Doctoral Dissertation

Shibaura Institute of Technology

Perceptions of Colored Pictograms for Communication in Factory Emergencies

March 2019

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Perceptions of Colored Pictograms for Communication in Factory Emergencies

BY

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

IN THE
FUCTIONAL CONTROL SYSTEMS
GRADUATE SCHOOL OF ENGINEERING AND SCIENCE
SHIBAURA INSTITUTE OF TECHNOLOGY

MARCH 2019

Declaration of Authorship

I, Suopor HIRANCHIRACHEEP, declare that this thesis titled, “Perceptions of Colored Pictograms for Communication in Factory Emergencies,” and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at Shibaura Institute of Technology.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at Shibaura Institute of Technology or any other institution, this has been clearly stated.
- Where I have consulted the published work of other, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.

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(Suopor HIRANCHIRACHEEP)

Date: _____

Abstract

Pictograms are very useful for communication, not only with those who speak different languages but also with an environment in different job ranks. In many manufacturing settings, companies have implemented warning pictograms to ensure they don't get any accidents or/and to get much higher production efficiency. Therefore, Comprehension of warning pictograms has become an important indicator of safety measures.

This study examined the effects of cultural and educational background factors on the comprehension of coloured pictograms for emergency situations in manufacturing environments. Pictograms should promptly communicate particular conditions to people who may not share a common language. The author designed coloured pictograms for such manufacturing tasks as push, step, and turn and then present them to factory workers having different cultural and educational backgrounds. A questionnaire survey was conducted to identify the behaviour patterns of subjects viewing seven differently coloured pictograms: white, black, red, yellow, green, blue, and pink. Questionnaire responses were obtained from 138 worker subjects, where the instructions were expressed in their native languages from three different countries: Thailand, Myanmar, and Cambodia. Moreover, the questionnaire was presented to 80 Japanese students and 178 Thai students in English instructions.

The author also analysed the data using one-way ANOVAs among seven colours for each pictogram and T-tests among pairs of worker groups for each colour to determine the culture and education differences. A statistical analysis of the results showed that educational background was statistically significant for some colours but not for all colours.

The author identified a statistically significant difference between educational and cultural backgrounds. Thus, my results show that differences in the interpretation of the meaning of coloured pictograms were more affected by educational backgrounds than by cultural differences. The interpretations of the lowest-educated groups were different from those of the high- educated ones. My results suggest that factory managers need to provide comprehensive on-the-job training on signs posted in factories, in particular to low-educated employees. Workers should be given explicit instructions about the links between safety functions and pictogram colours.

“Education is one of the country's most important jobs. Either prosperity or deterioration of a country depend mainly upon the citizent's education. Hence, the strenghtened education is indeed needed.”

His Majesty King Bhumibol Adulyadej

The Great king of Thailand

Acknowledgments

I realize that the fulfillment of Ph.D. task is a collective effort, which involves the guidance, cooperation, support and. Dozens of people have helped and encouraged me immensely. I would like to sincerely express my appreciation to all people who have made this dissertation possible. I'll never forget what they've done for me.

It is with immense gratitude that I acknowledge the support and help of my supervisors, Prof. Atsuko K. Yamazaki, Ph.D. (Main-charge) who continually and convincingly conveyed a spirit of adventure in regard to research and performance a professional lecturer. She, especially, assisted me overcome many crisis situations and give me the opportunity to achieve a better life. Definitely, this dissertation would not have been accomplished without her. She still contributed and extended her valuable assistance to achieve in a memorandum of understanding (MOU) between Shibaura Institute of Technology (SIT) and Nakhon Ratchasima Rajabhat University (NRRU).

Moreover, my deepest thanks and appreciation to Prof. Hiroshi Hasegawa, Ph.D. (Sub-charge) advise me how to succeed this research. I would like to extend my gratitude to the rest of my dissertation committee: Prof. Masahiro Inoue, Prof. Kazunori Mano and Prof. Vichai Saechout for their insightful comments. I am appreciatively indebted to them for their very valuable comments even at during their difficult times.

I owe my deepest gratitude to committees and the president of NRRU who allow me to get educational leave under the financial support by human resource development scholarship of NRRU. In my experience as a Ph.D. Student, I'm certain that my ability can be an asset to NRRU. I am honored as Ph.D. Student at Shibaura Institute of Technology (SIT)

for spending four years. I had a chance to study with great and kind professors until I will get certificate of sub-major. Moreover, I had work experiences with international friends in an international environment and with people from all over the world. Their friendship and good humor which had made my life much more enjoyable. In the future, I would bring my good skill learnt by SIT system to my job at NRRU and become a great supervisor to my students.

I am grateful to Mr. Chitapong Wechtaisong, Ms. Sarunya Kanjanawattana and Ms. Tipporn Laohakangvalvit for their kindly guidance, generousness, help and friendship that I needed. In particular, I thank Diversity Communication Laboratory members and admirable working atmosphere of this laboratory, Thai friends in SIT or Thailand. I would also like to thank all the participants for their cooperation in my research. In addition, I still get positive attitude to be a good person in order to create excellent stories from Mr. Palitchoke Ayanaputra as role models.

Last but not least, I would like to thank my family for supporting me spiritually throughout completing this dissertation. They did not only allow me to follow my dreams, but also motivate me to control my destiny. I realize from my family that everyone has their own struggles and own fights. Sometimes hurt is needed to make me grow.

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Chapter 1

Introduction

This chapter introduces stimulant that convince me to propose this doctoral dissertation which entitled “Perceptions of Colored Pictograms for Communication in Factory Emergencies”. This chapter also presents background of communication gaps at workplaces Furthermore, I will show problem statements which will be investigated and determined that this dissertation provides. Finally, summary of this chapter and an organization of this dissertation will be described.

1.1 Motivation

Many companies have increased their global manufacturing production and moved such facilities to countries with lower labour costs to achieve optimal total cost. Under such circumstances, employees from various cultural and language backgrounds often work in teams, especially in manufacturing settings in Southeast Asian countries. It is a sub region of Asia, roughly be described as geographically situated east of the Indian subcontinent, south of China and north of Australia, between west of the Indian Ocean and the east of Pacific Ocean. Southeast Asian country is composed of eleven countries of impressive diversity in religion, culture and history: Brunei, Burma (Myanmar), Cambodia, Timor-Leste, Indonesia, Laos, Malaysia, the Philippines, Singapore, Thailand and Vietnam. Figure 1.1 illustrates the statistical data of immigration data in Thailand from 2014 to 2017. A blue line in the line graph represents as the number of migrant workers from Myanmar. An orange line represents the number of migrant workers from Cambodian. The total number of migrant workers for Myanmar and Cambodian presents as a green line. Based on the statistical data, the trend of foreign workers migration was up dramatically, especially in 2017. The number of migrant workers from Myanmar was much higher than the number of migrant workers from Cambodian since 2014.

Many problems have been reported, especially those associated with language communication gaps at workplaces, such as an increase in the number of accidents, product defects, and delivery delays. According to Eurostat, 3,515 fatal and 2,487,794 non-fatal accidents involving the loss of at least four calendar days from work occurred in the multilingual European Union in 2012 [1]. One major cause is communication problems among co-workers from different language backgrounds or at varying job ranks. Factory workers often have to cooperate with people from diverse cultural and language backgrounds [2]. Therefore, high-quality communication is necessary to adhere to correct production procedures toward meeting manufacturing objectives and achieving high levels of productivity. This is also an important element in ensuring effective responses to emergency situations in factories.

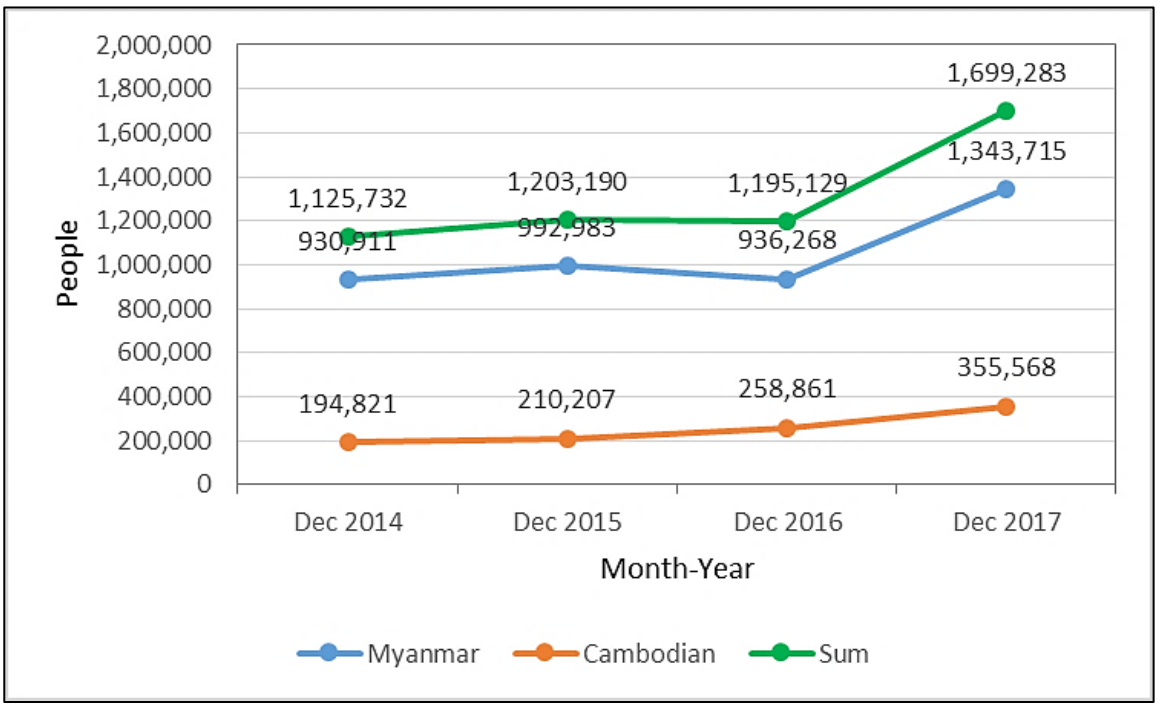


Figure 1.1 Number of migrant workers from Myanmar and Cambodian in Thailand

1.2 Problem statement

In actual workplaces, an organization's entire staff must comprehend the identical meaning of coloured signs to prevent injuries or to be clearly informed of possible danger. The meaning of a coloured pictogram that shows a required action in a factory emergency must be clearly understood by every single worker and manager, despite the workforce having different linguistic, cultural, or educational backgrounds. Therefore, coloured pictograms must be designed by taking into account a variety of culture- and education-based perceptions of colours and actions. In this study, the author developed new pictograms in different colours that clearly convey the meanings of operations required for emergency situations in manufacturing settings. The author focused on the perception of importance for actions expressed by coloured pictograms and investigated how different educational levels as well as the cultural differences of staff members affected subjects' actions based on their perceptions of the depicted operations.

1.3 Objective

The purpose of this dissertation is to investigate the importance given by students and workers to the actions (push, step, and turn) represented by the seven coloured pictograms (white, black, red, yellow, green, blue, and pink) and to determine whether cultural backgrounds or educational levels affect the perceptions of the coloured pictograms in conveying procedures for emergency situations in manufacturing environments.

1.4 Structure of this dissertation

This dissertation consists of seven chapters including this chapter. The following are an organization of dissertation which explains structure of each remaining chapters from Chapter 2 to Chapter 7, which are organized as illustrated in Figure 1.2.

Chapter 2 presents literature reviews of existing researches in signs/pictograms, cultural difference, people with low education, and workers with lower education in manufacturing settings in safety field which are beneficial to contribute this dissertation. This survey is very necessary to achieve the dissertation goals.

In Chapter 3, overall questionnaire of pictograms for required actions and surveying with workers. It describes common actions to guide workers.

Chapter 4 presents results from respondents who were working at factory in Thailand and studying in Japan or Thailand.

Chapter 5 presents the statistical analyses on the data obtained from the survey. To examine whether the degree of importance given to each pictogram differed based on the three actions represented by the pictograms. Then, we analysed the differences in the degree of importance among the seven colours and finally tested each colour between the subject groups by t-tests to determine the culture and education differences.

Chapter 6 presents the discussion of this dissertation which discusses what this dissertation researched, evaluated, found, as well as solved. Furthermore, this chapter also discusses the new finding from this dissertation.

Chapter 7 presents the conclusion of the dissertation which summarizes all of dissertation processes from the first step until the last one including the motivation to purpose the dissertation's topic, the dissertation goals, the design, and statistical analyses. Finally, future work are explained.

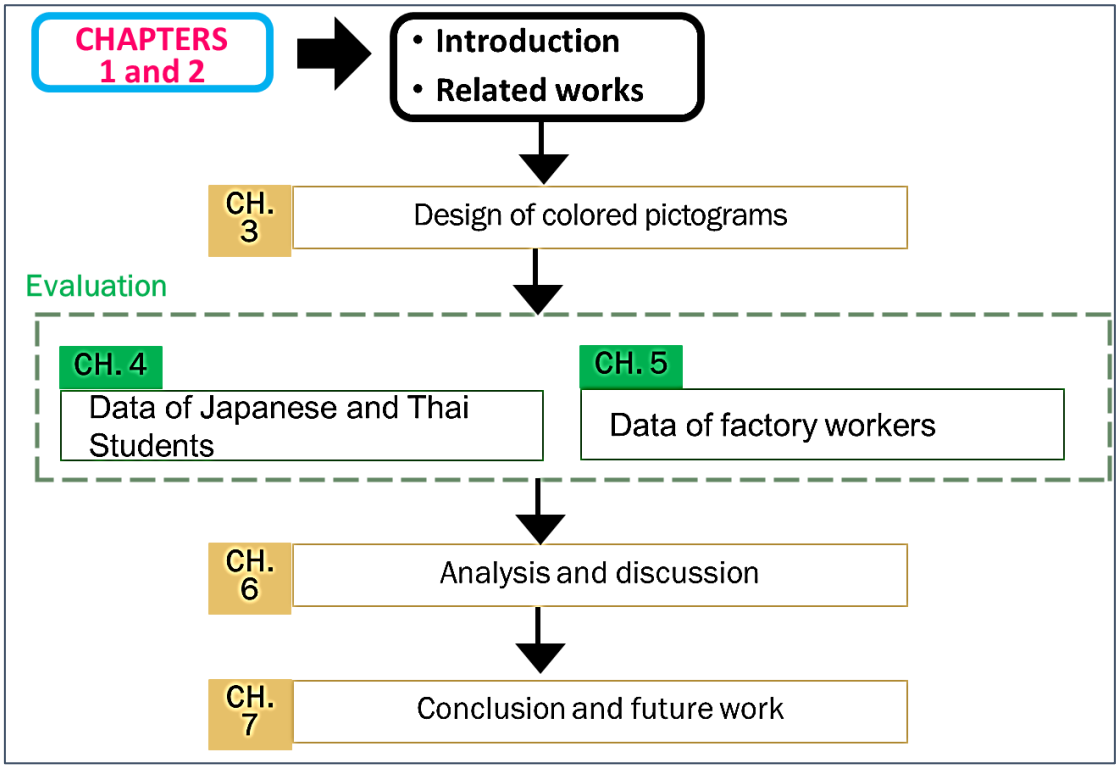


Figure 1.2 Structure of this thesis

Chapter 2

Related Works

2.1 Introduction of pictograms

Pictograms are believed to originate from prehistoric cave paintings and ancient hieroglyphics. Pictograms are non-verbal communication symbols representing commonly associated concepts. They are prevalently used as a visual communication tool to convey information and messages instantaneously. Such non-verbal communication is very useful, especially in emergency situations or when verbal communication is not possible [3] [4]. Icons and marks used in computers and electronic devices are also classified as pictograms. They are sometimes referred to as “signs” or “symbols.” All of them are collectively referred to as “graphical symbols” by the International Organization for Standardization (ISO) and as “pictorial symbols” by the (JISC) [5]. In addition, symbols called “ideograms” are used

to represent a particular idea or concept. In many cases, however, all graphical and pictorial representations that are used to convey information and messages are referred to as "pictograms."

Pictogram Ideogram Communication (PIC) is the most famous set of communication icons. It was developed by Subhas Maharaj [6], a Canadian speech therapist, to support communication for people with difficulties in oral and/or written communication. These PIC symbols were also published in Japan in 1995 after they were adapted to communication in Japanese. PIC symbols have been widely used and studied as a communication support tool for children with disabilities. They have also been used in online chatting between children speaking different languages [7]. Another example of pictograms developed for communication support is a set of approximately 300 symbols created in accordance with the Design Principles of Pictorial Symbols for Communication Support (JIS T0103), established by Japanese Standards Association (JSA) 2005 . While most of the JIS T0103-certified symbols represent objects and places, about 15 percent represent actions and movements in Figure 2.1. Some of them even express emotions. They are among those included in the JIS Design Principles of Pictorial Symbols for Communication Support.

Figure 2.1 Pictograms for described actions in morning situations: in the morning, wake up, wash a face, and brush teeth.

The principles of using colour in safety signs and pictograms have been developed. The principles of using colour in safety signs and pictograms have been developed by such organizations as the International Organization for Standardization (ISO), the Japanese Industrial Standards Committee (JISC), and the Industrial Accident Prevention Association. ISO 7010 prescribes design principles incorporating shapes and colours for safety signs. In these principles, red, yellow, blue, and green are respectively used for prohibitions or fire equipment, warnings, mandatory directions and escape routes, and safety conditions, as shown in Table 2.1 and Table 2.2 [8] [9].

According to the standards determined by JISC, red symbols denote "prohibited" or "stop" messages [10] (Figure 2.2). Although these colour standards have been incorporated in sign standards for creating pictograms at organizations and factories, pictograms drawn in red, yellow, and green still convey different meanings, which have not been united standards at many workplaces, are shown in Table 2.3 [11] [12] [13] [14] [15] [16] [17] and Table 2.4. In addition, there are similar pictograms in emergency situation of International standards for safety signs: ISO 7010 in Table 2.5 [9].

Figure 2.2 Safety pictograms of Public Information Symbols [10]

Table 2.1 Design principles of each type of International standards for safety signs: ISO 7010 [8]

Type of Sign	**Shape**	**Design**	**Pictogram**
Prohibitive Action/Equipment which are prohibited	Circular	Black pictogram on white background with red border and diagonal line	
Warning These signs give warning of potential risks	Triangular	Black pictogram on yellow background with black border	
Mandatory A course of action which must be taken	Circular	white pictogram on blue background	
Escape routes And safety equipment	Rectangular or Square	white pictogram on green background	
Fire Equipment Location of fire fighting equipment	Square	white pictogram on red background	

Table 2.2 Examples of Safety sign, reference number and referent of International standards for safety signs: ISO 7010 [9]

Category				
E	**F**	**M**	**P**	**W**
Evacuation route, location of safety equipment or safety facility, safety action	**Fire equipment signs**	**Mandatory action signs**	**Prohibition signs**	**Warning signs**
 **E001** Emergency exit (left hand)	 **F001** Fire extinguisher	 **M001** General mandatory action sign	 **P001** General prohibition sign	 **W001** General warning sign
 **E002** Emergency exit (right hand)	 **F002** Fire hose reel	 **M002** Refer to instruction manual/booklet	 **P002** No smoking	 **W002** Warning; Explosive material
 **E003** First aid	 **F003** Fire ladder	 **M003** Wear ear protection	 **P003** No open flame; Fire, open ignition source and smoking prohibited	 **W003** Warning; Radioactive material or ionizing radiation
 **E004** Emergency telephone	 **F004** Collection of firefighting equipment	 **M004** Wear eye protection	 **P004** No thoroughfare	 **W004** Warning; Laser beam

Table 2.3 (a) Similar pictograms have not been incorporated in sign standards on internet [11] [12] [13]

Meaning	Pictograms	URL
Emergency call point		https://borehamwood-signs.co.uk/collections
Fire door		https://signmaker.blog/2018/08/09/fire-safety-signs-does-it-apply-to-me-and-my-business/
Fire exit		https://www.shutterstock.com/image-vector/green-safety-sign-vector-emergency-exit-150066827?irgwc=1&utm_medium=Affiliate&utm_campaign=Eezy%20Inc&utm_source=38919&utm_term=www.vecteezy.com

Table 2.3 (b) Similar pictograms have not been incorporated in sign standards on internet [14] [15] [16] [17]

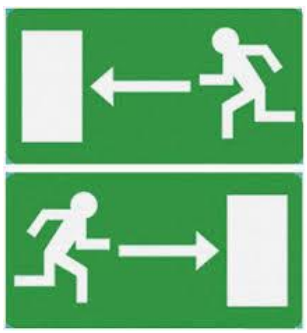
Meaning	Pictograms	URL
Fire extinguisher		https://www.riigiteataja.ee/en/eli/518112015005/consolide
Emergency telephone		https://www.riigiteataja.ee/en/eli/518112015005/consolide
Emergency exit		https://pixabay.com/en/output-exit-emergency-exit-note-476122/
Fire escape exit sign		https://www.indiamart.com/proddetail/fire-escape-exit-sign-9845496333.html

Table 2.4 Bottom for stopping Emergency on internet [18] [19] [20] [21]

Pictograms	URL
	https://www.linecad.com/emergency-stop-push-button/
	http://www.zerosigns.co.uk/shop/safety-signs/health-and-safety/emergency-stop-green/
	https://stickerart.com.au/showproduct-emergency-stop-button-symbol.html
	https://www.yeint.fi/en/electronics/switches-1/rotary-switches/emergency-stop-sticker-oe60mm

Table 2.5 Similar pictograms of International standards for safety signs: ISO 7010 [9]

Meaning	Pictograms
Emergency stop button	
Emergency telephone	
Fire alarm call point	
Fire emergency telephone	

Furthermore, pictograms are used to communicate medication instructions. These are other examples of using pictograms when verbal communication is not effective [22] [23], especially for improving comprehension of people with low literacy, the elderly and children [24] [25] [26] [27] .The use of pictograms for communication and information provision is prevalent. They are used not only as support tools for people with disabilities and public information, but also to represent various hazards, such as on labels of agricultural or other chemicals [28] [29] [30]. Although pictograms are seldom used to show procedures in manufacturing setting, pictograms for manufacturing processes can convey meanings effectively and comprehensibility without relying on language. Pictograms are often

regarded as effective means of communication at companies where many workers from various countries and different cultural backgrounds work, since they can be used to improve occupational risk prevention at manufacturing sites. Therefore, many health and safety training or educational programs for employees at manufacturing companies include learning about pictograms and signs. Yamazaki and Taki indicated that well-designed pictograms for an action combined with the object conveyed meaning effectively, where safety and productivity are significant [31]. Hiranchiracheep el al. examined the effects of educational and cultural backgrounds on colored pictogram instructions in terms of behavioral perception for actions in manufacturing. The results showed a significant difference among groups with different educational backgrounds [32].

There have also been studies conducted on how to use pictograms to show the parameters of special analytical instruments [33] [34] [35] [36]. As the use of pictograms is spreading, an increasing number of studies are being conducted to review them, not only in terms of their shapes but also in terms of their colors and presentation methods, so that they can be used universally [37] [38] [39]. In a study by Waterson et al. they gathered evaluation data from more than 200 young children to evaluate new safety pictograms [37]. Through the summative assessment of the effectiveness of the new pictograms, particularly in an example of formative evaluation, they outlined a useful set of guidelines for designing safety signs for young children.

2.2 Cultural difference

According to some previous studies, cultural differences affect the interpretation of pictograms. Cho examined [40] cross-cultural differences in pictogram interpretations by people from United States and Japan. She suggested that cultural difference in pictogram interpretations could be used as an agent construction basis based on human provided interpretations. She proposed detecting method of cultural differences in cross-cultural pictogram interpretations automatically. During calculation, bilingual dictionaries and thesaurus were included to extract bilingual pairs of the two countries' interpretation words. There were bold lined pictograms as 18 of 30 pictograms are assessed to have some cultural differences (Figure 2.3).

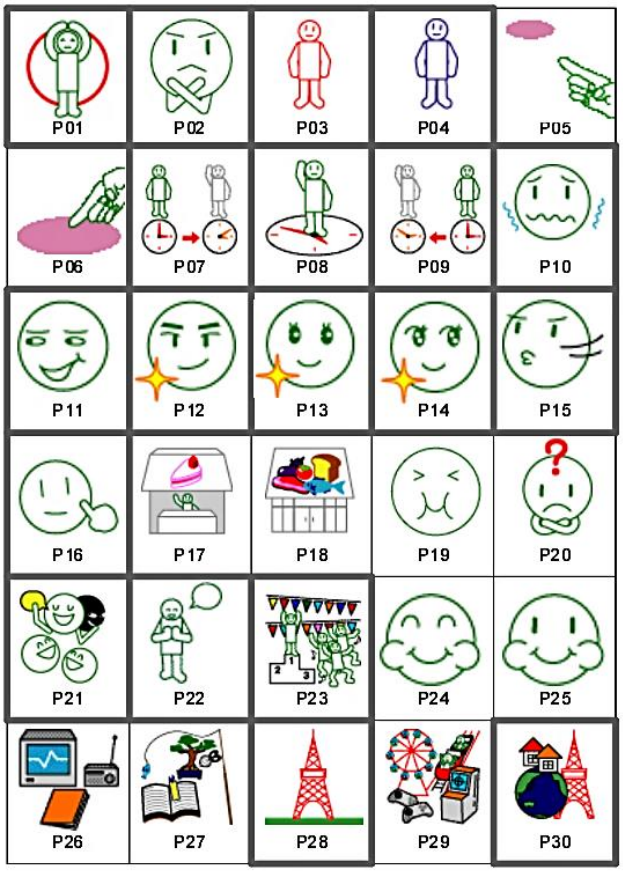


Figure 2.3 Thirty pictograms questioned for cultural differences [40]

Piamontea et al. [34] evaluated cultural differences in the interpretation of graphical symbols. Their results obtained from American and Swedish subjects indicate that there were differences in pattern ratings between two nationality groups and the differences may be culturally linked. The test method used three sets of icons and pictograms representing seven referents or functions of the videotelephone (Figure 2.4).

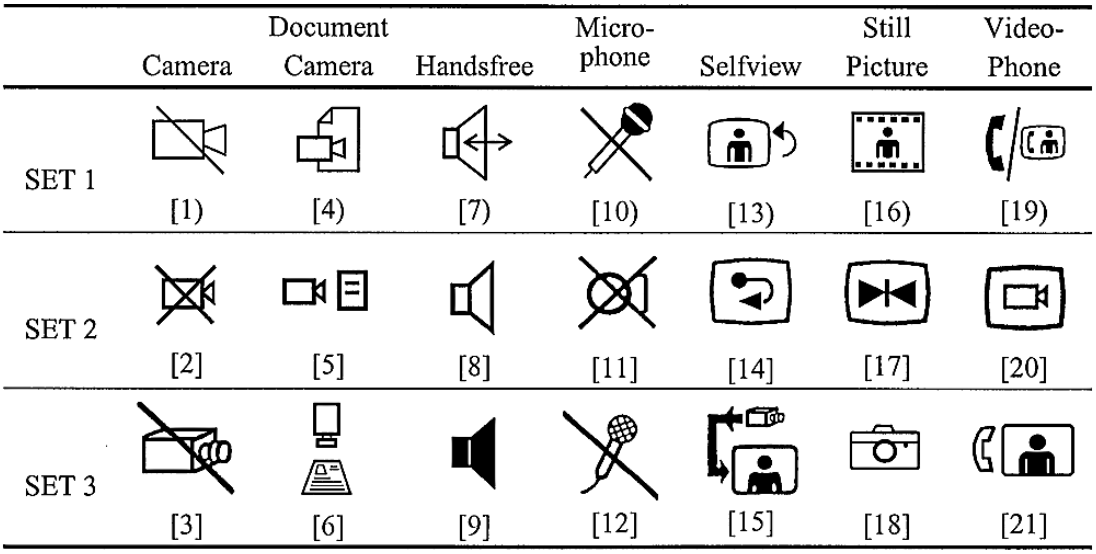


Figure 2.4 Icons and pictograms representing seven referents or functions of the videotelephone [34]

However, the results in this study show that differences in the interpretation of the colored pictogram meanings were more affected by educational backgrounds than cultural differences. In actual workplaces, an organization's entire staff must comprehend the identical meaning of coloured signs to prevent injuries or to be clearly informed of possible danger. The meaning of a coloured pictogram that shows a required action in a factory emergency must be clearly understood by every single worker and manager, despite the workforce having different linguistic, cultural, or educational backgrounds. Therefore, coloured pictograms must be designed by taking into account a variety of culture- and education-based perceptions of colours and actions.

2.3 People with low education

2.3.1 Adults with low education

The studies of medication pictograms have focused on elderly patients with low literacy who display declining cognitive abilities and memory. Therefore, the comprehension of pictograms can assist in the care of the elderly in order to establish methods to convey medication instructions. Among the studies on the comprehension of medication pictograms, those conducted by Mansoor and Dowse [22] and Dowse and Ehlers [41] are particularly well known. Both studies assessed the effectiveness of pictograms in showing how to take and store medicines in African countries with low literacy rates. The results suggested that the US-designed pictograms that had been deemed effective were not interpreted in the same way in South Africa and that medication pictograms would need to be designed with consideration of cultural context. Knapp et al. [42] examined whether the medication pictograms used in South Africa and the US could be understood by patients in the UK. The results showed that for both the US and South African versions, only three of the 10 pictograms were understood by more than 85 percent of the subjects. Meanwhile, Cho [40] developed rather complicated pictograms by themselves and showed them to subjects, some US nationals and some Japanese nationals, to analyze the differences in their interpretations. The results indicated that different cultural backgrounds could cause different interpretations of pictograms.

Meanwhile, Shimizu et al. [43] studied the use of pictograms to convey medication instructions in Japan. Their study examined whether the pictograms of medication instructions added on medicine bags could facilitate the understanding of the information, and found that medicine bags with instructions both in text and pictograms increased comprehension among more than 60 percent of the subjects. Patients aged 60 years and over appreciated the pictograms more than younger ones. Based on these studies, the Risk/Benefit Assessment of Drugs – Analysis and Response (RAD-AR) Council, a voluntary association consisting of pharmaceutical companies in Japan, published medication pictograms in 2004. They aimed to explain proper medication use in a way that everyone, including children and elderly people, could understand. The medication pictograms developed by the RAD-AR Council were intended to be displayed on medication instruction sheets provided along with

prescriptions. As of 2006, a total of 51 pictograms had been developed. Some pictograms were combined to illustrate medication instructions.

Figure 2.5 Medication pictograms developed by the RAD-AR Council [44]

Kheir et al. [24] developed and evaluated comprehension of medicine label instructions in a culturally diverse multiethnic population with low literacy skills. Participants were randomized to one of three study groups: text plus verbal instructions, pictogram-only label, and pictogram with verbal instructions. The results showed that the pictogram with verbal instructions group achieved better comprehension. Van Beusekom [27] examined 10 pharmaceutical pictograms and identified how the design could be improved for understandability by low-literacy patients in the Netherlands. Thirty adequately literate and 25 low-literate participants (assessed with the Dutch version of the

Rapid Estimate of Adult Literacy in Medicine: REALM-D) were asked to verbally explain the meaning of each pictogram. The results of the study indicated that adequately literate participants could more easily understand pictograms than people with low literacy. Five pictograms of the adequately literate group and two pictograms of the low-literacy group reached 67% understanding for the ISO cut-off. Designing pictogram characteristics should focus on familiarity, simplicity, and showing the intake and effect of medicine.

The United States Pharmacopeia Convention (USP) developed 81 pharmaceutical pictograms as 'standardized graphic images that help convey medication instructions, precautions and/or warnings to patients with a lower level reading ability and patients for whom English is a second language. The USP pictograms have been tested for comprehension by Ng et al. [26]. They examined comprehension of USP pictograms for older Hong Kong residents (65 and above). The first group was presented with text labels and another group with the text labels plus supplementary pharmaceutical pictograms. This study showed that older people favored the addition of pharmaceutical pictograms to written text for conveying medical information. Zargarzadeh and Ahamdi [45] investigated the understandability of three pictograms selected as most applicable by participants and their recall after educational mini-sessions. The groups with lower levels of literacy had more difficulty interpreting them than those with a high level of literacy.

2.3.2 Children with low education

To develop pictograms as an effective communication tool, it is essential to examine whether they are easy for the target group to understand. In particular, children's curiosity and a lack of experience and knowledge is critical to easily understand the pictograms in an instant. Lin et al. [46] investigated four- to six-year-old preschool children and aimed to identify how they understand warning pictograms (signs, frames, and colors). They used a questionnaire to determine children's understanding of warning pictograms and color; and an interview was conducted with the subjects to verify the extent of their comprehension. The results showed that children had stronger recognition of "Palm" among all warning pictograms (Palm, Cross, Oblique Line, Skull, Exclamation Point), stronger recognition of "Triangle Frame" among all warning frames (Triangle Frame, Circular Frame, Diamond

Frame, Octagonal Frame, Inverted Triangle Frame), and stronger recognition of the color "Red" among all warning colors (Orange, Red, Green, Blue, Black). In addition, they associated them with familiar objects. Waterson et al. [37] analyzed various designs for safety signs and accident rate data on board trains for children (aged five-10). The result showed that posters and labels were given a blue background and the colour yellow was used for the background text in order to maximize the contrast between pictures and text as requested by the children. Moreover, to reinforce good behavior and the safety characters, the characters were always put on the "good" circle and never overlapped with pictograms highlighting bad behavior.

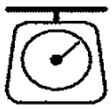
Figure 2.6 Good behavior and the safety characters of various designs for safety signs [37]

Korenevsky et al. [39] recruited adolescents (aged 12-18) from the volunteer organization of the Children's Hospital of Eastern Ontario (CHEO) in Ottawa, Ontario, as well as from a youth organization at the hospital to identify the common graphic elements for defined categories of pictograms and identify the key graphic elements common to all pictograms. For all 21 pictogram categories, at least 80% of survey respondents agreed that the storyboard conveyed the intended meaning. The result indicated that the context in which pictograms are presented is important to their correct interpretation. Categories had few preferred pictograms such as "take with an empty stomach", "take one tablet", or "do not take if breastfeeding".

2.4 Workers with lower education in manufacturing settings

Migrant workers in a factory often have to cooperate with colleagues who have diverse culture and language backgrounds. Therefore, pictograms can be used to enhance swift communication without conversing in the same language, where safety and productivity are critical. Yamazaki and Taki [47] investigated the comprehension of pictograms in manufacturing settings for actions such as 'cut', 'push' and 'measure'. Their comprehensibility was examined by Questionnaires A and B. Questionnaire A contained pictograms with objects of intended actions, and Questionnaire B had pictograms without objects. The results indicate that well-designed pictograms for an action combined with an illustration of an object can be used effectively in manufacturing settings. In addition, pictograms showing use of a tool for actions such as cutting and measuring tended to be comprehended more correctly and spontaneously. Hiranchiracheep et al. [32] examined the effects of educational and cultural backgrounds on colored pictogram instructions (push, step and wheel) in terms of behavioral perception. Pictograms in seven different colors (White, Black, Red, Yellow, Green, Blue and Pink) were used in the survey with three different countries (Thailand, Myanmar and Cambodia). Results showed significant difference among groups with different educational backgrounds. This suggests that educational background may have more effect on the interpretation of colors used in pictograms than cultural background.

Table 2.6 pictograms for an action combined with an illustration of an object [47]

Pictogram meaning	Cut	Scale	Push	Call	Hit	Step
(a) With the object						
(b) Without the object						

2.5 Discussion

The first advantage of pictograms is that a graphical representation focused only on the necessary information can be understood intuitively and instantly; however, there may also be a disadvantage. Excessive filtering of information and oversimplified representations may cause confusion [48]. Another advantage of pictogram communication is that information can be easily understood by anyone, regardless of language, culture, or age. Neither prior knowledge nor education is required to understand pictograms. This is why graphical symbols are used for the public. However, pictorial symbols often vary across countries and societies. This is because cultural context and individual cognitive performance affect the interpretation of symbols and icons [22] [40] [41] [42]. Moreover, some pictograms can be used only in certain cultural spheres (Mori 2006). For example, the International Federation of Red Cross and Red Crescent Societies (IFRC) has two different emblems, one for Christian societies and one for Muslim societies [48]. United States Pharmacopeial Convention (USP) [49] pictograms are the most widely used and studied pictograms in the healthcare domain, but eventually they turned out to be slightly different from those used in other countries. These examples indicate that it is difficult to create a truly universal icon that can be used regardless of cultural context [5].

The American National Standards Institute (ANSI) as the American standard and the International Organization for Standardization (ISO) as the European standard have been developed to mitigate this issue [50] [51]. They have laid a foundation for the JIS-certified public information symbols. However, these ANSI, ISO and JIS standards cannot be applied to many pictograms. The uniform design principles set for public information symbols by the ISO Technical Committee on Graphical Symbols cannot eliminate regional differences [5]. The study conducted by Kostelnick on the influence of cultural context on the comprehension of pictograms and pictographs indicated that the proper selection of information signs would depend on the familiarity of the symbols included in the signs to people in that culture as well as the complexity of cultural backgrounds of the target group, particularly when applying pictograms to children.

Tzeng et al. also assessed the recognition of pictograms from a psychological perspective. The results suggested that the test subjects preferred pictogram designs similar to those traditionally used in their home countries. Many other studies also showed that people's comprehension of pictograms could be greatly affected by their familiarity with the symbols and symbolic elements included in the pictograms. Therefore, it is thought that each pictogram should be carefully examined as to whether it will be easily understood by the target group in the intended situation

2.6 Conclusion

The use of pictograms enhances illiterate populations' comprehension, including people with low health literacy, children and workers with lower education. Some of the reviewed studies about the use of pictograms for health education point out that pictograms can be very effective when they are used in combination with written or oral instructions. The author found only a few articles on the use of pictograms in manufacturing settings, compared to the existence of many studies on the use of pictograms to educate people for health and medical purposes. This gap in the literature underlines the need for more research in this area to provide a more comprehensive approach to pictograms in manufacturing settings, in particular situations where swift and reliable information transfer is needed, such as in dealing with an accident.

In this study, the author developed new pictograms in different colours that clearly convey the meanings of operations required for emergency situations in manufacturing settings. The author focused on the perception of importance for actions expressed by coloured pictograms and investigated how different educational levels as well as the cultural differences of staff members affected subjects' actions based on their perceptions of the depicted operations.

Chapter 3

Design of Colored Pictograms

3.1 Designing pictograms

In this study, the author focused on the common actions used in response to emergencies in factories. The author chose three typical actions: push a button, step on a pedal, and turn a handle. These actions are often taken to stop a machine, reduce a vehicle's speed, or loosen/tighten a valve. The author developed three pictograms for these common actions to guide workers in performing these tasks. Yamazaki and Taki demonstrated that pictograms for actions are comprehended better when they include an object along with a part that represents an action (a 'verb' part), compared to those without an object. Therefore, the author designed pictograms that consist of a verb part and an object part for the action. Accordingly, the push pictogram has a hand, an arrow, and a button, while the step action is represented by a foot, an arrow, and a pedal. Likewise, an arm & hand, an arrow, and a

handle denote the turn action. Pictograms for taking actions are usually represented by black symbols or black lines, but the author used other colours for the parts of the pictograms that represent the verb of the action in order to investigate the effects of colour on the subject's perception of the importance of the action. Figure 3.1 shows the basic, uncoloured pictograms for actions in emergency situations at factories.

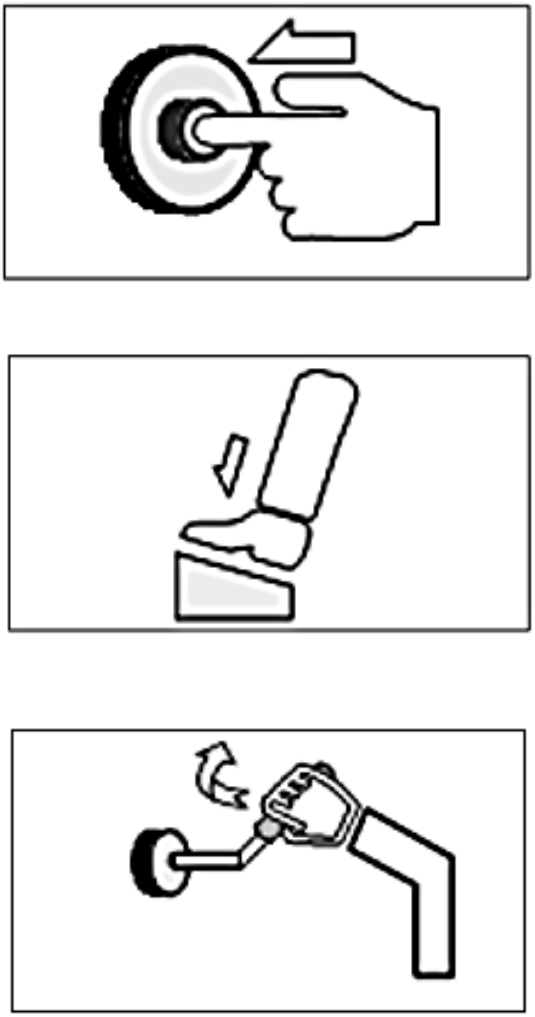


Figure 3.1 Uncoloured pictograms for required actions in emergency situations: push a button, step on a pedal, and turn a handle

3.2 Choosing color

From the principles of using colour in safety signs and pictograms, the principles of using colour in safety signs and pictograms have been developed by such organizations as the International Organization for Standardization (ISO), the Japanese Industrial Standards Committee (JISC), and the Industrial Accident Prevention Association. ISO 7010 prescribes design principles incorporating shapes and colours for safety signs. In these principles, red, yellow, blue, and green are respectively used for prohibitions or fire equipment, warnings, mandatory directions and escape routes, and safety conditions [8] [9] . Moreover, pink signs are appeared online as emergency sign [52] [53].

Therefore, the author chose seven colours for the action parts of each pictogram: white, black, red, yellow, green, blue, and pink. Other parts of the pictograms were drawn in black. Consequently, the author created a set of seven differently coloured pictograms for each action. Figure 3.2 shows each coloured pictograms for push actions in emergency situations at factories.

3.3 Designing questionnaires

To examine how effectively coloured pictograms can convey the importance of the action represented by each pictogram, the author created a questionnaire that evaluated the degree of urgency felt by subjects for the actions represented by differently coloured pictograms. A part of the questionnaire is shown in Figure 3.2. The author conducted surveys to evaluate how much importance is conveyed by each coloured pictogram and to verify how workers' cultural backgrounds or educational levels affect the perceptions of pictograms in terms of the importance of procedures during emergency situations.

Figure 3.2 Coloured pictograms for required actions of push a button (in white, black, red, yellow, green, blue and pink)

3.3.1 Web-based questionnaires

The author created an online questionnaire to collect the data for analysis as follows.

1. Introduction in the first section, the author described this survey: objective and how to (Figure 3.3).

2. Questions of personal information in the second section, subjects were asked as follows (Figure 3.4).

- gender and age
- What is your type of industry or business?
- What is your job category?
- What is your final education?
- What is your nationality?
- What's your current country of residence?
- What is your native language?

3. Each coloured pictograms for actions in the third section (Figure 3.5), subjects were asked how effectively coloured pictograms can convey the importance of the action represented by each pictogram as follows (Figure 3.4).

- How much do you think it is important to push?
- How much do you think it is important to step?
- How much do you think it is important to wheel?

4. After finishing all section, participants submitted their questionnaires

Table 3.1 Option answer for question of "What is your type of industry or business?" and "What is your job category?"

What is your type of industry or business?	**What is your job category?**
• Agriculture and forestry/Fishing industry/Mining • Construction/Architecture/Civil engineering • Machinery-related manufacturing • Materials and chemical-related manufacturing • Electrical and electronics-related manufacturing • Other manufacturing industries • Electricity supply • Gas and water supply • Information and communication industry • Transportation industry • Wholesale/Retailing • Finance/Insurance • Real estate business • Restaurant/accommodation • Medical care/Welfare • Education/Learning support • Other services • Public service • Others (Please specify)	• Account Manager • Administration • Building Operator • Business Development • Consultant/Contractor • Customer Service • E-Commerce • Engineering • Executive Management • Facilities Manager • Finance/Accounting • HR/Recruitment • Journalism • Legal • Logistics • MIS / IT • Application Developer • MIS / IT - Data Center • MIS / IT - Operations • MIS / IT - Security • MIS / IT - Storage • MIS/IT – Telecommunication • Manufacturing • Marketing Manager • Marketing, PR, Advertising • Network Management • Operations / Administration • Operations / Administration-Security • Operations Manager • Property Owner • Purchasing / Procurement • Research / Development • Sales • Sales Manager • Technical Support • Training / Education • Real Estate Management • Others (Please specify)

Table 3.2 Option answer for question of “What is your final education?”, “What is your nationality?”, “What's your current country of residence?”, and “What is your native language?”

What is your final educational level?	**What is your nationality? and What's your current country of residence?**	**What is your native language?**
1. Junior high school student	Japan	Thai
2. Junior high school graduate	Thailand	Malay
3. High school student	Malaysia	Filipino
4. High school graduate	Philippines	Vietnamese
5. University or College student	Vietnam	Indonesian
6. University or College graduate	Indonesia	Cambodian
7. Master's course student	Cambodia	Lao
8. Master's course graduate	Laos	Tamil
9. Graduate doctoral student	Singapore	Chinese
10. Graduate School of doctoral graduates	China	Brazilian
	Brazil	Portuguese
11. Others (Please specify)	Others (Please specify)	Others (Please specify)

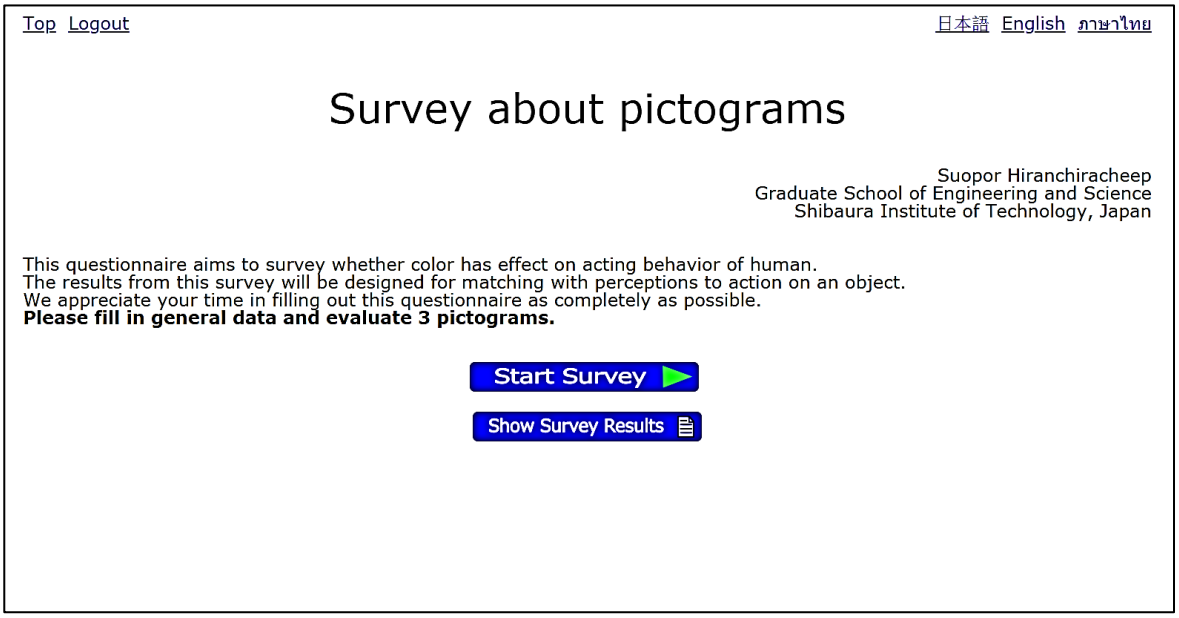


Figure 3.3 Introduction in the first section of the online questionnaire

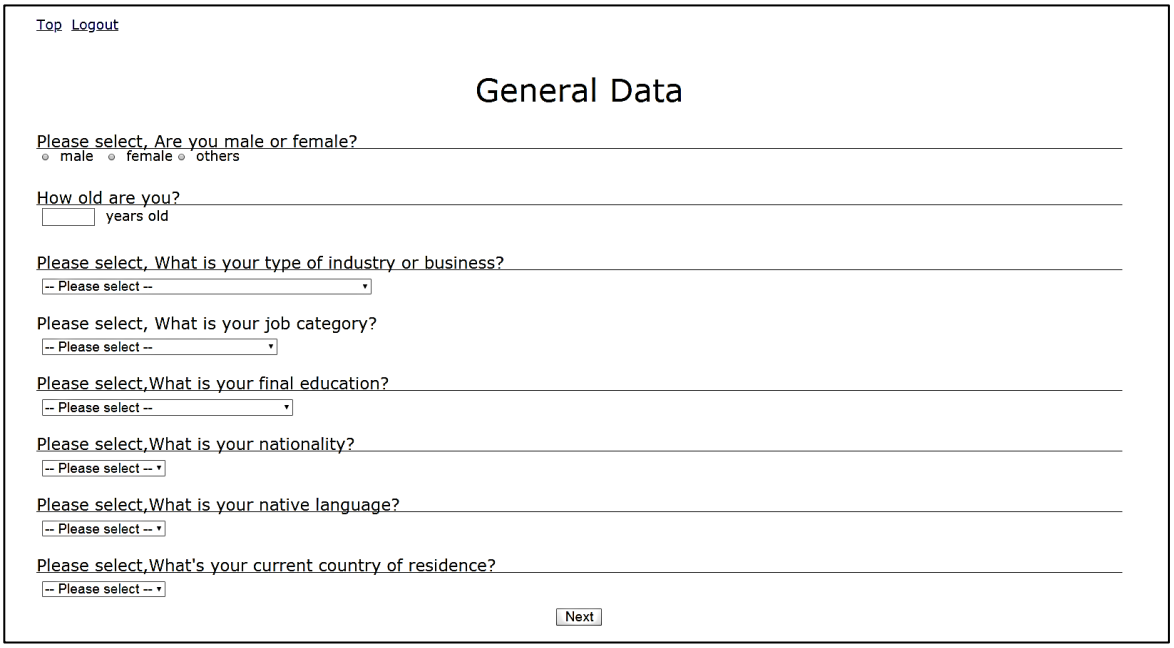
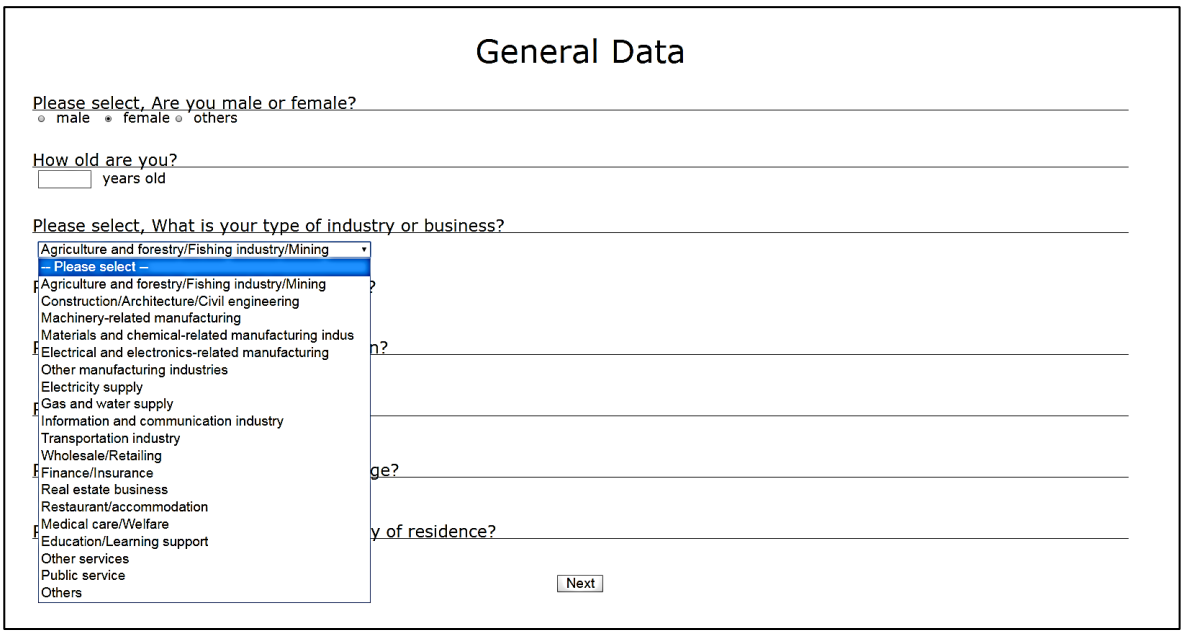
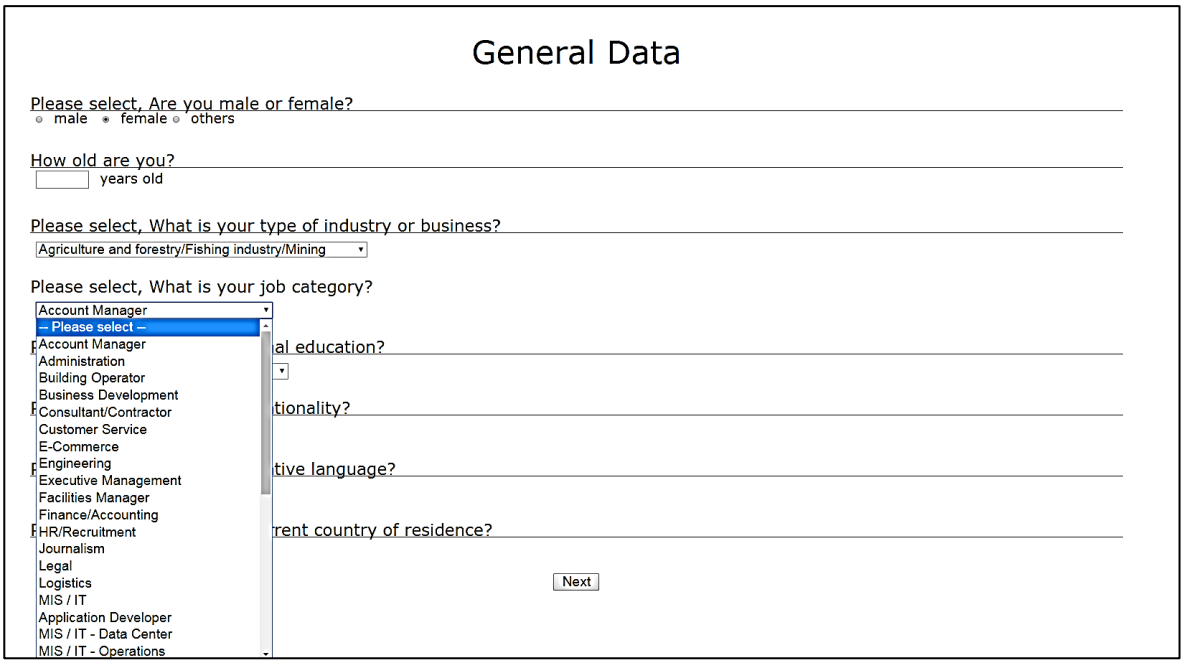


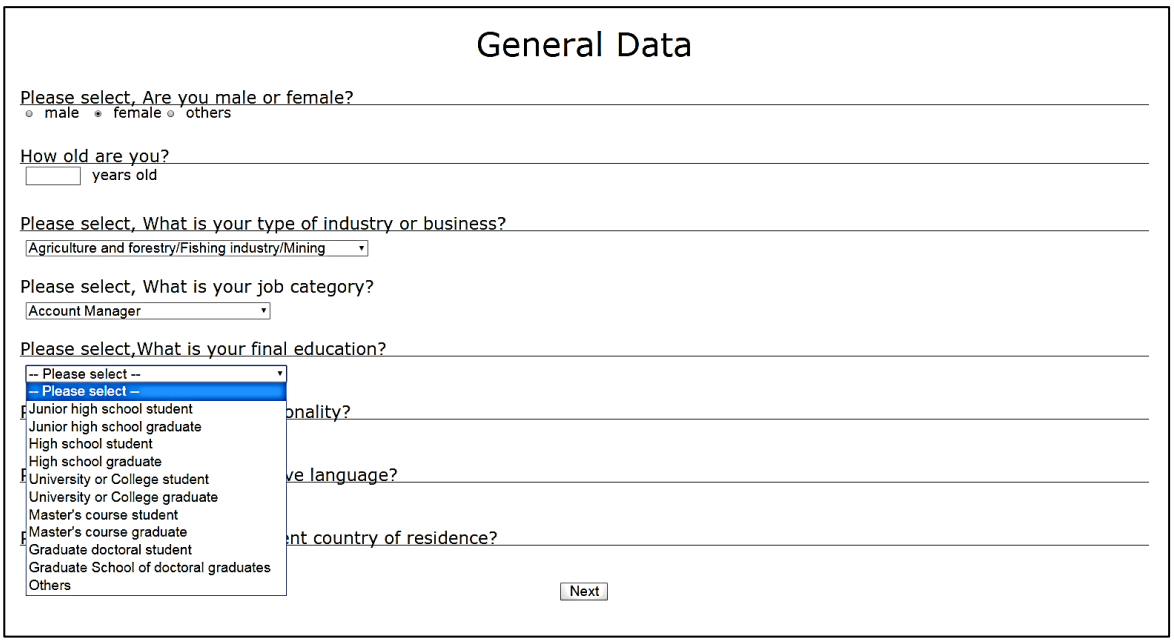
Figure 3.4 Questions of personal information in the second section of the online questionnaire



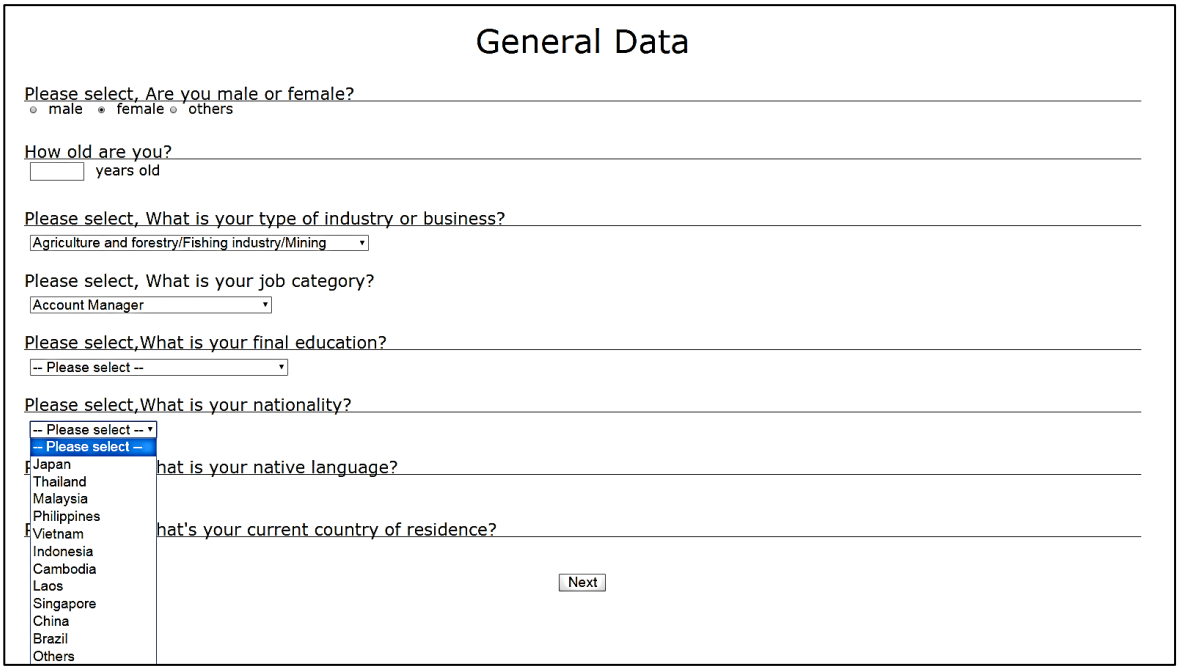
(a) Dropdown menu of industry type or business type



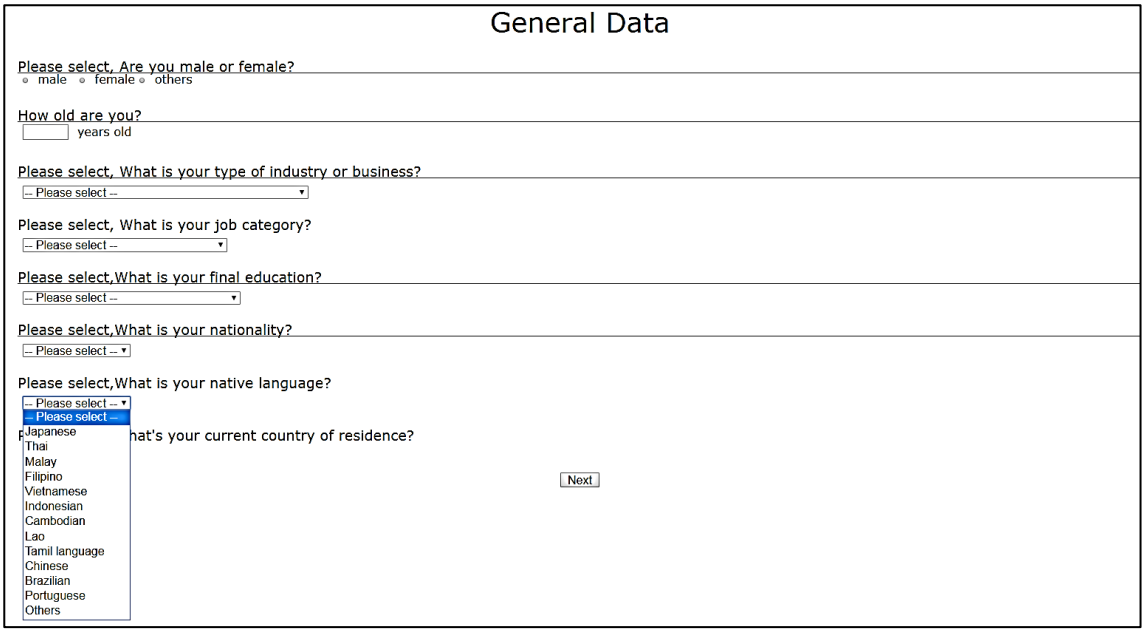
(b) Dropdown menu of job category: major



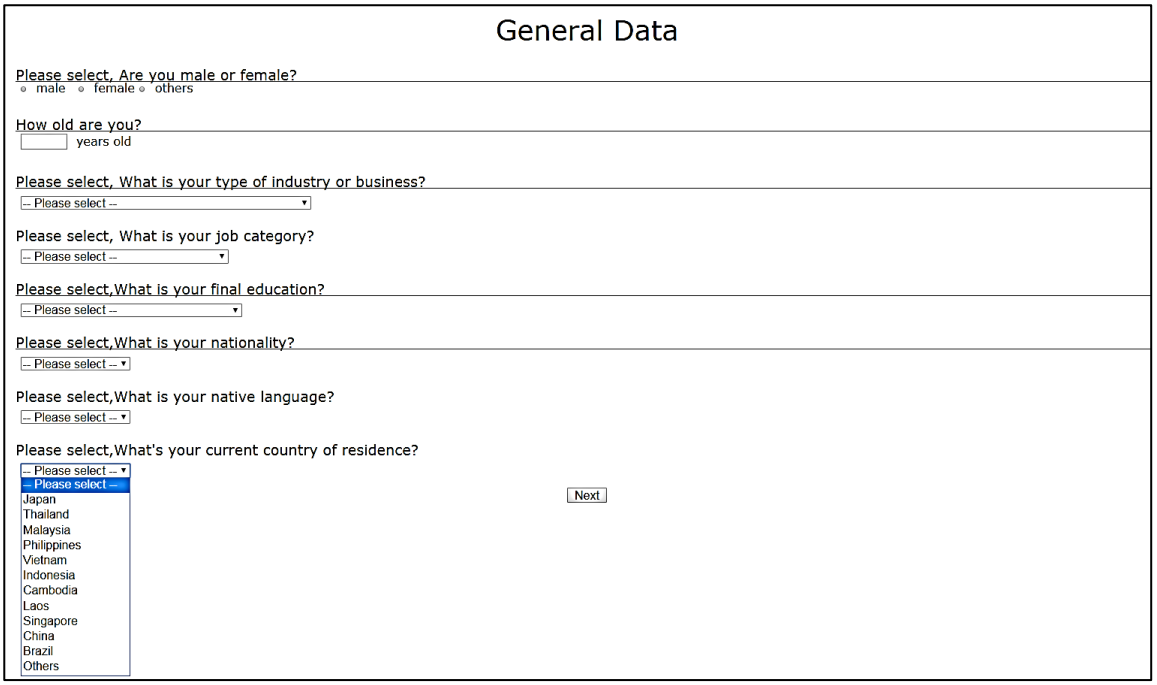
(c) Dropdown menu of education



(d) Dropdown menu of nationality

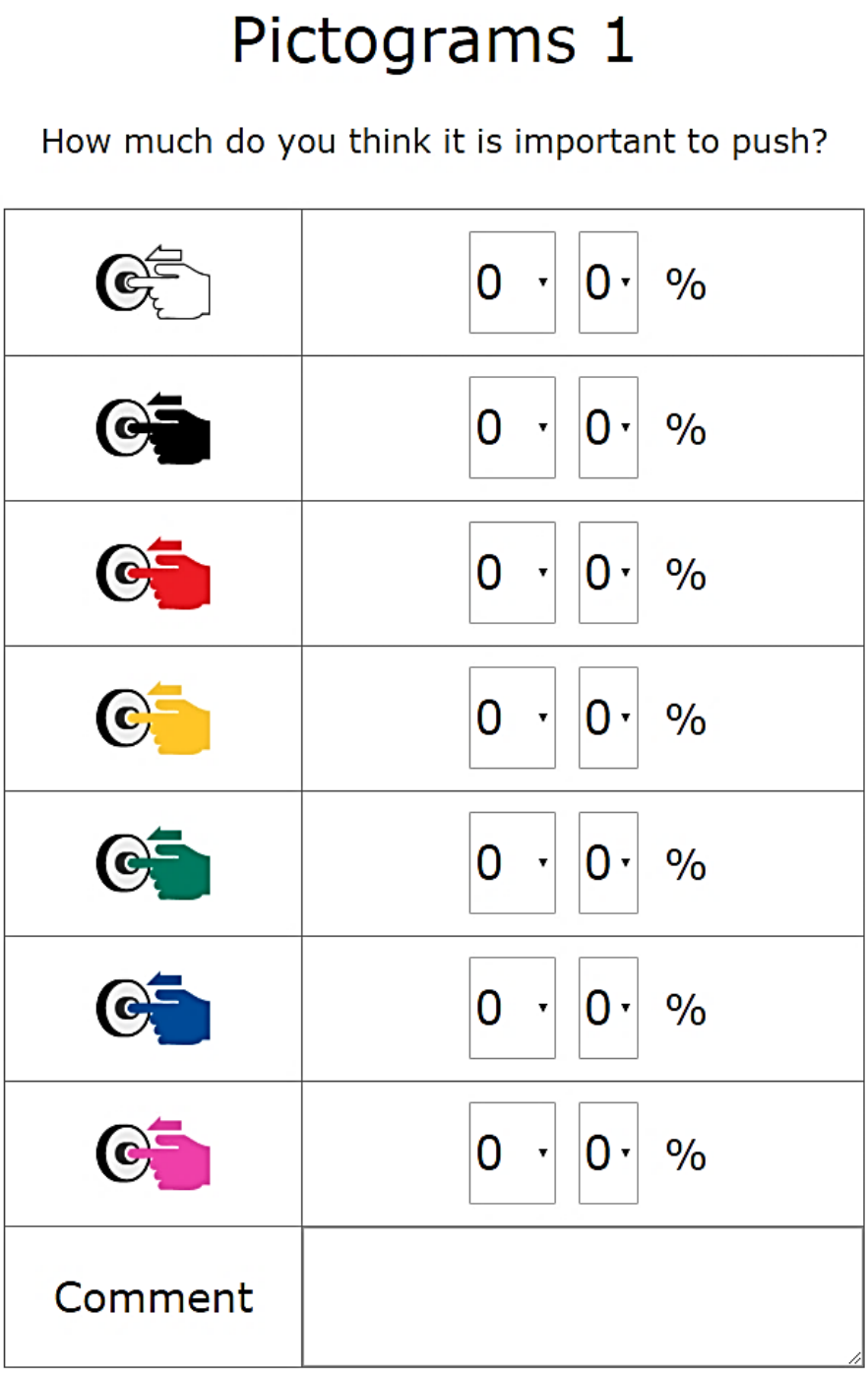


(e) Dropdown menu of native language

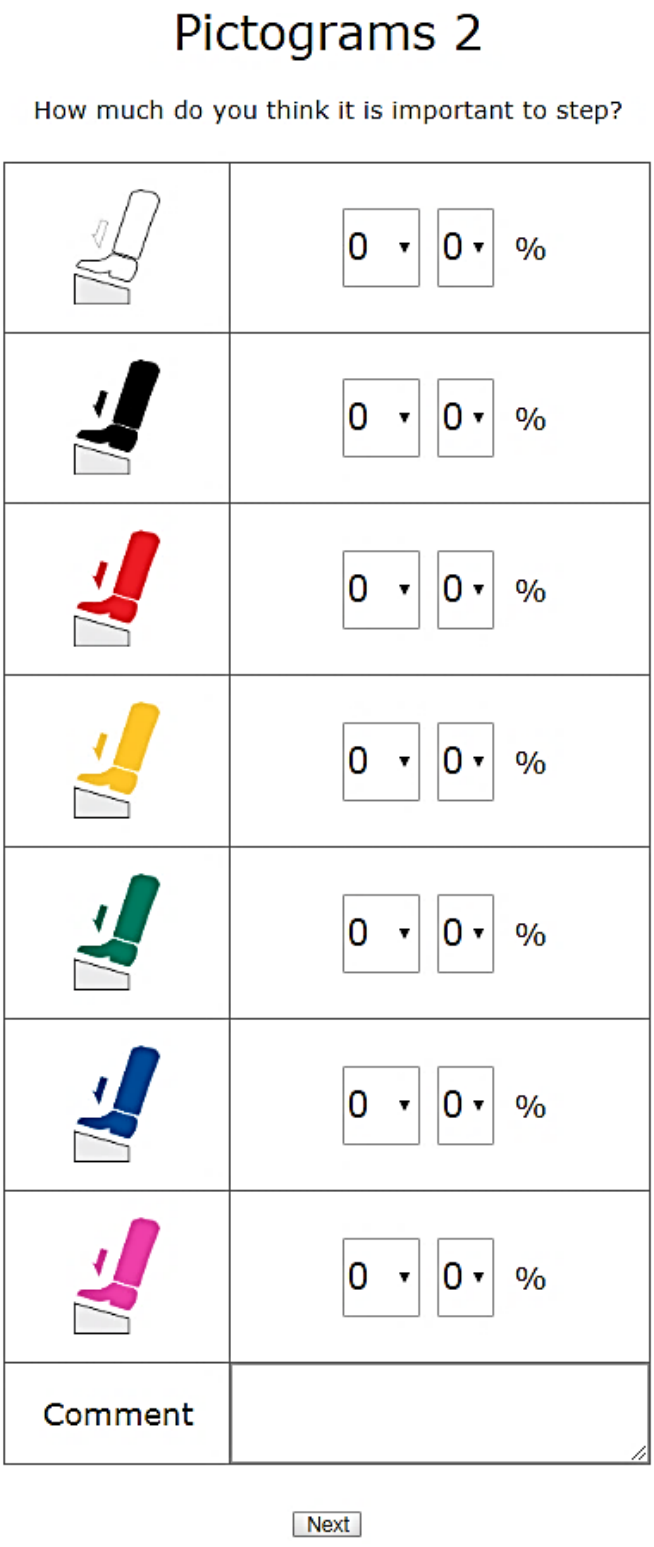


(f) Dropdown menu of current country of residence

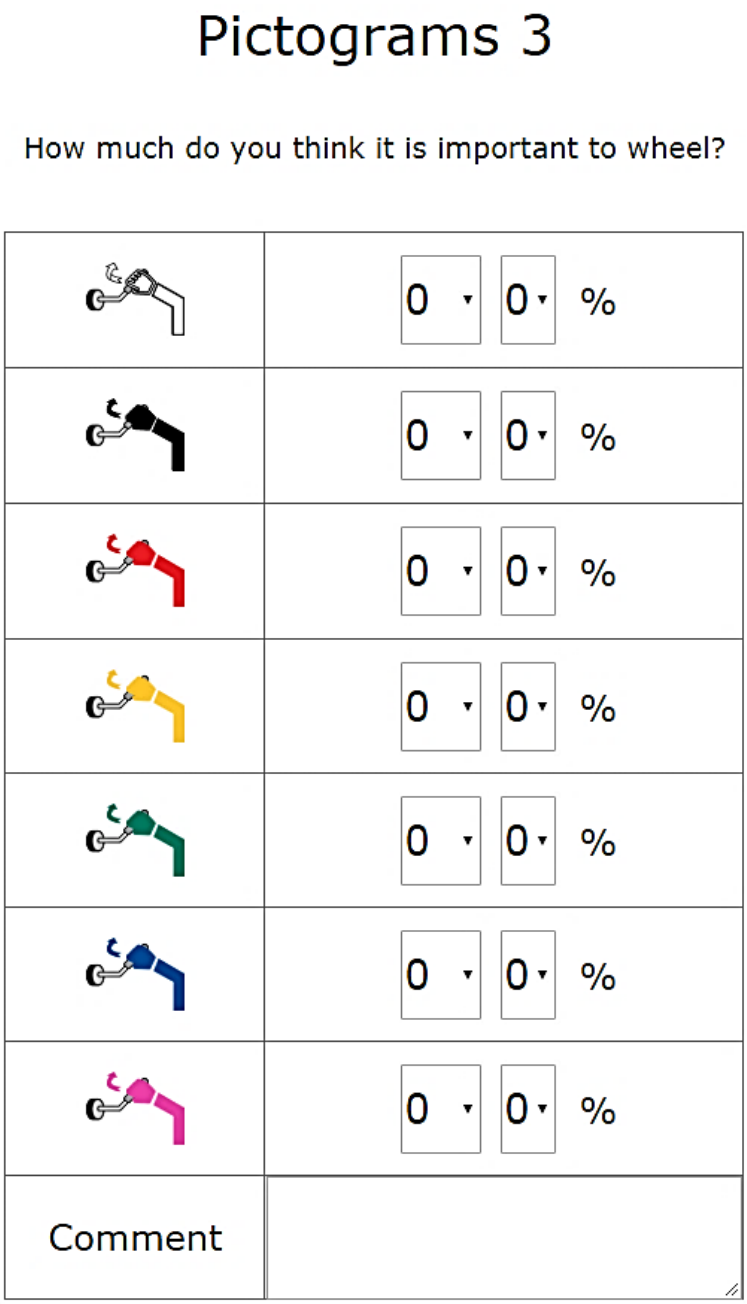
Figure 3.5 Dropdown menu of questions of personal information in the second section of the online questionnaire



(a) Each coloured pictograms of push button



(b) Eeach coloured pictograms of step pedal

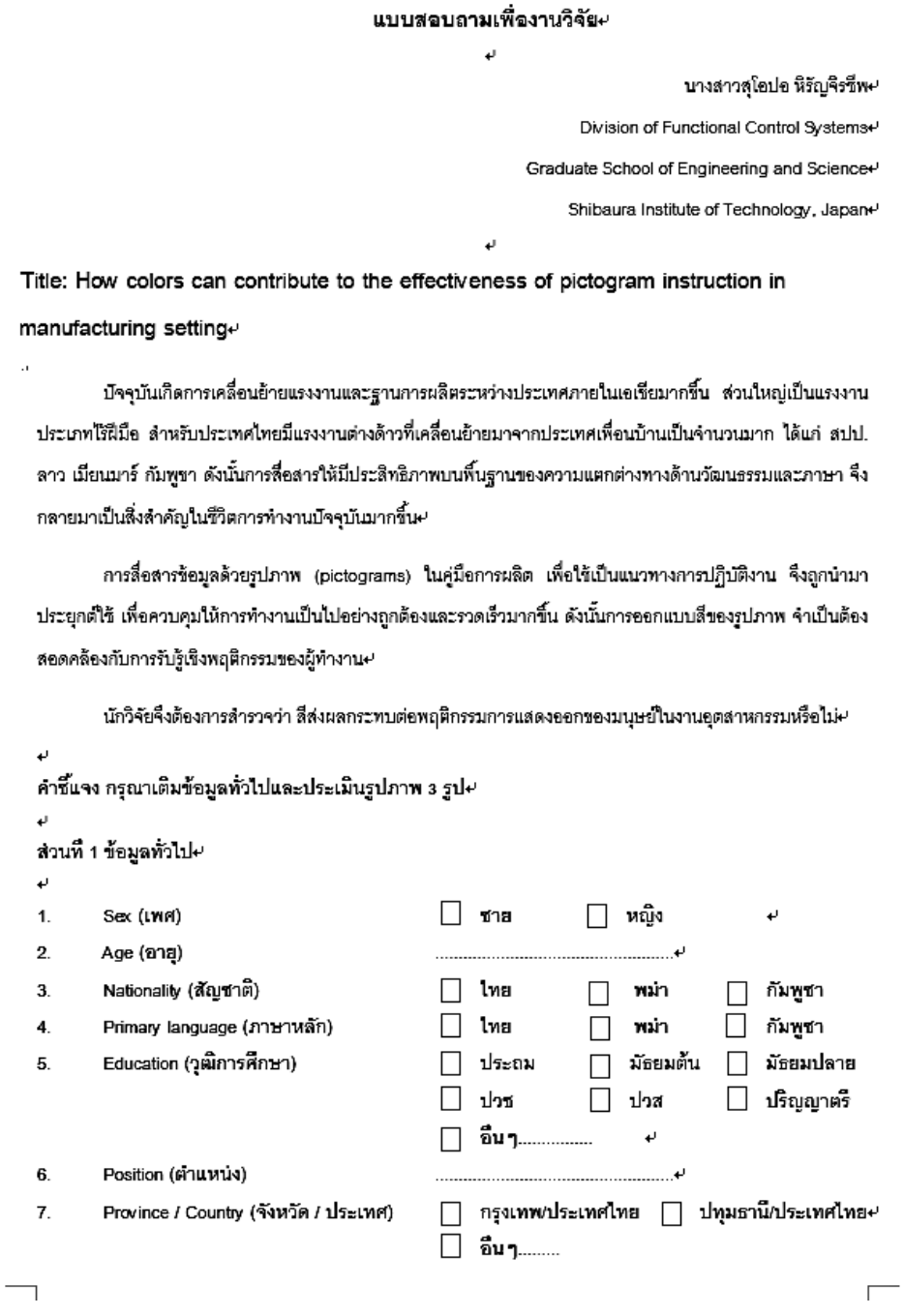


(c) Each coloured pictograms of turn handle

Figure 3.6 Each coloured pictograms for actions in the third section of the online questionnaire

3.3.2 Paper-based questionnaires

The author created a paper-based questionnaire to collect the data from Thai subjects with secondary school or vocational diploma and Burmese and Cambodian subjects with primary school educational level.



แบบสอบถามเพื่องานวิจัย

นางสาวสุโอปอ หิรัญจิรชีพ
Division of Functional Control Systems
Graduate School of Engineering and Science
Shibaura Institute of Technology, Japan

Title: How colors can contribute to the effectiveness of pictogram instruction in manufacturing setting

ปัจจุบันเกิดการเคลื่อนย้ายแรงงานและฐานการผลิตระหว่างประเทศภายในเอเชียมากขึ้น ส่วนใหญ่เป็นแรงงานประเภทไร้ฝีมือ สำหรับประเทศไทยมีแรงงานต่างด้าวที่เคลื่อนย้ายมาจากประเทศเพื่อนบ้านเป็นจำนวนมาก ได้แก่ สปป. ลาว เมียนมาร์ กัมพูชา ดังนั้นการสื่อสารให้มีประสิทธิภาพบนพื้นฐานของความแตกต่างทางด้านวัฒนธรรมและภาษา จึงกลายมาเป็นสิ่งสำคัญในชีวิตการทำงานปัจจุบันมากขึ้น

การสื่อสารข้อมูลด้วยรูปภาพ (pictograms) ในคู่มือการผลิต เพื่อใช้เป็นแนวทางการปฏิบัติงาน จึงถูกนำมาประยุกต์ใช้ เพื่อควบคุมให้การทำงานเป็นไปอย่างถูกต้องและรวดเร็วมากขึ้น ดังนั้นการออกแบบสีของรูปภาพ จำเป็นต้องสอดคล้องกับการรับรู้เชิงพฤติกรรมของผู้ทำงาน

นักวิจัยจึงต้องการสำรวจว่า สีส่งผลกระทบต่อพฤติกรรมการแสดงออกของมนุษย์ในงานอุตสาหกรรมหรือไม่

คำชี้แจง กรุณาเติมข้อมูลทั่วไปและประเมินรูปภาพ 3 รูป

ส่วนที่ 1 ข้อมูลทั่วไป

1. Sex (เพศ) ☐ ชาย ☐ หญิง
2. Age (อายุ) .....
3. Nationality (สัญชาติ) ☐ ไทย ☐ พม่า ☐ กัมพูชา
4. Primary language (ภาษาหลัก) ☐ ไทย ☐ พม่า ☐ กัมพูชา
5. Education (วุฒิการศึกษา) ☐ ประถม ☐ มัธยมต้น ☐ มัธยมปลาย ☐ ปวช ☐ ปวส ☐ ปริญญาตรี ☐ อื่นๆ.....
6. Position (ตำแหน่ง) .....
7. Province / Country (จังหวัด / ประเทศ) ☐ กรุงเทพ/ประเทศไทย ☐ ปทุมธานี/ประเทศไทย ☐ อื่นๆ.....

Figure 3.7 Introduction in Thai of paper-based questionnaire

3.4 Conclusion

This chapter presents designing common actions used in manufacturing procedures in factories. The author chose three typical actions: ‘push’ a button, ‘step’ on a pedal and ‘wheel’ a handle. The author created a questionnaire not only web-based Questionnaires but also Paper-Based questionnaires to ask how importance a subject feels for a step represented by a differently colored pictogram; white, black, red, yellow, green, blue and pink.

Chapter 4

Colored Pictogram Evaluation by Japanese and Thai Students

To examine the importance given by students to the actions represented by the coloured pictograms and to determine whether cultural backgrounds or educational levels affect the perceptions of the pictograms in conveying procedures for emergency situations. In experiment, we chose university students with Thai and Japanese nationalities as subjects to see if their cultural differences affect their perception of pictograms in various colors since many studies have noted that cultural differences are important factors for the perception of signs and pictograms [25]. The perception of the meaning colors has been also recognized as different across different cultures. In this survey, we choose the students with the same educational backgrounds: undergraduate and graduate students at accredited universities in

Thailand and Japan. Therefore, a main factor to affect the perception of the colored pictograms was assumed to be differences in their cultures.

4.1 Participants

The questionnaire was presented to two groups: one group of Japanese university student subjects and another group of Thai student subjects. Eighty Japanese students (44 males and 36 females) responded to the questionnaire in which the instructions were expressed in Japanese, and their ages ranged from 18 to 22 years. None of the Japanese subject had worked at a factory by the time of this study.

Table 4.1 Personal background data of student subjects: gender, age range, nationality, and educational level

Demographic Category		**Nationality**	
		Thais	**Japanese**
Gender	Male	78	44
	Female	95	36
	others	5	0
Age	12–17	0	0
	18–27	175	80
	28–37	3	0
Educational level	Graduate/under-graduate degree	178	80

As for the group of Thai student subjects who responded to the questionnaire, their ages ranged from 18 to 37 years, and 178 subjects participated in this study (78 males, 95 females and 5 others), as shown in Table 4.1 They were given the same questionnaire with the instructions in Thai language

4.2 Method

4.2.1 Method of Japanese university student subjects

The following are the questionnaire procedures:

1. The author had explained the introduction of my research in the first section of the questionnaire and each parts of questionnaire.
2. All subjects were asked to answer questions for each subject's personal information in the second section of the questionnaire.

    2.1. sex,
    2.2. age,
    2.3. major
    2.4. the length of study at SIT
3. After that, they answer the questionnaires to indicate how important each pictogram was by marking its percentage on the scale ranging from 0 to 100 in the questionnaire as follows:
    3.1. 'push' a button with each colors : white, black, red, yellow, green, blue and pink
    3.2. 'step' on a pedal with each colors : white, black, red, yellow, green, blue and pink
    3.3. 'wheel' a handle with each colors : white, black, red, yellow, green, blue and pink
4. The last question is in case they didn't understand the procedure well, they can tell reasons (free description)

4.2.2 Method of Thai university student subjects

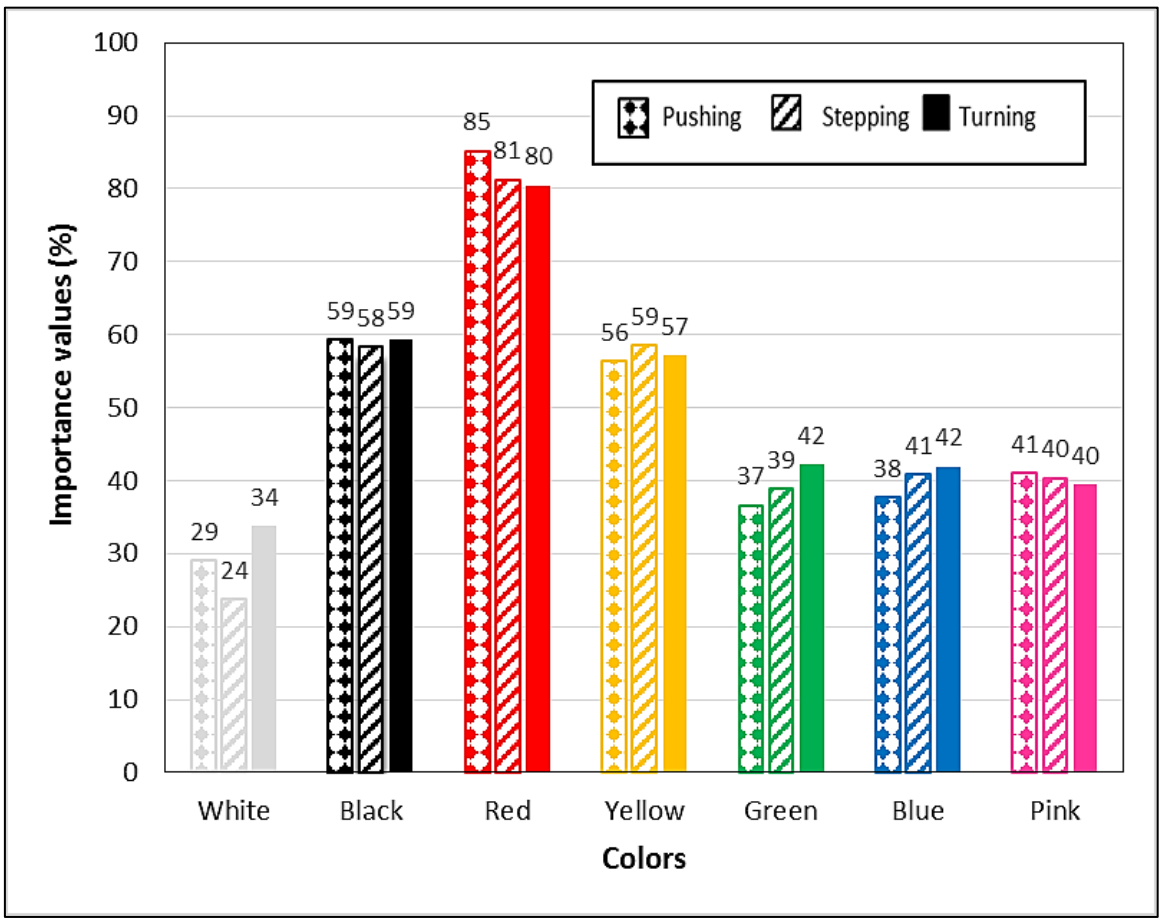
The following are the questionnaire procedures by online:

1. A lecturer had explained the introduction of my research and each part of questionnaire on internet.
2. For the first page, all subjects found objective of the online questionnaires.
3. For the second page, they had filled out and selected personal information as follows:

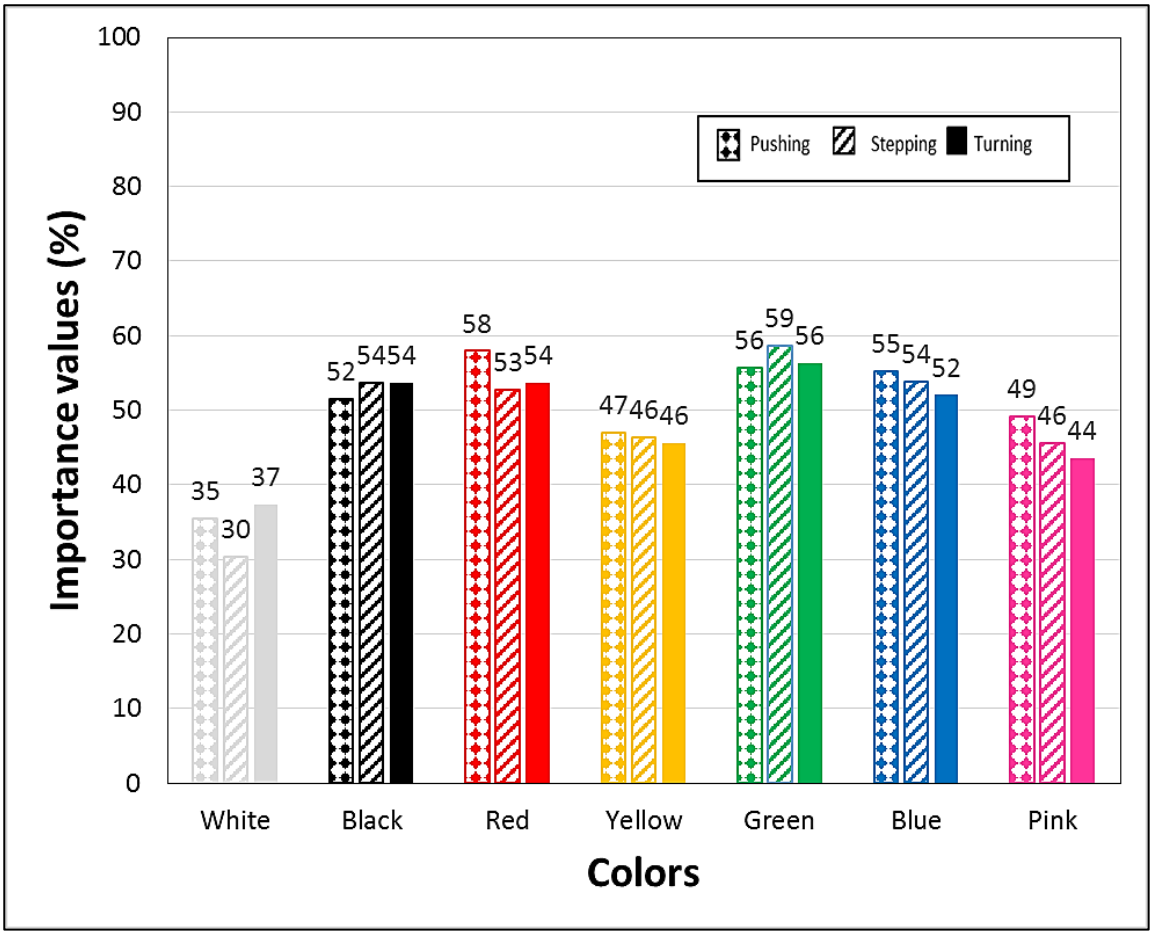
    3.1. sex,
    3.2. age,
    3.3. type of industry or business
    3.4. job category: major
    3.5. education
    3.6. nationality
    3.7. native language
    3.8. current country of residence
4. For the third page, they answer the question of each pictogram whose difference seven colors as “how much do you think it is important to push?”
5. For the third page, they answer the question of each pictogram whose difference seven colors as “how much do you think it is important to step?”
6. For the third page, they answer the question of each pictogram whose difference seven colors as “how much do you think it is important to wheel?”
7. The last page is in case they didn’t understand the procedure well, they can tell reasons (free description)

4.3 Results

After the author received responses from all subjects, the author averaged the scores for each pictogram and also performed bar graphs to see there were tendency in the levels of reception among the colored pictograms as well as the subject groups. The author collected 258 responses from Japanese and Thai subjects. Figures 2 (a) and (b) presents the average values obtained from the subjects. We divided the results into two graphs by nationality; (a) Japanese and (b) Thai. Each graph shows seven categories of colours; white, black, red, yellow, green, blue and pink.



(a) Japanese students Subjects



(b) Thai students Subjects

Figure 4.1 Average importance values obtained of students for each pictogram colour from two groups with different culture backgrounds

For the Japanese subjects, the author found that red marked the highest value (over 80%) for all types of pictograms. White marked the lowest average value, which was less than 35%. For the Thai subjects, the author found that green marked the highest value (over 55%) of the scale for every type of pictograms. In contrast, the white color showed the lowest one, which was less than 40%. These graphs show that both Thai and Japanese groups interpreted the all actions (push, turn, step) represented by the pictogram as having the same importance even if they are in different colours. As seen in Figures 2 (a) and (b), Japanese

students interpreted the red pictograms as the most important for all actions represented by the pictograms. On the other hand, the Thai students regarded the green ones as the most important actions to take for emergency situations, and they rated the red pictograms as the second-most important. However, the difference between the average scores given to the green and red pictograms by the Thai subjects was small for all actions. The average scores given by the Japanese students were very close to the ones given by the Thai students for the black, yellow and pink pictograms. The pictograms in white were interpreted the least important by both Thai and Japanese students.

4.4 Statistical analysis

The author performed the following statistical analyses on the data obtained from the survey of Thai and Japanese students. To examine whether the degree of importance given to each pictogram differed based on the three actions represented by the pictograms (push, step, and turn), we computed a one-way analysis of variance (ANOVA) among the actions for each nationality group. Then, the authors tested each colour between the subject groups by t-tests to examine whether there is a difference between the two group in terms of their perceptions of the colored pictograms

4.4.1 One-way ANOVA results among the actions

Table 4.2 (a) shows the result of a one-way ANOVA test preformed for the Japanese subjects, and Table 4.2 (b) shows the result of a one-way ANOVA test preformed for the Thai students. The ANOVA test results indicate that there was no significant difference among the importance of pictograms in terms of actions for both the Thai and Japanese student groups. Therefore, the results suggest that the differences in the perceptions of the pictograms for both student groups were derived from the colours of the pictograms.

Table 4.2 One-way ANOVA results of students among three pictograms for each colour

(a) Japanese students

	White	Black	Red	Yellow	Green	Blue	Pink
Meaning of push pictogram	29.13	59.31	85.19	56.44	36.63	37.69	41.06
MS (within groups)	23.75	58.31	81.25	58.56	38.81	40.88	40.38
MS (within groups)	33.81	59.25	80.44	57.13	42.19	41.94	39.50
F*	4.295	0.043	1.707	0.231	2.167	1.211	0.112
P**	0.015	0.958	0.184	0.794	0.117	0.300	0.894
MS (among groups)	2028.229	25.104	516.354	94.063	628.229	391.354	49.063
MS (within groups)	472.261	588.563	302.561	407.418	289.844	323.252	438.622

* df (between groups) = 2 * df (within groups) = 117 ** $\alpha = 0.05$

(b) Thai students

	White	Black	Red	Yellow	Green	Blue	Pink
Meaning of push pictogram	35.47	51.53	57.96	46.96	55.73	55.19	49.18
Meaning of step pictogram	30.36	53.70	52.80	46.42	58.63	53.87	45.66
Meaning of turn pictogram	37.42	53.63	53.66	45.67	56.31	52.06	43.62
F*	2.655	0.281	1.099	0.132	0.602	0.624	1.69
P**	0.071	0.755	0.334	0.877	0.548	0.536	0.186
MS (among groups)	2366.511	269.871	1360.097	74.904	418.946	440.934	1406.642
MS (within groups)	891.180	958.872	1237.505	568.831	695.613	706.522	832.373

* df (between groups) = 2 * df (within groups) = 531 ** $\alpha = 0.05$

4.4.2 T-test results between two pairs for each colour

Based on the results of the ANOVA tests, a t-test was performed between the Thai student group and the Japanese student group for each colour to see if there is a significant difference between the two groups in terms of the perception of the pictogram of an action according to a colour. Table 4.3 shows the result of a t-test preformed for each colour between the Japanese and Thai subjects. The test results show that there was a significant difference between the average scores of importance given by the Thai subject group and the Japanese subject group for red, yellow, green and blue pictograms.

Table 4.3 T-test results between two pairs of Thai and Japanese students for each colour

	White	**Black**	**Red**	**Yellow**	**Green**	**Blue**	**Pink**
T	1.887	-1.959	-9.974	-4.522	7.507	5.539	2.06
Df	194.063	189.762	253.942	160.097	218.146	211.236	196.789
P	0.061	0.052	< 0.001[a]	< 0.001[a]	< 0.001[a]	< 0.001[a]	0.041

4.5 Discussion and conclusion

In this survey, three actions represented by pictograms in different colours were shown to Thai and Japanese university students to determine whether cultural backgrounds can affect the perceptions of the pictograms in conveying procedures for emergency situations. The results of the survey showed that at the same kind of educational levels both groups interpreted the importance of the actions represented in the coloured pictograms. The

results suggest that scores for the importance of each pictogram can be affected by its colour, rather than the action indicated by the pictogram. The importance levels indicated by the Thai group and the Japanese group showed a difference between the two groups for colours often used for ISO and JIS signs (i.e, red, yellow, green and blue). In this survey, the author could not identify whether the different perception of importance for the pictograms in these colours was due to cultural differences between these two groups or different trainings that the subjects have received. However, Japanese students tend to see ISO and JIS signs in these colors in their daily live more than Thai students. For example, many Japanese high schools have programs to teach students safety measures at school by showing them JIS signs [54] [55] . On the other hand, the safety of students in Thailand is considered to be of low priority compared with other issues, lacking not only an effective policy but also practical training with regard to the health and safety of schoolchild. Moreover, Thai students usually do not have the same kind of safety trainings before they enter a university [56]. Therefore, the differences of perception of the coloured pictograms between Thai and Japanese students were probably derived from their differences in safety trainings. The result also indicates that a colour can be an important factor to show the importance of an action shown by a pictogram since both Thai and Japanese students rated the white pictograms as the least important, but they rated the red and green ones much higher than the white pictograms.

Chapter 5

Colored Pictogram Evaluation by Factory Workers

5.1 Participants

The author conducted a survey using questionnaires with four subject groups: low-educated Thai workers, high-educated Thai workers, low-educated Burmese workers, and low-educated Cambodian workers. The questionnaire respondents were 40 Thai subjects (23 males and 17 females), 40 Burmese subjects (26 males and 14 females), and 40 Cambodian subjects (19 males and 21 females). All subjects were working at a cosmetics factory.

Twenty of the Thai subjects had graduate or undergraduate university degrees, and the rest had education levels of secondary or vocational schools. All of the Burmese and Cambodian subjects had primary school levels of education. Table 1 summarizes the personal background data of the subjects in the factory.

Table 5.1 Personal background data of factory worker subjects: gender, age range, nationality, and educational level

Demographic Category		**Nationality**		
		Thais	**Burmese**	**Cambodians**
Gender	Male	23	26	19
	Female	17	14	21
Age	12–17	0	0	0
	18–27	11	22	24
	28–37	28	14	14
	38–47	9	4	2
	48 or above	10	0	0
Educational level	Primary school	0	40	40
	Secondary school	38	0	0
	Vocational diploma	2	0	0
	Graduate/under-graduate degree	18	0	0

5.2 Method

5.2.1 Method of low-educated workers

The following are the questionnaire procedures:

1. Leader of low-educated workers had explained the introduction of my research

and each part of questionnaire.

2. All subjects were asked to answer questions for each subject's personal information in the first section of the questionnaire.

    2.1. sex,
    2.2. age,
    2.3. Nationality
    2.4. Primary language
    2.5. Education
    2.6. Position
    2.7. Province

3. After that, they answer the questionnaires to indicate how important each pictogram was by marking its percentage on the scale ranging from 0 to 100 in the questionnaire as follows:
    3.1. 'push' a button with each colors : white, black, red, yellow, green, blue and pink
    3.2. 'step' on a pedal with each colors : white, black, red, yellow, green, blue and pink
    3.3. 'wheel' a handle with each colors : white, black, red, yellow, green, blue and pink
4. The last question is in case they didn't understand the procedure well, they can tell reasons (free description)

5.2.2 Method of high-educated Thai workers

The following are the questionnaire procedures by online:

1. A responsible woman had explained my research to each subjects privately, then sent the online questionnaire to them.
2. For the first page, all subjects found objective of the online questionnaires.

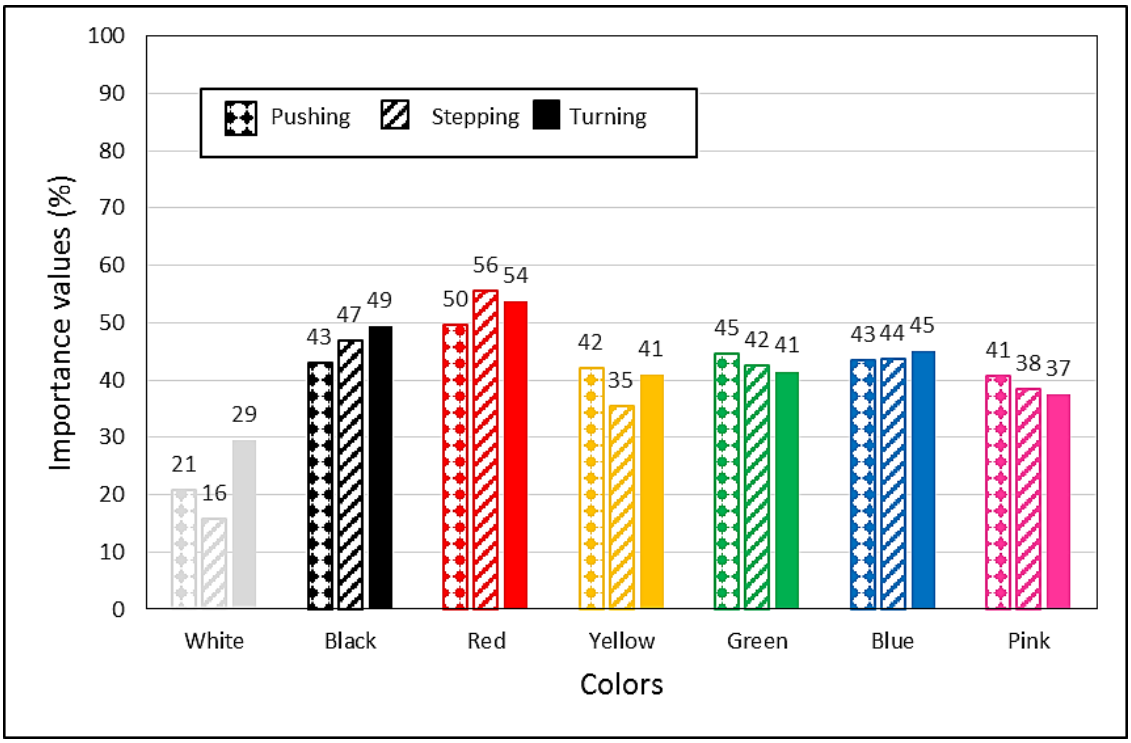
3. For the second page, they had filled out and selected personal information as follows:

    3.1. sex,
    3.2. age,
    3.3. type of industry or business
    3.4. job category : major
    3.5. education
    3.6. nationality
    3.7. native language
    3.8. current country of residence
4. For the third page, they answer the question of each pictogram whose difference seven colors as “how much do you think it is important to push?”
5. For the third page, they answer the question of each pictogram whose difference seven colors as “how much do you think it is important to step?”
6. For the third page, they answer the question of each pictogram whose difference seven colors as “how much do you think it is important to wheel?”
7. The last page is in case they didn’t understand the procedure well, they can tell reasons (free description)

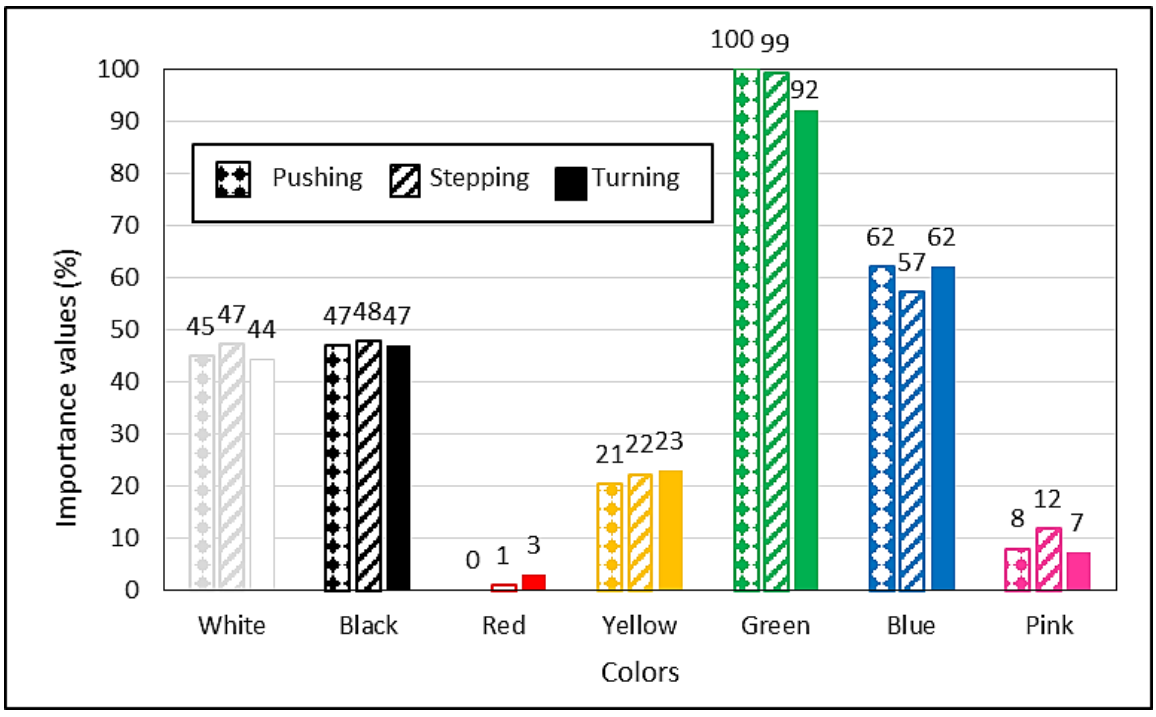
5.3 Results

The author collected 138 responses from respondents who were working at factory in Thailand. Figures 3 (a) through (c) present the average importance values obtained from them. We divided the results into three graphs of respondents based on education: (a) undergraduate or graduate degree, (b) secondary school education or a vocational diploma, and (c) education through the primary school level. Each graph shows the average values for the seven colour categories. For the subjects with undergraduate or graduate education, we found that red marked the highest value (over 50%) for all types of pictograms. White marked the lowest average value, which was less than 30% for the high-educated group. On

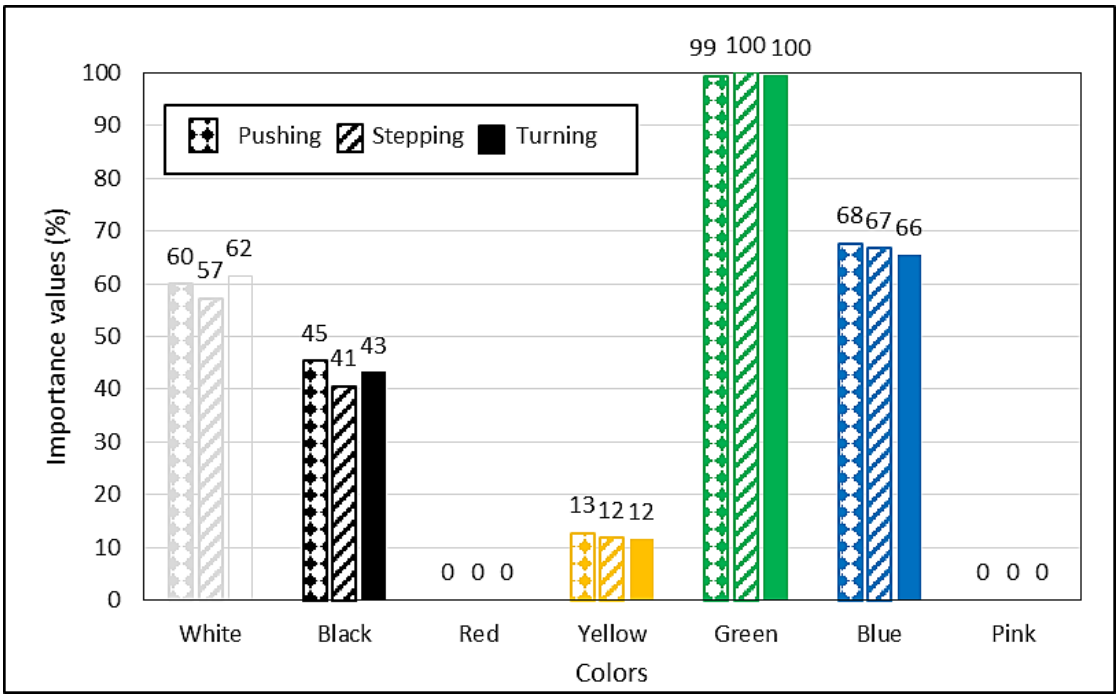
the other hand, the results for the coloured pictograms from low-educated workers, including Thais, Burmese, and Cambodians, showed very different tendencies from the results for the high-educated subjects. The lowest average value for the low-educated subjects was 0% for the red pictograms, which was obviously the lowest average value among the seven colours. However, the green pictograms had the highest average value (exceeding 99%) for the low-educated subjects. The results obtained from the two groups with different cultural backgrounds and similar educational backgrounds showed similar characteristics. The results of the average values for the low-educated respondents from Cambodians and Burmese closely resembled those from Thai workers without undergraduate or graduate degrees. On the other hand, the results from the high-educated Thai respondents were very different from those obtained from the low-educated Thai workers, although both groups share the same cultural background.



(a) Thai subjects with undergraduate or graduate degrees



(b) Thai subjects with secondary school or vocational diploma



(c) Burmese and Cambodian subjects with

primary school educational level

Figure 5.1 Average importance values obtained of workers for each pictogram colour from three groups with different educational backgrounds

5.4 Statistical analysis

The author performed the following statistical analyses on the data obtained from our survey of factory workers. To examine whether the degree of importance given to each pictogram differed based on the three actions represented by the pictograms (push, step, and turn), we computed a one-way analysis of variance (ANOVA) among the actions. Then, the author analysed the differences in the degree of importance among the seven colours by one-way ANOVA and finally tested each colour between the subject groups by t-tests to determine the culture and education differences.

5.4.1 One-way ANOVA results among the actions

The ANOVA results among the actions of the pictograms for each pictogram colour showed no significant differences except for the green pictograms with the groups of low-educated Thais (Tables 5.2(a) through (d)). We present the ANOVA results of the respondents from four groups: (a) Burmese (b) Cambodians, (c) low-educated Thais, (d) and high-educated Thai workers. These results suggest that the degree of importance given by the subjects to each pictogram had been clearly instructed by the company in Thailand. Since the only variation in each pictogram was the colour difference, the degree of importance used in rating the pictograms can be regarded as the degree of importance given to each colour.

Table 5.2 One-way ANOVA results among three pictograms for each colour

(a) Burmese respondents

	White	Black	Red	Yellow	Green	Blue	Pink
Meaning of push pictogram	50.50	48.75	0.00	19.75	100.00	69.50	0.25
Meaning of step pictogram	48.00	48.50	0.00	20.50	100.00	70.25	0.00
Meaning of turn pictogram	50.50	49.25	0.00	19.00	99.00	69.00	0.00
F*	0.773	0.062	***	0.137	1.000	0.107	1.000
P**	0.464	0.94	***	0.872	0.371	0.898	0.371
MS (among groups)	83.333	5.833	0	22.500	13.333	15.833	0.833
MS (within groups)	107.863	94.231	0	164.509	13.333	147.415	0.833

* df (between groups) = 2 * df (within groups) = 117 ** $\alpha = 0.05$

*** No output of IBM SPSS Statistics 24 program because all data have identical values, i.e. 0

(b) Cambodian respondents

	White	Black	Red	Yellow	Green	Blue	Pink
Meaning of push pictogram	69.25	42.00	0.00	5.75	98.75	65.75	0.00
Meaning of step pictogram	66.50	32.75	0.00	3.25	100.00	63.25	0.00
Meaning of turn pictogram	72.50	37.00	0.00	4.00	100.00	62.00	0.00
F*	0.459	1.066	***	0.592	1.000	0.538	***
P**	0.633	0.348	***	0.555	0.371	0.585	***
MS (among groups)	360.833	857.500	0	65.833	20.833	145.833	0
MS (within groups)	785.791	804.081	0	111.239	20.833	270.897	0

* df (between groups) = 2 * df (within groups) = 117 ** $\alpha = 0.05$

*** No output of IBM SPSS Statistics 24 program because all data have identical values, i.e. 0

(c) Thai respondents, from low-educated workers

	White	Black	Red	Yellow	Green	Blue	Pink
Meaning of push pictogram	44.88	47.00	0.25	20.50	100.00	62.00	8.00
Meaning of step pictogram	47.25	47.75	1.00	22.25	99.25	57.25	11.75
Meaning of turn pictogram	44.25	47.00	3.00	23.00	92.25	62.00	7.25
F*	0.7	0.049	1.087	0.177	5.787	0.608	1.123
P**	0.499	0.952	0.340	0.838	0.004	0.546	0.329
MS (among groups)	100.208	7.500	80.833	65.833	730.833	300.833	232.500
MS (within groups)	143.157	153.654	74.338	372.03	126.282	494.679	206.966

* df (between groups) = 2 * df (within groups) = 117 ** $\alpha = 0.05$

(d) Thai respondents, from high-educated workers

	White	Black	Red	Yellow	Green	Blue	Pink
Meaning of push pictogram	20.78	42.89	49.67	42.11	44.50	43.39	40.67
Meaning of step pictogram	15.67	46.83	55.56	35.44	42.44	43.61	38.44
Meaning of turn pictogram	29.44	49.39	53.67	40.89	41.44	45.06	37.39
F*	1.201	0.13	0.085	0.292	0.041	0.017	0.06
P**	0.309	0.878	0.918	0.748	0.96	0.983	0.942
MS (among groups)	873.185	193.019	162.741	226.741	43.685	14.741	50.389
MS (within groups)	727.129	1483.344	1904.479	776.000	1062.772	864.265	837.426

* df (between groups) = 2 * df (within groups) = 51 ** $\alpha = 0.05$

5.4.2 One-way ANOVA results among seven colours

Table 5.3 One-way ANOVA results among seven colours for each pictogram

	Low-educated Burmese	Low-educated Cambodians	Low-educated Thais	High-educated Thais
Meaning of white pictogram	49.67	69.42	45.46	21.96
Meaning of black pictogram	48.83	37.25	47.25	46.37
Meaning of red pictogram	0.00	0.00	1.42	52.96
Meaning of yellow pictogram	19.75	4.33	21.92	39.48
Meaning of green pictogram	99.67	99.58	97.17	42.80
Meaning of blue pictogram	69.58	63.67	60.42	44.02
Meaning of pink pictogram	0.08	0.00	9.00	38.83
F*	1072.702	396.728	278.865	1.735
P**	< 0.001[a]	< 0.001 [a]	< 0.001 [a]	0.119
MS (among groups)	54679.63	63003.84	43619.47	9965.764

[a] P-Value of IBM SPSS Statistics 24 program is 0.000.

5.4.3 T-test results between two pairs for each colour

Table 5.4 T-test results between two pairs of worker groups for each colour

	White	Black	Red	Yellow	Green	Blue	Pink
	a) Low-educated Thais vs. High-educated Thais						
T	5.611	0.149	-7.971	-2.932	10.678	2.526	-5.709
Df	56	56	56	56	56	56	56
P	< 0.001[a]	0.882	< 0.001[a]	< 0.001[a]	< 0.001[a]	< 0.001[a]	< 0.001[a]
	b) Low-educated Thais vs. Low-educated non-Thais						
T	4.446	-1.503	-2.143	-3.549	2.834	2.169	-6.602
Df	118	118	118	118	118	118	118
P	< 0.001[a]	0.136	0.034	< 0.001[a]	0.005	0.032	< 0.001[a]
	c) Low-educated Burmese vs. Low-educated Cambodians						
T	-5.401	3.312	*	7.248	0.156	2.358	1
Df	78	78	*	78	78	78	78
P	< 0.001[a]	< 0.001[a]	*	0.004	0.749	0.718	0.043

[a] P-Value of IBM SPSS Statistics 24 program is 0.000.

* Program cannot be computed because the standard deviation of both groups is 0.

The key significance of our study is found in our result showing no statistical difference among the three action pictograms of each colour for each nationality. For groups of low-educated workers with different education levels (secondary school and vocational diploma) on the same factory floor, we found no significance, mostly because colours are so critical, explaining why we see such complicated ANOVA results. Thus, colour is the most important factor. For the following groups of workers, low-educated Burmese, low-educated Cambodians, and low-educated Thais, analysis among the coloured pictograms showed a very significant difference of $p < 0.001$ (Table 5.3). The green pictogram obtained the highest degree of importance from low-educated Burmese (mean importance value = 99.67 %), and the second-highest degree of importance was from low-educated Cambodians (mean importance value = 99.58 %). On the other hand, the results for the coloured pictograms from high-educated Thais showed no significant difference, where $p = 0.119$. The red pictogram obtained the highest degree of importance, and the black pictogram had the second-highest degree. In contrast, the white colour showed the lowest degree of importance.

In addition, the author addressed whether a significant difference existed among subject groups with varying cultural and educational backgrounds in terms of their degrees of importance (Table 5.4). T-tests ($\alpha=0.05$) were performed for each colour among three pairs of subject groups: low-educated and high-educated Thais, low-educated Thais and low-educated non-Thais, and low-educated Burmese and low-educated Cambodians. The t-test results showed a very significant difference at the $p<0.001$ for each colour in all of the pairs. The author found that among the groups of low-educated and high-educated Thai workers, subjects who shared a culture but had different levels of education, the responses showed a significant difference of colour pairs, such as white, red, green, yellow, and pink. On the other hand, no significant difference was observed for the black pictograms in any pair.

Nevertheless, the results for all identically coloured pictograms for each pair with different cultural backgrounds but similar educational backgrounds showed very significant differences in both low-educated groups: low-educated Thais and low-educated non-Thais. This tendency was especially significant with white, yellow, and pink pictograms.

Furthermore, the results obtained from two groups with different cultural and slightly different educational backgrounds also showed that many pairs had highly significant

differences. Thus, the results of this study show that different interpretations of the meaning of coloured pictograms were more affected by educational background than cultural differences. The low-educated group did mark almost 100% for the green pictograms and 0% for the red, perhaps because these two groups (Burmese and Cambodians) interpreted the meaning of importance differently based on their surroundings, since their factory has many pictograms, including emergency exits, fire equipment signs, fire hose reels, warnings, and prohibitions. Thus, they are generally familiar with green and red pictograms.

However, the average results of the degree of importance for the coloured pictograms in Table 5.3 show different P-Values among the seven colours for each pictogram. The low-educated workers had P-Value < 0.001, while the high-educated Thais did not show a significant difference. For the results in Table 5.4, we presented statistical results provided by three different sets of paired subjects: low-educated and high-educated Thais, low-educated Thais and low-educated non-Thais, and low-educated Burmese and low-educated Cambodians. Note that the first paired subjects, i.e., low-educated and high-educated Thai workers, had greatly different education levels but the same culture. The second paired subjects, i.e., low-educated Thai and low-educated non-Thai workers, had only slightly different education levels but different cultures. The third paired subjects, i.e., low-educated Burmese and low-educated Cambodians, had different cultures but the same educational level. We found that the first paired subjects presented five pairs showing strongly significant differences (i.e., P-value less than 0.001) based on particular colours; for the second paired subjects, we found three such pairs. Based on the findings from the first and second paired subjects, education level positively affected the workers' comprehension and perception. For example, workers with a higher degree of education more accurately interpreted the coloured pictograms than did the low-educated workers. Moreover, the third paired subjects presented two pairs who showed weakly significant differences. The results indicate that education level is a likely factor in one's comprehension of coloured pictograms. This was particularly pronounced in the cases of red pictograms, which had the same value of 0 from every subject, and green pictograms, which were non-significant and thus indicating no significant difference in performance between Burmese and Cambodians ($p > 0.05$). The difference in education level evidently affected worker interpretation of pictograms more than did cultural differences.

According to previous studies, cultural differences affect the interpretation of colours and signs. Cho examined cross-cultural differences in pictogram interpretations by Americans and Japanese and suggested that such cultural differences can be used as a basis for agent construction. Piamontea et al. evaluated cultural differences in the interpretation of graphical symbols, showing results for American and Swedish subjects. These subjects showed differences in pattern ratings, and the authors concluded that the differences might be culturally linked. However, the results in our study show that differences in the interpretation of the meanings of coloured pictograms were more affected by educational backgrounds than by cultural differences. The statistical T-test results of importance values for the coloured pictograms in Table 5.4 show an unequal number of pairs with significant differences between the highest- and lowest-educated groups.

Chapter 6

Analysis and Discussion

6.1 Overall analysis and discussion

The purpose of this study was to investigate the importance levels of pictograms (push, step, and turn) among seven colours (white, black, red, yellow, green, blue, and pink) and to examine the effects of cultural and educational background factors on the comprehension of coloured pictograms for emergency situations in manufacturing environments. The results of this study show that differences in the interpretation of the meanings of coloured pictograms were more affected by educational background than by cultural differences. In particular, highly educated workers interpreted the meanings of pictograms better than low-educated workers. The main purposes of warnings and safety

signs are to make better decisions regarding safety issues, to make workers at factories aware of hazards, and to prevent injuries [57]. Raskin noted that a lack of understanding or a misinterpretation can lead to injury [58]. This study found that the degree of importance given to coloured pictograms did not convey the intended information to low-educated workers successfully, probably due to the lack of adequate training in symbolic representation. The results of this study and a note by Wogalter and Laughery [57], as well as a study by Raskin [58], suggest that an effective training program to promote the intended messages of such signs be conducted. Factory facilitators who are responsible for environmental health and safety training should provide appropriate educational programs for workers to acquire a knowledge of industrial signs and the intended meanings of their colors as a way to help prevent workplace accidents. Supervisor commitment to safety and performing the safety.

6. 2 Education levels on the interpretation

Education levels had an impact on the interpretation of the pictograms in my study. Several previous studies also reported that education levels can affect the comprehension of pictograms. Participants with a low level of education performed relatively poorly on tasks assessing their comprehension of the meanings of icons and pictograms, compared to those with higher levels of education [59] [60]. Knapp et al. [61] provided survey results showing that educational levels had a positive effect on the total scores of interpreting pharmaceutical pictograms. Rajesh et al. [62] also showed that more literate participants could more correctly interpret pictograms related to the antiretroviral therapy of Indian patients. In this study, the author found a significant difference between the highest and lowest educated groups. The highest educated workers comprehended the meaning of the pictograms much better. An analysis of the results also indicates that the subjects in the two groups interpreted the meanings of the coloured pictograms differently based on their previous experiences, which typically involved differing job ranks. However, the highest educated workers did not comprehend the information provided by the pictograms 100% correctly. These results strongly suggest that activities and/or training related to safety signs should be regularly provided to workers of all educational levels and at all job rankings because they must

always be conscious of safety sign messages and be able to react to emergency situations, thus preventing accidents.

6. 3 A multi-layer chain subcontracting system

In manufacturing settings in Thailand, there is a multi-layer chain subcontracting system. Therefore, workers who have different cultural and educational backgrounds may work in the same company for a short time. The results of our study for low-educated temporary workers from different cultures showed that they inaccurately interpreted the coloured pictograms. This finding agreed with the results of Ma et al. [63], who noted that the high mobility of workers usually produces the dangerous concept that they have no responsibility for safety. Therefore, they might have a lower perception of risk than other workers, implying that they should become familiar with the use of safety signs and be able to easily interpret their correct meanings. The results here suggest the need to enhance subcontract workers' awareness for risk perception and to build a culture of workplace and organizational safety through training. Lingard et al. suggested that safety culture was an important factor in reducing industrial injury rates [64]. It would be beneficial if environmental health and safety training facilitators could provide training and educational activities continuously for new workers, particularly for workers with lower educational levels. Even though subcontract workers are employed for a short time, such educational programs would train them to act appropriately based on the intended meanings of workplace pictograms.

6. 4 Colours provide an important means of recognition in many fields

Colour provides an important means of recognition in many fields. However, the author must face the basic problem that different cultures use different colours for different purposes. Even though there are many organizations for standardization, the colours of signs are not the same in real situations. Chan et al. implied that the comprehensibility of messages could be increased if signs were designed independent of culture [65]. The results of our research showed that the interpretation of colored pictograms was less affected by cultural differences

than by educational differences. Therefore, using colors in pictograms was more effective than using pictograms without colors, since a degree of culture independence could be achieved at higher levels of formal and informal education. As seen in Table 3, over 50% of the highest-educated group of Thai workers could correctly understand the meaning of the red pictograms. On the other hand, none of the low-educated subjects could give the correct meaning of red pictograms. For the highest educated group of Thai workers, red could be interpreted as having various meanings ranging from prohibition to encouragement. In contrast, the low-educated groups, including Thais, Burmese, and Cambodians, interpreted the red pictograms as actions that must be avoided. They might have interpreted red and pink pictograms simply as denoting prohibition. Therefore, it is important to understand that more literate participants interpreted red pictograms more correctly and that low-educated groups must become specifically aware of the use of colours in safety signs to prevent immediate threats to property and safety.

6.5 Job ranks of workers and career directions

Regarding the job ranks of workers, in many factories in Thailand, workers usually learn the meaning of coloured pictograms through their daily life experiences and career directions. The results of our research in Table 5.3 show that the red pictograms held the highest importance in the interpretation by high-educated workers, while the green pictograms were interpreted by the low-educated workers as having the highest importance. It is likely that such comprehension performance is related to their daily life experiences and career directions. Yoon et al. noted that for safety issues, differences in awareness levels existed between site general managers and occupational health and safety (OHS) managers [66]. That result was consistent with those of previous studies implying that workers in different positions interpreted the meaning of pictograms differently. Of course, the best performance was achieved by high-educated subjects whose life experiences were intricately linked with their experiences on the factory floor. However, all workers must comprehend particularly important signs, such as those instructing staff in the proper way to take action. Based on the findings of this study, when workers with lower education can grasp the meaning of a

coloured pictogram, it is very likely that workers with a higher educational level can also understand it. Activities and training aimed at such common understanding would not be so expensive but could help avoid burdensome countermeasures required after mistaken actions.

6.6 Training

To interpret the use of pictograms correctly, industrial facilities should offer practical training for employees. For example, participants must be able to identify an abnormal simulation. Furthermore, they should know the appropriate solutions and be prepared to take swift, immediately action by pushing an emergency button, which is often coloured in red. In this sense, appropriate training on the principles of colour use in safety signs and pictograms should be given to production workers, who may hold incorrect perceptions of coloured pictograms. Knapp et al. also found that higher levels of activities and/or training were positively correlated with correct comprehension [61]. It was also suggested that the safety management office should use familiar symbols as much as possible [67]. Moreover, safety management personnel should take responsibility for providing appropriate training in signage to workers. Such training would help to ensure that workers were able to comprehend sign meanings and would reinforce safety culture. For example, production workers at lower-ranked positions often do not receive sufficient training on responding to emergency situations that require stopping machines, since the decision to stop a machine is usually made only by high-educated Thai workers in higher-ranking positions. Accordingly, the lower-ranking Thais, Burmese and Cambodians, who do not receive sufficient training on the use of red signs in handling emergencies, probably interpret the meaning of red in pictograms simply as a prohibition.

Chapter 7

Conclusion and Future Work

7.1 Conclusion

The author examined whether the effects of educational background had more significance for the interpretation of coloured pictograms than cultural background in a factory setting. Using questionnaires, the author collected responses from 138 subjects: Thais, Burmese, and Cambodians. In terms of behavioural perception required for swift action in manufacturing settings, particularly in emergency situations, my results showed a

significant difference among groups with different educational backgrounds. The author also analysed the data using one-way ANOVAs among seven colours for each pictogram and T-tests among pairs of worker groups for each colour. The author identified a statistically significant difference between educational and cultural backgrounds. Thus, my results show that differences in the interpretation of the meaning of coloured pictograms were more affected by educational backgrounds than by cultural differences. The interpretations of the lowest-educated groups were different from those of the high- educated ones. My results suggest that factory managers need to provide comprehensive on-the-job training on signs posted in factories, in particular to low-educated employees.

7.2 Future work

In my next study, the author plan to conduct an experiment to examine the perceptions of coloured pictograms by workers at a factory from physiological and neurological points of view. The author will conduct perception-reaction experiments with factory workers as subjects for coloured pictograms to identify how their comprehension of the pictograms can be affected by colours. Furthermore, the author will use an optical imaging technique to measure brain functioning when subjects react to different coloured pictograms. In the experiments, the author plan to present coloured pictograms to workers having different cultural and educational backgrounds in a factory. In addition, questionnaires for managers of the factory will be created to identify what factors cause exceptional differences among factory workers. The author also plans to interview managers for this purpose and offer possible guidance on developing training content for safety awareness.

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Appendix A

List of Publications

A.1 Journal Paper

[J.1] **S. Hiranchiracheep**, A.K. Yamazaki, and A. Naowanondha, " A development and Comprehension of Pictograms for Educational Purposes", *Ratchaphruek Journal*, Vol.16, No.3, pp. 10-18 , Sep 2018.

A.2 International Conference Papers

[C.1] O. Lasunon and **S. Hiranchiracheep**," Integrated learning towards a trend of the 21st century classroom", *Proc. of the 10th Southeast Asian Technical University Consortium (SEATUC 2016)*, Feb 2016.

[C.2] **S. Hiranchiracheep** and A.K. Yamazaki," A preliminary survey to investigate the effects of colors in pictogram instructions for global manufacturing settings", *Proc. of the International Society of Affective Science and Engineering (ISASE)*, Mar 2016.

[C.3] **S. Hiranchiracheep,** A.K. Yamazaki, and W. Foypikul," A preliminary surveying of the meaning of colored pictogram instructions for emergency settings in manufacturing", *Proc. of the 20th International Conference on Knowledge Based and Intelligent Information and Engineering Systems (KES)*, Sep 2016.

[C.4] N. Takoolprom, **S. Hiranchiracheep**, C. Wechtaisong and S. Kamolchai, " Impact of P2P live-streaming application to internet service provider and private network: A case study on sopcast application", *Proc. of the 8th International Graduate Research Conference (iGRC2017)*, Dec 2017.

[C.5] K. Eto, H. Takase, H. Matsuda, A.K. Yamazaki, H. Yoshida, K. Ito, C. Ogiwara, I. Saeki, A. Shimizu, **S. Hiranchiracheep,** " Development of web-based learning materials to support assisting-skill acquisition using 3DCG", *Proc. of the 22th International Conference on Knowledge Based and Intelligent Information and Engineering Systems (KES)*, Sep 2018.

[C.6] C. Wechtaisong, **S. Hiranchiracheep**, P. Dhephasadin Na Ayudhaya, and A.K. Yamazaki" Promoting and participating in the research exchange/laboratory internship project", *Proc. of the 13th Southeast Asian Technical University Consortium (SEATUC 2019)*, Accepted.

A.3 Workshop

[W.1] **S. Hiranchiracheep** and A.K. Yamazaki, (2016, February). A preliminary surveying of effect of colors in pictogram instruction with Japanese-speaking subjects. In SEATUC 2016 Intensive Workshop

[W.2] **S. Hiranchiracheep** and A.K. Yamazaki, (2018, July). Pictogram Communication for Safety Measures at Manufacturing Sites, IEEE Professional Communication Society, Japan Chapter, 1st Workshop & Technical Meeting 2018