEIOU

1. Introduction

While the focus on how the rapid progress of science and technology can as well contribute to human and environmental sustainability, it is equally important and adequate to understand how the public perceive the meaning of sustainability via means in science communication [1,2]. Science communication is an area of practice and research that continues to experience steady growth in the amount of activities, courses, and practitioners in the field during the past two decades. While it remains, and continues to be, a widely-researched topic, science communication has varying definitions and applications in different fields and countries. Since the 1990's, the dominant model of science communication research and practice has shifted from deficit models towards engagement models [3,4]. However, some practitioners still perceive science communication as a one-way (e.g., deficit model) delivery of knowledge from scientists to the public, or the expert group to the knowledge "deficit" group, respectfully. The current study adopts a much broader definition as suggested by Burns, O'Connor, and Stocklmayer, who integrated various elements of a two-way (e.g., engagement model) communication model, and defined science communication as "the use of appropriate skills, media, activities, and dialogue to produce one or more personal responses to science" [5] (p. 191).

Science Edu-Communication emerges as a model utilized for new production and research avenues in recent science communication progress [6]. A consistent pursue of both science communication and science education on promoting public understanding of science has been found by scholars [7–10]. In this vein, developing a scale for "Science Edu-Communication (SEC)" as an instrument and framework is the goal of this study, which aims to quantitatively and qualitatively measure the purpose, features, means, methods, and effects of science edu-communication in interactions with the public. More specifically at this early emerging stage of SEC, it is needed to evaluate its effectiveness via personal perceptions toward SEC.

Recently, significant reviews within the UK have recognized four key factors that increased the need for science communication with the public [11]: (1) The public's reduced trust in scientists, mainly derived from scientists' increased reliance on funding from industrial and private sources, possibly influencing them to promote the goals of special interest groups; (2) The public placing a lower value on "Big Science" (i.e., larger-scale scientific projects that are generally funded by national governments, such as the Large Hadron Collider) [12], resulting in increased difficulty in justifying significant financial investment; (3) Advanced technology has created unparalleled conveniences for the public to not only consume knowledge but also contribute personal opinions regardless of their factual validity [13]; (4) "Democratic deficit" [14], meaning an ostensibly democratic government has lost the public's trust by not fulfilling democratic principles [15,16], appearing in the process of decision-making regarding science and technology policies [11].

In response to the demands of science communication, there are several primary approaches to engage the public with science. Bultitude summarized these in three categories: (1) Traditional journalism, such as newspapers, magazines, TV, and radio, that inform audiences of contemporary high-profile issues, but tend to resort to the one-way deficit-model of focused communication; (2) Live or face-to-face events and settings, such as science museums, science festivals, and public lectures, that allow scientists more control of content and reduce third party distortion of communication, but only reach a limited audience; (3) Online social media that encompasses both one-way and two-way communication depending on the platform and the audience's preferences, and can reach a large potential audience with significantly less time and space limitations [17]. Moreover, social media (e.g., Facebook special interest group in science) help promote, moderate and mediate the public with science with positive impact [18].

However, one important question is: "How do we know whether science communication is successfully delivering something of value to the public?" Jensen pointed out the importance of science communication in an evaluation stating [19]:

> *"High-quality impact evaluation that is judiciously employed, skilfully conducted and effectively shared can provide a basis for practitioners to discover what aspects of science communication initiatives are working, in what ways, with which audiences and why.".* (p. 1)

Considerable amounts of science communication studies have been conducted to analyse the effectiveness of various science communication methods. For example, Koolstra introduced a mix of quantitative and qualitative methods to analyse the publics' opinion of the image of science and scientists [20]. Levine and his colleagues utilized a mixed-methodology to evaluate science communication regarding health issues using an online platform, "MyPlate" [21]. Baram-Tsabari & Lewenstein developed a pre- and post-instrument to evaluate scientists' public communication skills in writing [22]. Although considerable numbers of science communication evaluations have been developed, the methodology and conceptual basis of these particular initiatives is challenging to develop well, multiplying the difficulty of coherently evaluating science communication [23]. This situation may restrict the advancement of science communication practices, quality and their effectiveness [19].

Burns et al. provided an outcome-based framework to define science communication from an audience's perspective called the AEIOU framework (the vowel analogy): Awareness of science

(A); Enjoyment or other affective responses to science (E); Interest in science (I); the formation of science-related Opinions (O); and Understanding of science (U) [5]. For the current study, these metrics form the most important components of the SEC scale used to analyse audiences' responses regarding a science communication activity or experience. As Wu and colleagues introduced a research trend in Science Edu-Communication (SEC) [6], the current study sought to establish and validate a conceptual framework using dimensions of the AEIOU framework for effective evaluation of science communication experiences.

2. Theoretical Framework

To analyse how the public perceive scientific information is a good way to promote their understanding toward sustainability of the environment. Synonyms of science communication, such as public awareness of science (PAS), public understanding of science (PUS), scientific literacy (SL) and science culture, have been commonly used among different research fields and researchers. Burns et al. pointed out the common ground of these synonyms and suggested a framework to define the research and practice of science communication [5]. More importantly, as an outcome of science communication, he argued that recipients of any form of effective science communication should be able to express or determine their:

> *"Awareness (A), including familiarity with new aspects of science; Enjoyment (E), or other affective responses, e.g., appreciating science as entertainment or art; Interest (I), as evidenced by voluntary involvement with science or its communication; Opinions (O), the forming, reforming, or confirming of science-related opinions; and Understanding (U) of science, its content, processes, and social factors."* (p. 191)

The current study utilized literature review to revise the definitions of the AEIOU framework in accordance with contemporary conditions (e.g., development of social media, advancements in technology, etc.) to the develop the SEC-AEIOU instrument.

2.1. Awareness of Science

The above statement on *Awareness* by Burns et al. may be extended to the idea that *Awareness* " ... provides the foundations of knowledge, broadens the mind and opens up personal and public opportunities that did not previously exist." (p. 196) [5]. On the other hand, Gilbert, Stocklmayer, and Garnett defined the public awareness of science (PAS) as a set of positive attitudes toward science and technology [24]. Such an attitude can be explained by "attitude toward science" and defined as *"feelings, beliefs and values held about the enterprise of science*, school *science, and the impact of science on society or scientists"* (p. 1053) [25]. In order to assess these sets of beliefs, literature has documented a range of measurements [26–30], including attitudes towards scientists, sense of nature of science, importance of science, the value of science in society, attitudes towards science instruction, the perception of science teachers, and the intention of pursuing a career in science related work. Thus, it seems that *Awareness* serves as a prerequisite attitude for determining whether one can further embrace new values or ideas regarding the current or future impact that science can have on one's life. From the above studies, it may be concluded that *Awareness* towards science is an important consideration regarding public participation in science communication activities. Thus, for the purpose of the current study focusing on the science communication activities, *Awareness* is explored as: Being aware of the importance of science and technology, and having a sense of the nature of science.

2.2. Enjoyment or Other Affective Responses to Science

Enjoyment can be described as "a pleasurable experience" (p. 197) that evokes positive feeling, and further deepens motivation to explore subsequent matters about science [5]. Many studies have shown that engagement in leisurely science learning, such as visiting science museums, aquariums, science centres, national parks, botanical gardens, live science demonstrations, or science theatres, provides the public with enjoyment [31–34]. Also, some research has discovered *Enjoyment* as an affective factor that can motivate individuals to engage in leisurely science learning [33,35]. Thus, *enjoyment* is highly-related to learning effectiveness [36–39], especially when science is to be communicated with lay-people. Thus, *Enjoyment* is a desirable component in science communication. The current study adopts *Enjoyment* as how current technology brings forth an enjoyable life experience.

2.3. Interest in Science

Interest is an intrinsic form of motivation [40], which can drive an individual to learn more about a topic of interest [41]. Research has shown that *Interest* has a great impact on learning processes. Adults and children invest more effort and attention when content interests them [42,43]. Specifically, *Interest* is always directed towards an object, activity, field of knowledge, or goal. Thus, *Interest* is distinct from one individual to another. An individual's *Interest* in science is explored through different subject areas or tasks [25,44,45]. Kurath proposed that interest may be the key to improving the public's understanding of science [46]. In addition to the three dimensions (i.e., conceptual, procedural, and affective paths) Jenkins proposed that to make sense of the progress of public understanding of science, *Interest* is a possible fourth dimension [47]. Guided by internal motivation, citizens can be motivated to voluntarily engage in science. From several definitions of *Interest* and for the purpose of the current study, we adopted *Interest* as a broader concept of one's general interest in science. The current study defined *Interest* as a desire that tends to result in involvement with or engaging in more scientific issues, events, or activities.

2.4. Opinions Formation

It is crucial for a literate person to hold some views, express their opinions, and make decisions on socio-scientific issues [48]. However, a person's opinions are very complex, and *strongly* linked with one's beliefs and perceptions [49], and can also be influenced by one's environment. Ball-Rokeach and DeFleur have shown that a majority of the public relies on information from the media as their primary source of information [50]. Beyond formal education in science, the media becomes the most accessible, available, and sometimes only source for the public to acquire information about scientific discoveries, controversies, events, and scientists' work [51]. In recent years, scholars have examined how mass media messages can influence the public's beliefs and perceptions of science and scientific issues. Scholars have examined dynamics such as how real-world exposure to science stories influences beliefs about science [52], how narrative structure may affect interpretation [53,54], and how the differences in various media affect public perceptions [51]. The media is a significant medium for science communication activities. In other words, science communication to some extent can be very effective when it is able to cause participants to form, reform or affirm their opinions regarding science and society. Therefore, *Opinion formation* can be seen as an important factor in influencing the public, and was defined in the current study as opinions or views formed in the public's reflection to support their own views toward certain scientific issues.

2.5. Understanding of Science

Miller proposed three aspects of understanding of science: (1) the comprehension of key scientific terms and concepts, (2) an understanding of the norms and methods of science (i.e., the nature of science), and (3) an understanding of the impact of science and technology on society [55]. Similarly, Jenkins uses the terms conceptual, procedural, and affective to describe public understanding of science [47]. *Understanding* of science is a multidimensional concept, which could and should be approached and measured from several different viewpoints. Among the mentioned aspects, measuring the understanding of contemporary key scientific terms from the public may be one approach to depict the understanding of science. Several studies have been conducted to measure civic understanding of science and individuals' basic core of conceptual knowledge about science. Lord and Rauscher used primary and middle school science textbooks and this conceptual core of scientific understanding as the starting point for their specific measurements [56]. Miller identified a set of basic constructs, which are intellectual foundations for reading and understanding contemporary issues [57]. Instead of using experts' selection of content to test for science understanding, Brossard and Shanahan used the 31 most frequently occurring scientific terms (from a list of randomly selected terms from a scientific dictionary, the Oxford Dictionary of Science) from media to construct a media-based understanding of science test [58]. Rundgren, Rundgren, Tseng, Lin, and Chang assessed understanding of science using the 50 most frequently occurring scientific concepts in both Taiwanese news articles and textbooks [59]. Thus, comprehension of contemporary key scientific terms can serve as a basis of literacy for a citizen and help develop understanding of science or further engagement in any scientific events. The current study defined *Understanding* as the comprehension of scientific knowledge obtained.

3. Methodology

3.1. Participants

This study sought to evaluate personal experiences with science edu-communication (SEC) by developing a 5-dimensional survey, namely based on AEIOU. The study collected survey data from 121 students during their early participation in two "liberal education" undergraduate classes at the same university (i.e., Environment and Communication: EC). The participants took the survey in the middle of the semester. The survey was not part of the assessment of the class. The purposes of the EC course varied but were mainly concentrated on comprehension of communication paths regarding environmental issues and science, with the goal of helping develop students' understanding of the role and functions of broadcast media in environmental education for the public; learning and understanding theories of communication; understanding and cultivation of media literacy and citizenship, etc. It was expected that students who took this course held some interest or intent to better understand science and communication. In order to achieve this goal, the EC course utilized a wide range of science communication activities, such as: lecture presentations, visits to science-related and communication-related associations, discussing science issues from the perspectives of the internet and broadcasting news, practicing science news writing, and appreciating science-related documentary or film.

The demographic information (gender, age, major, frequency of weekly media and internet usage, news reading frequency, and TV watching frequency) of the class was collected. As shown in Table 1, about 69.4% were female students and 30.6% were male students. Approximately 69.4% were sophomore and junior undergraduate students. A few interesting observations occurred, such as female students showed more interest in taking a course that discussed interdisciplinary issues involving science communication and the environment than male students did (69.4% to 30.6%) Non-science major students (75.2%) showed more interest in the course than science major students did (24.8%). More than 52% of the participants use media and internet daily, however, that did not necessarily indicate high frequency news reading (i.e., more than 3 quarters of the participants (77.7%) revealed only occasional news reading per week). Moreover, nearly 3 quarters (74.3%) of students revealed that they occasionally to rarely watch TV, which could suggest that students more frequently receive media content via the Internet rather than TV, and could use internet for purposes other than news reading. Table 1 provides descriptive statistics of the participants' demographic information.

Table 1. Demographic statistics.

Measure	Category	Number	Percentage (%)
Gender	Female	84	69.4
	Male	37	30.6
	Total	121	100
Age	Freshman	29	24
	Sophomore	54	44.6
	Junior	30	24.8
	Senior	7	5.8
	Super senior	1	0.8
	Total	121	100
Major	Non-science major	91	75.2
	Science major	30	24.8
	Total	121	100
Frequency of media and internet usage per week	Frequently (>6 days)	63	52.1
	Normally (4–6 days)	23	19
	Occasionally (1–3 days)	28	23.1
	Rarely (<1 days)	7	5.8
	Total	121	100
Frequency of news reading per week	Frequently (>6 days)	2	1.7
	Normally (4–6 days)	23	19
	Occasionally (1–3 days)	94	77.7
	Rarely (<1 days)	2	1.7
	Total	121	100
Frequency of TV watching per week	Frequently (>6 days)	15	12.4
	Normally (4–6 days)	16	13.2
	Occasionally (1–3 days)	42	34.7
	Rarely (<1 days)	48	39.6
	Total	121	100

3.2. Item Generation

In addition to collecting demographic information, a survey was designed to measure science edu-communication (SEC) perceptions (i.e., *Awareness*, *Enjoyment*, *Interest*, *Opinion formation*, and *Understanding*) [5]. Five-point Likert scale was utilized to measure the question items of the AEI constructs. The answer choices ranged from "Strongly disagree (1)" to "Strongly agree (5)". According to our approach to *Awareness*, "being aware of the importance of science and technology, and having a sense of the nature of science", and; *Enjoyment*, "how current technology may bring forth an enjoyable life experience to the users", we adapted items from a national-wide scientific literacy survey developed by Huang in Taiwan (see Table 2) [60]. For *Interest*, four items were developed to assess the "desire that tends to result in involvement with or engaging in more scientific issues, events, or activities".

Table 2. Question types of AEIOU and full question items.

AEIOU Dimensions	Number of Items	Question Type	Full Question Items
Awareness	6	Likert Scale	1. Although there might be less immediate benefit, basic research in science is necessary and should be supported by the government. 2. Science/technology has a lot to do with my daily life. 3. Science can help increase the quality of living environment for future generations. 4. The scientific knowledge that is now recognized may change or be eliminated in the future. 5. Researchers usually utilize diverse methods to study certain scientific issues. 6. The researcher's view of science can affect the interpretation of the phenomena he observes.
Enjoyment	3		1. Science and new technologies make my work more interesting (the definition of work is broad). 2. Advancements in science and technology allow me to fulfil things I want to do. 3. Science/technical inventions make my life happier.
Interest	4		1. I am eager to find more information when I encounter unfamiliar scientific content. 2. I habitually go find extra information after I watch science-related content. 3. I enjoy in exploring science as a habit. 4. I like to keep the time to attend popular science activities.
Opinion Formation	2	Open-Ended	1. What steps would you propose to assess Taipei's living conditions and environment? 2. Which is safer, a taller or shorter building, in the event an earthquake hits? Please describe and explain your response.
Understanding	4	Semi-Open-Ended with True-False	1. When the seismic wave propagates from the source, it will be destroyed by the terrain and the earthquake will be reduced. 2. The Da-Tune volcano is going stationary, and there is no possibility of eruption. 3. The main design concept of earthquake-resistant buildings is to strengthen the foundation. 4. Ocean acidification is caused by the acid pollutants emitted by the factory, which fall into the sea with precipitation patterns such as rain, snow and sputum.

In addition, *Opinion formation* and *Understanding* (i.e., O and U) were assessed using two and four question items, respectively. A framework, "Scientific Literacy in the Media (SLiM)", was used to generate O and U question items [59]. According to SLiM, biology issues (45.26%) were the most frequently appearing scientific concepts in Taiwanese media and textbooks, and earth science/natural disaster (37.9%) were the second most frequent. The present study skipped biology topics and administered two and four open-ended questions regarding O and U, respectively, eliciting opinions on earth science based on the premise that Taiwanese students would be more familiar with earth science related issues (i.e., earthquakes, typhoons, landslides, weather, and climate, etc.) than biology issues. For example, Taiwanese Central Weather Bureau indicates that (TCWB), on average, 26,686 earthquakes occur every year in Taiwan. In 1999, 49,928 earthquakes were recorded. In addition, TCWB reported that 3~5 typhoons attack Taiwan every year. These natural disasters have together caused severe damage to Taiwanese living conditions. As for constructs of understanding, the scale we utilized was a true-false question accompanied by semi-open ended questions. The purpose of this format was to require participants to express their thoughts with support and concrete rationale for their opinions and understandings to supplement "Opinion Formation" and "Understanding" data. The draft of the AEIOU-questionnaire was reviewed by two science education researchers for content validity and relevance.

3.3. Data Analysis

SPSS 21 statistical software was used to analyse the collected data. Specifically to determine the number of AEI factors, the researchers applied exploratory factor analysis (EFA) along with principal axis factoring analysis with Promax rotation. Next, convergent validity of the AEI scale was also examined using EFA. Convergent validity indicates that the variables within a single factor are highly correlated. This is evident by the factor loadings where variables should load significantly only on one factor. Therefore, it is best to have factor loadings greater than 0.5 for each factor. In addition, results from the Kaiser–Meyer–Olkin Measure of Sampling Adequacy (KMO) (0.782) and Bartlett's Test of Sphericity ($\chi 2$ (78) = 680.615, $p < 0.001$) indicated that the data was appropriate for factor analysis to proceed [61].

For the opinion formation construct, qualitative analysis was conducted to code open-ended answers under the categories of "Common concept" and "Scientific concept". Driver, Asoko, Leach, Scott, and Mortimer defined common concept as a range of knowledge schemes that were drawn to interpret the phenomena people encountered in their daily lives [62]. These were strongly supported by "Personal" experiences. On the contrary, scientific concept was invented and defined according to scientific and societal developments in the professional scientific community, and were unlikely to be discovered by individuals' own observations of the natural world. Based on the aforementioned, all the participants' open-ended responses were coded and numbered into "Common concept" and "Scientific concept" by two researchers with subsequent discussion on inconsistent results. These results were sent to a science educator for review of content validity, and the coding table was then formed (Table 3). The results were then used to calculate and compare the occurrences of "Common concept" and "Scientific concept" responses.

As for understanding dimension, four true/false questions were asked. In addition, the participants needed to explain their rationale when answering "false" (i.e., "false" and a correct explanation together were counted as one point). In order to improve reliability, item discrimination was examined using an Independent Samples *t*-test. We first scored each participant's test and ranked their scores. Next, the top 25% and the bottom 25% of students were separated for analysis [63]. Finally, SPSS Version 21.0 was used to run the Independent Samples t-test, with independent variables (i.e., 8 question items used for understanding) and dependent variables (i.e., top score and bottom score group). Significance levels adopted in this study are at the 0.05 level commonly used in educational research.

Table 3. Factor loadings and Cronbach's alpha values for AEI.

Item	Factor 1	Factor 2	Factor 3
Factor 1: Awareness (A)			
A 01	0.673		
A 02	0.602		
A 03	0.586		
A 04	0.763		
A 05	0.846		
A 06	0.564		
Factor 2: Enjoyment (E)			
E 01		0.637	
E 02		0.724	
E 03		0.838	
Factor 3: Interest (I)			
I 01			0.864
I 02			0.871
I 03			0.742
I 04			0.672
Eigenvalues	3.677	1.177	2.346
% of Variance	28.282	9.057	18.048
Cronbach's alpha (α)	0.824	0.766	0.865

4. Results

4.1. Exploratory Factor Analysis for AEI

Results indicated that the output 3-dimensional structure was consistent with the original three dimensions of A, E, and I (Table 3), and consisted of 13 question items (A: 6 items, E: 3 items, I: 4 items). To illustrate, the current analysis used a principal axis factoring analysis with Promax rotation to depict the factor structure. Eigenvalues were obtained for each factor. When the values obtained were greater than 1, the factors were considered representative [64]. Overall, AEI factors accounted for 55.39% of the total variance. The first factor, "Awareness", with an eigenvalue of 3.68, included six items (Cronbach's alpha = 0.82). The second factor, "Enjoyment", with an eigenvalue of 1.18, included three items (Cronbach's alpha = 0.77). The third factor, "Interest", with an eigenvalue of 2.35, included four items (Cronbach's alpha = 0.87). Table 3 shows the factor loadings after rotation. Each item meets the minimum criteria of having a primary factor loading of 0.5 or above, and not having cross-loading of 0.5 or above. Thus, the AEI scale was determined valid in the current study.

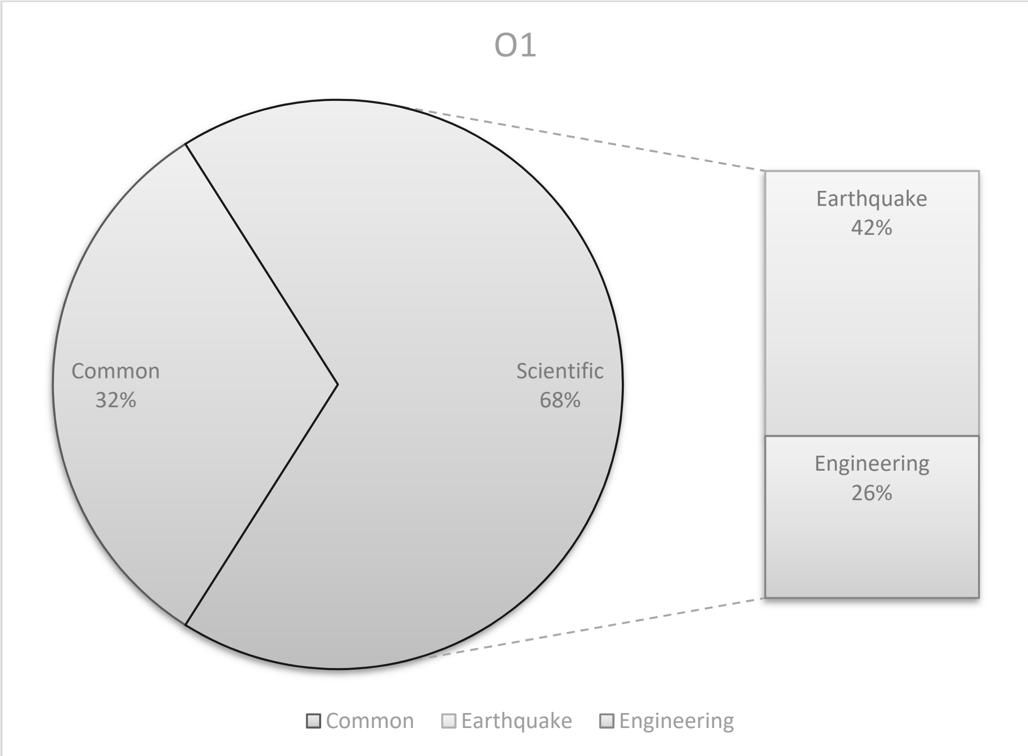
4.2. Coding Analysis for Opinion Formation

Table 4 shows the coding result of participants' responses in two opinion items. "Scientific concept" was categorized into five concepts: Engineering, Earthquakes, Natural disasters, Man-made disasters, and Geography. "Common concept" was categorized into three concepts: Security, Infrastructure, and Over-development. Each of these concepts corresponded to certain codes, extracted from participants' answers.

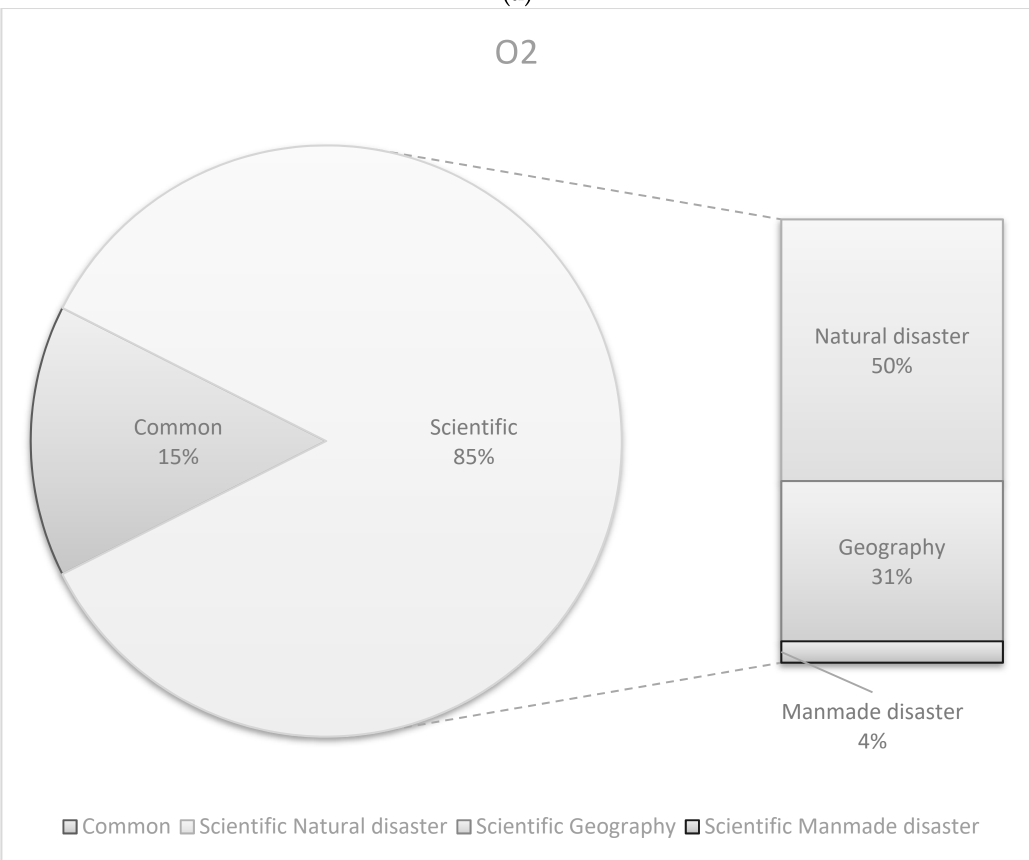
Opinions were coded as concepts, and the percentages of scientific vs common concepts indicated that participants emphasized scientific concepts more frequently than common concepts in this science communication experience. Figure 1a,b shows the ratio of scientific concept in two items at 68% and 85% respectively. Within the scientific concept, different concepts were identified and calculated in percentages. Earthquake concepts (42%), such as magnitude, intensity scale, and resonance effect, is the topic participants mainly refer to in the first question. In question number two, Natural disaster concepts (50%), such as typhoon, torrential rain, and debris flow disaster, are the main theme in participants' answers.

Table 4. The results of coding analysis opinions.

Type	Concepts	Codes	Items
Scientific	Engineering	1 Vibration control, 2 Structural steel	O1
	Earthquakes	3 Magnitude, 6 Seismic wave, 7 Resonance effect, Intensity scale	
	Natural disasters	5 Torrential rain, 9 Typhoon 2 Earthquake, 4 Volcano, 13 Debris flow disaster, 18 Tsunami, 16 Soil liquefaction	O2
	Manmade disasters	11 Urban heat island, 3 Nuclear power plant, 7 Industrial pollution	
	Geography	1 Basin, 7 Soft soil,14 Clammy weather	
Common	Security	1 Age of building, 3 Escape, 5 Feeling of vibration	O1
	Infrastructure	1 Defective drainage, 5 Soil and water conservation, 9 Anti-seismic construction	O2
	Over-development	2 High-rising buildings, 4 Population density, 6 Human activities, 8 Developed city	



(**a**)



(**b**)

Figure 1. (**a**) Percentage of opinion type and scientific concepts for O1 opinion items; (**b**) Percentage of opinion type and scientific concepts for O2 opinion items.

4.3. Independent Sample t-Test for Understanding

Table 5 illustrated whether there was a significant difference between the low and high score group for each understanding item. All items had a statistically significant difference (U1, t(60) = −9.837, $p \leq 0.001$; U2, t(60) = −7.194, $p \leq 0.001$; U3, t(60) = 11.898, $p \leq 0.001$; U4, t(60) = −4.464, $p \leq 0.001$), meaning each item passed item discrimination examination. As a result, the Cronbach's alpha for the four items was 0.608, suggesting that the items had acceptable internal consistency [64,65].

Table 5. Independent sample *t*-test between each understanding item and scores.

Items	Low Score Group (N = 35) Mean (SD)	High Score Group (N = 27) Mean (SD)	*t*-Test
U1	0.00 (0.00)	0.74 (0.45)	−9.837 **
U2	0.28 (0.46)	0.96 (0.19)	−7.194 **
U3	0.03 (0.17)	0.85 (0.36)	11.898 **
U4	0.00 (0.00)	0.37 (0.49)	−4.464 **

* $p < 0.05$, ** $p < 0.01$.

5. Discussion and Limitations

The survey from this study was administered to 121 students from Taiwan. "Awareness", "Enjoyment" and "Interest" constructs satisfied the conditions of reliability and validity as analysed through explanatory factor analysis, showing that the scale (SEC-AEIOU) is a valid and reliable instrument. The analysis revealed that the three-factor structure (AEI) accounted for 55.39% of the total variance, and the overall Cronbach's alpha of the scale was 0.82. Next, the primary factor loading of each item was 0.5 or above, which supported the three-factor structure. In terms of the "Understanding" construct, the results of the t-test indicated acceptable item discrimination, with an overall Cronbach's alpha of 0.61 for the scale.

As for qualitative analysis of opinion, the coding table (Table 4) was submitted to experts to confirm content validity. The amount of "Common concept" and "Scientific concept" present in participants' answers was then calculated and compared. The results implied that participants had successfully formed scientific concepts regarding earthquakes and natural disasters. This may result from participants' prior interest in taking the Environment and Communication course described in the study. However, this result could also be traced back to the influence of media and educational efforts in Taiwan, a country that encounters multiple natural disasters on a frequent basis (e.g., earthquakes, typhoons, volcanoes, and climate change). As a result, the concepts of earth science and natural disasters (37.9%) frequently appear in Taiwanese media and textbooks [59]. The assumption in our study that Taiwanese people should be familiar with earth science-related issues is consistent with what the participants revealed in their "Opinion" portion of the survey.

Specifically, in Taiwan, TV news helps audiences understand science and triggers discussion of scientific issues [66]. Earth science and natural disasters are usually discussed in Taiwanese news channels. According to Chen, weather news and broadcasts occupied 17.35% of TV programs from nine TV stations, second only to drama programs in 23.32% [67]. Participants have great opportunity to access information regarding earth science/natural disasters, and learn some scientific concepts from weather news and broadcasts. In addition, in 2004, the Ministry of Education in Taiwan issued the "White Paper on Disaster Precautions Education" to enhance curriculum involving natural disaster knowledge and precaution skills. Especially in the field of earth science, some outstanding science educational efforts have been carried out in recent years. A regional Quake-Catcher Network (QCN) server in Taiwan was built to promote citizen seismology [68]. Liang, Chen, Wu, Yen, and Chang operated the Citizen Seismologists in Taiwan Project (CSTaiwan), which was designed to make recorded QCN seismic data useful in classrooms, and to elevate the quality of earthquake science education [69]. The current study showed that participants have already formed earth science and natural disaster related scientific opinions, which to an extent reflects the positive outcome of current educational efforts in the field of earth science and natural disasters.

However, the results on Opinion were rather similar from participant to participant and tended to resemble each other. Other divergent perspectives or topics, such as earthquake engineering, man-made disasters, geography, etc. were rarely mentioned. The media should have the ability to frequently and prominently expose various perspectives to the public, so that audiences will consider other important issues for discussion [70]. In addition, the Taiwanese educational system mainly stresses learning material and content that are related to high school curriculums or university entrance examinations [71]. This phenomenon could be another reason for the limited range of opinions observed in the current study. Though critical opinions were aroused, it is still essential to discuss why other concepts were absent or went unmentioned, and deliver an appropriate strategy to craft a better science communication environment to learn from in the future.

While the science edu-communication scale using AEIOU constructs measures participants' experiences with science communication, it may also be directed to the participants' experience toward science education in a broader sense (i.e., citizen/public science education). Literature has recently increased attention towards research linkages between science communication and science education, emphasizing shared goals and avenues for collaboration [6–8,10]. Moreover, special editions of several journals or issues and the emergence of more journals (beyond *Public Understanding of Science* and *Science Communication*) have started to advocate for the need to research and practice science communication and science education together, such as: 2015 special issue on "*Bridging Sci. Educ. and Science Communication Research*" in *Journal of Research in Science Teaching (JRST)*; 2014 special issue on "*Understanding the Public Understanding of Science: Psychological Approaches*" in *Educational Psychologist*, the emergence of *International Journal of Science Education, Part B: Communication and Public Engagement* since 2011; *Journal of Science Communication (JCOM)* since 2002; *Journal of Science & Popular Culture* starting in 2017; and the emergence of *Public Communication of Science and Technology (PCST) Network*. These journals and mediums discuss the overlap of science communication and education and contribute to a similar goal.

Although various evaluations of the impact of informal science projects on scientific knowledge and attitudes have been published [72,73], most literature has been devoted to studying the context of science museums [74,75], zoos and aquariums [76,77], and other settings removed from the formal classroom. The need to develop an instrument to evaluate the current and increasing blend of science education and science communication is becoming more commonly discussed. The current study suggests that the AEIOU framework can be utilized to understand various science education and communication activities and the effects they have on individuals at a more granular level.

However, limitations due to the inconsistent format across the AEIOU items (i.e., AEI were in Likert scales, O in open-ended question, and U in true-false question), may result in lower applicability in different or more flexible circumstances and/or with larger amounts of participants. Moreover, it may hinder the capability of researchers in analysing all of AEIOU as a combination of "attitude" variables when conducting statistical procedures and generalizing the results. To improve this concern as further development of SEC scale, while the definition of "Opinion formation" is shaping, reconstruction, or reconfirmation of one's position toward certain scientific-related issues, we may transform content-specific open-ended question items in the current study to survey-type of items, such as "*I am used to have my own position in scientific-related issues*"; or "*I understand why there are different scientific reports in the media that are polarized or different in position*". As for "Understanding", while the definition is focused on understandings of the scientific procedure, personal preferences, content, or social factors involved in science communication, the true-false question items may be transformed to survey-type of items such as "*I can understand new scientific concepts or key terms based on today's science communication environment*"; or "*Science news or social media articles should demonstrate educational purposes*".

Additionally, since the scientific concepts in OU were formulated based on Taiwanese media and textbooks [59], it is recommended that further research be carried out using situationally based scientific concepts in appropriate domestic contexts. Furthermore, each AEIOU construct is not simply a single unitary construct, but rather consists of a large number of sub-constructs. Given that the major goal in the current study was to profile a framework for inclusive evaluation of science communication, the study mainly emphasized the larger scope of AEIOU rather than detailed sub-constructs. Further research may consider detailed sub-constructs as adding more value to the AEIOU dimensions of science edu-communication scale.

The present study sought to depict a picture of science communication outcomes from personal responses of awareness, enjoyment, interest, opinion formation, and understanding toward science. More importantly, this framework for science edu-communication (SEC) may be also considered as an effort to depict public understanding toward how science and technology can contribute to human and environmental sustainability. It may serve as a starting point for science communicators, educators, and institutions to develop a systematic and standardized evaluation procedure, and improve the quality of future and current science communication activity and evaluation. It is hoped that the proposed AEIOU construct may provide an educational metric of benefit to the field of science education in a broader scope (citizen/public science education). In other words, this construct hopes to support a robust framework to facilitate the trend of bridging science communication and science education.

Author Contributions: All authors contributed to the paper. Data curation, Formal analysis, Investigation, Methodology, L.Y.W., S.P.W., Funding acquisition, C.-Y.C., L.Y.W.; Project administration, C.-Y.C., L.Y.W.

Funding: This work was supported by the Ministry of Science and Technology, Taiwan under Grant "106-2511-S-033-010-MY2". This work also financially supported by the "Institute for Research Excellence in Learning Sciences" of National Taiwan Normal University (NTNU) from The Featured Areas Research Center Program within the framework of the Higher Education Sprout Project by the Ministry of Education (MOE) in Taiwan.

Conflicts of Interest: The authors declare no conflict of interest.

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