DEVELOPMENT OF URBAN HEAT ISLAND E-MODULE FOR HIGH SCHOOL STUDENT IN SURAKARTA CITY, INDONESIA

SITI AZIZAH SUSILAWATI

SULTAN IDRIS EDUCATION UNIVERSITY

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DEVELOPMENT OF URBAN HEAT ISLAND E-MODULE FOR HIGH SCHOOL STUDENT IN SURAKARTA CITY, INDONESIA

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ABSTRACT

The objective of the study is to design and develop an Urban Heat Island e-module for high school students in Surakarta using the Borg and Gall model of Design and Development Research (DDR). The research method consisted of need analysis, design and development, and implementation and evaluation of the e-module's effectiveness for students' achievement, collaboration skills, and Urban Heat Island (UHI) awareness. The need analysis samples employed multistage sampling. The design and development phase used the Fuzzy Delphi method to validate the e-modules involving 11 experts in Geography Education and the UHI field. The research design in the implementation and evaluation phase used a quasi-experimental approach where a sample of schools was tested using stratified random sampling. The research results reveal a threat of UHI in Surakarta, as indicated by the increased Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI). Additionally, the result shows that the evaluations of the e-module by the teachers and students are 97.3% and 92.6% respectively. Then, the experts' consensus decision on the evaluation of feasibility in the design and development phase using the Fuzzy Delphi method gave a feasibility of 98.3%. The results of the teachers' and students' feasibility were 83% and 83% respectively. Those of the implementation and evaluation of the e-module indicated differences in learning achievement outcomes and UHI awareness between control and experimental groups, but there was no significant difference in the learning achievement of urban and rural students. The implication of the study can contribute to the knowledge of the UHI phenomenon. The UHI knowledge has implications for achieving the seven SDG goals of sustainable urban development, increasing climate resilience, improving public health, and sustaining ecosystems.

PEMBANGUNAN E-MODUL PULAU PANAS BANDAR UNTUK PELAJAR SEKOLAH MENENGAH DI SURAKARTA, INDONESIA

ABSTRAK

Tujuan kajian ini adalah tentang pembangunan E-modul Pulau Panas Bandar untuk pelajar Sekolah Menengah di Surakarta Indonesia dengan menggunakan model Design and Development Research (DDR) pada model Borg dan Gall. Kaedah kajian terdiri daripada analisis keperluan, reka bentuk dan pembangunan, serta pelaksanaan dan penilaian keberkesanan E-modul terhadap prestasi pelajar, kemahiran berkolaborasi, dan kesedaran Pulau Panas Bandar. Sampel analisis keperluan diperoleh melalui multistage sampling. Tahap perancangan dan pembangunan menggunakan kaedah Fuzzy Delphi untuk memvalidasi E-modul yang melibatkan 11 orang pakar dalam bidang Pendidikan Geografi dan Pulau Panas Bandar. Reka bentuk kajian pada tahap pelaksanaan dan penilaian menggunakan quasi eksperimen di mana sekolah-sampel diuji menggunakan stratified random sampling. Dapatan kajian menunjukkan bahawa terdapat ancaman Pulau Panas Bandar di Surakarta yang ditunjukkan dengan peningkatan Land Surface Temperature (LST) dan Normalized Difference Vegetation Index (NDVI). Hasil kajian juga menunjukkan bahawa penilaian keperluan E-modul daripada guru dan pelajar masing-masing adalah sebanyak 97.3% dan 92.6%. Kemudian, konsensus pakar untuk penilaian kelayakan tahap reka bentuk dan pembangunan menggunakan Metode Fuzzy Delphi memberikan kebolehpercayaan sebanyak 98.3%. Hasil kelayakan guru dan pelajar masing-masing adalah sebanyak 83% dan 83%. Kumpulan hasil implementasi dan penilaian E-modul menunjukkan terdapat perbezaan prestasi pembelajaran dan kesedaran Pulau Panas Bandar antara kelas kawalan dan eksperimen, walaupun tidak terdapat perbezaan yang signifikan dalam prestasi pembelajaran pelajar bandar dan desa. Implikasi kajian ini memberikan sumbangan kepada pengetahuan mengenai fenomena Pulau Panas Bandar. Pengetahuan Pulau Panas Bandar mempunyai implikasi dalam mencapai tujuh matlamat pembangunan mampan (SDG) iaitu pembangunan bandar berkelanjutan, meningkatkan ketahanan iklim, meningkatkan kesihatan masyarakat, dan menjaga ekosistem.

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LIST OF ABBREVIATIONS

BEM	Building Energy Models
CCEE	Climate Change and Environmental Education
CCESD	Climate Change Education for Sustainable Development
CDD	Cooling Degree Days
EBBI	Enhanced Built-Up and Bareness Index
ECI	Environmental Criticality Index
EPA	The Environmental Protection Agency
ESD	Education for Sustainable Development
GNDVI	Green Normalised Difference Vegtetaion Index
IBI	Index-based Built-Up Index
IPCC	Intergovernmental Panel on Climate Change
LST	Land Surface Temperature
MCM	Micro Climate Models
MODIS	Moderate Resolution Imaging Product Spectroradiometer
NDBaI	Normalised Difference Bareness Index
NDBI	Normalised Difference Built-Up Index
NDVI	Normalised Difference Vegtetaion Index
NDWI	Normalised Difference Water Index
OECD	Organisation for Economic Co-operation and Development
PISA	Program for International Student Assessment
SAVI	Soil Adjusted Vegetation Index
SDGs	Sustainable Development Goals

UHI	Urban Heat Island
UI	Urnam Index
UN	United Nation
UNCRC	The United Nations Convention on the Rights of the Child
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	The United Nations Children's Fund
ZPD	Zone of Proximal Development

APPENDIX LIST

A	Human Research Ethics
B	Research Permit
C	URBAN HEAT ISLAND MODULE
D	Expert Judgement of Need Analysis
E	Instrument of Need Analysis
F	Permission to Adapt of The Awareness Instrument
G	Permission to adapt of The Collaboration Instrument
H	Expert Judgement
I	Validation of UHI Knowledge
J	Validation of UHI Collaboration
K	Validation of UHI Awareness
L	Effectiveness Sheet
M	Proofread Certificate
N	14 NDVISKT AND LSTSKT MAP

CHAPTER 1

INTRODUCTION

1.1 Introduction

Urbanization phenomena increase over time throughout the world. Population migration to urban areas transforms the building environment, urban settlements, lifestyle, cultures, behaviours, and environment. More people live in urban areas than rural areas, 55 per cent of the world's population resided in urban areas in 2018. In 1950, 30 per cent of the world's population resided in urban areas; by 2050, 68 per cent of the world's population is estimated to live in urban areas. There is significant variation of urbanization levels in different geographical regions (UN, 2019); (Chmutina & Bosher, 2017). The increase in urban population is driven by overall population growth and the increased population percentage in urban areas. Furthermore, almost 90 per cent of the population growth takes place in Asia and Africa. An illustration of urban population trends in the world is presented in Figure 1.1.

Human's increasing activities cause temporal and spatial climate change due to urbanization. Concentration of population in urban areas causes microclimate change. Global warming is a phenomenon that is currently felt throughout the world. Global warming is indicated by an increase in the world's temperature due to increased human activity. From the twenty-first century, climate warming has been projected to increase ranging from 1.0 to 3.7 depending on future greenhouse gas emissions (T. R. Anderson et al., 2016).

Figure 1.1

World Urbanization Prospects 1950-2035

Source: statistics from United Nations Population Division (2018)

The current impacts of urbanization include Urban Heat Island, flood, urban poverty, air pollution, violence, traffic spikes, and crime in a global context ((Himiyama, Satake, & Oki, 2019); (Chmutina & Bosher, 2017). Furthermore, based on the Sustainable Development Goals (SDGs) by 2030 education will be essential to achieve the entirety of these goals, including Goal 13 in climate action. Education for

Sustainable Development (ESD) transforms knowledge, skills, attitudes, and values to reach sustainability in society for all. The Sustainable Development Goals are a solid platform to consider a comprehensive curricular approach established. The Sustainable Development Goals require four skills besides literacy and numeracy–including readiness for primary education, technical and vocational skills, and skills needed to promote global citizenship and sustainable development (Care et al., 2017). (Joynes, Rossignoli, & Fenyiwa Amonoo-Kuofi, 2019) (2019), other terminology associated with21st Century Skills – especially life skills', but also including 'soft skills', 'transverse skills', 'critical skills' and 'digital skills' —are often considered synonymous with 21st Century Skills. However, some are diverse in personal, professional, and practical attributes. Furthermore, Joynes, Rossignoli, and Amonoo-Kuofi concluded, based on some literature, that the 21st Century Skills are classified into five critical areas associated with primarily professional features: (1) communication skills, including language and presentation of ideas, (2) collaborative skills, including group activity and social interaction management, (3) individual learning approaches, including critical thinking, metacognition, and new skills acquisition, (4) individual autonomy, including flexibility, adaptability and entrepreneurship, and (5) ICT and digital literacy, including use of technology as learning, communication, and collaboration instrument.

Achieving Goal 13 is supported by Goal 4, aiming to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all (*Sustainable Development GOALS*, 2015). With regard to education, Sustainable Development Goal 13 target explains that education is the key to mass understanding of climate change adaptation and mitigation, particularly at local level (Leicht, 2015).

The United Nations' concern about climate change is indicated in the United Nations Framework Convention on Climate Change (UNFCCC) in recent conference in Katowice, Poland, in December 2018, in which article Six of the UNFCCC highlights the importance of Education in dealing with climate change. Furthermore, the UNFCCC explains the importance of Education, Training, and Public Awareness and calls on States to undertake various actions, including developing and delivering education and public awareness programs on climate change and its impacts. Furthermore, there is a need to create educational and awareness materials, establish training programs and train various personnel, facilitate public access to climate change information, and foster public participation to deal with climate change. With regard to the importance of education in the climate change sustainability offered by (Mochizuki & Bryan, 2015) CCESD can be associated with the following three core learning pillars:

1. Learning to know – CCESD would involve understanding basic climate science, various dimensions and connections concerning the causes and consequences of climate change, and adaptation and mitigation strategies.
2. Learning to do – CCESD would encompass the development of relevant skills and action competences such as critical thinking, problem-solving, and systematic thinking skills, lifelong learning skills, and the skills to adapt and cope with risks and uncertainties.
3. Learning to live together and be – CCESD would introduce individuals to a range of knowledge, skills, and attitudes, such as knowledge of global issues, respect for values such as peace, human rights, and justice, and empathy for and openness to varying perspectives.

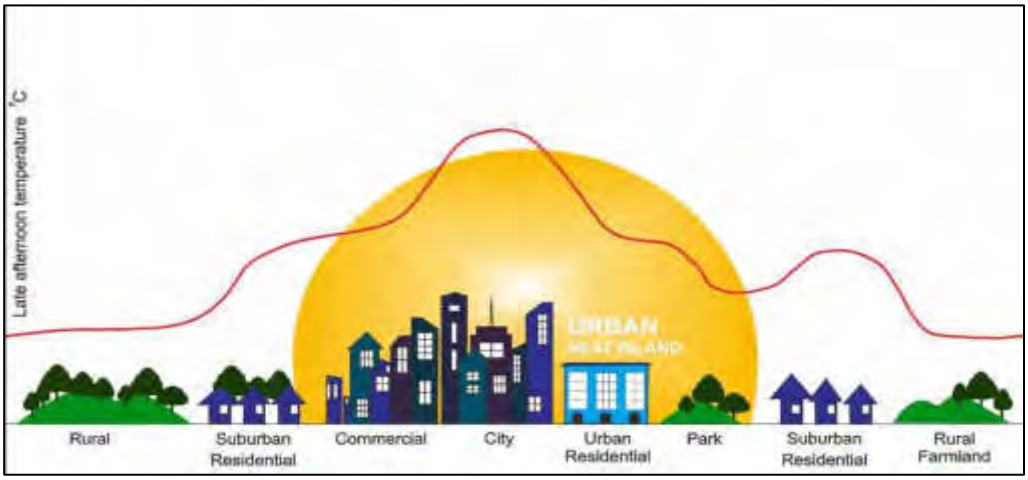
Mochizuki and Bryan believed that in order to achieve the aims of CCESD, learning process should be active, starting from learning to know, learning to do, and learning to live together and to be.

1.2 Background Research

The World Bank reported that Indonesia's cities are growing faster than those in other Asian countries at a rate of 4.1 % per year. By 2025, Indonesia would expect 68.5% of its population to live in urban areas (WorldBank, 2016). Urban Heat Island is one of the climate change phenomena in an urban area. Urban Heat Island occurs when urban temperature is higher than suburban temperature (Masumoto, 2015); (Heaviside, Vardoulakis, & Cai, 2016); (Mohajerani, Bakaric, & Jeffrey-Bailey, 2017). Figure 1.2 illustrates the Urban Heat Island phenomenon: high temperature in an urban area and gradual decrease in a rural area.

Figure 1.2

Urban Heat Island Illustration



Source: Author Illustration

In the midst of 20th century, many studies were conducted on urban atmospheres, including on Urban Heat Island, to capture the spatial detail of urban temperature phenomena. Today, the topic Urban Heat Island emphasizes urban temperature in the world. Theeuwes (2016) studied the physical based condition to analyze typical Urban Heat Island max at street level of northwestern Europe's different urban locations and climates types. The equation was tested in 14 urban areas across northwest Europe and it seemed to be robust. The comprehensiveness of this analytical condition takes into account applications beyond urban meteorological studies. Chapman (2017) studied the effects of climate change and urban growth on future urban temperature and the potential for increased heat stress on urban occupants. Urban development affected local temperature by up to 5 C in the Northeast US. In some areas, climate change increased the heat island, such as Chicago and Beijing, and decreased others, such as Paris and Brussels.

Based on the changes in land-use in Jakarta from 2000-2012, about 49.7% of green open space was converted into built-up area, resulting in increased surface temperature and creating the Urban Heat Island phenomenon in Jakarta (Rushayati, Prasetyo, Puspaningsih, & Rachmawati, 2016). Besides this, Urban Heat Island has also been widely studied by Indonesian researchers, such as Urban Heat Island identification on Jakarta and Lampung by Malik (2015). The results of the Urban Heat Island research in Lampung and Jakarta show that Urban Heat Island threats were identified in these two cities; in Lampung Urban Heat Island was identified in the morning but was weaker during the day, while in Jakarta Urban Heat Island was stronger; in the evening, Urban Heat Island was not identified in both cities. Bandar Lampung and Jakarta residents

were highly vulnerable to the rise in average temperature. Bandar Lampung was slightly less vulnerable than Jakarta (Manik & Syaukat, 2015).

Urban Heat Island is one of the climate change phenomena but not introduced at school, while Urban Heat Island threatens big cities in Indonesia. Considering the syllabus of Geography for Senior High School, global warming and its effects have been studied in grade X of Indonesian School Senior High School. Global warming is covered in the essential competences of the atmospheric dynamics (table 1.1). Based on the syllabus of Geography for grade X Senior High School above, Urban Heat Island can be included into the climate change indicators as one of the impacts of climate change. Urban Heat Island phenomenon should be introduced in schools, especially in urban areas. Urban students are threatened by Urban Heat Island in relation to uncomfortable learning. A conducive and comfortable learning environment promotes active learning. Rising urban temperature results in increased classroom temperature (Puteh et al., 2015). Regulation of Minister of Education No. 2 article 6 on the use of book in education units states (1) Textbook is used as a compulsory reference by educators and students in learning process, (2) in addition to the textbook as referred to in item 1, educators may use educator manuals, e-module, and reference books in learning process, (3) to increase students' knowledge and insight, educators can encourage students to read e-modules and reference books.

Urban Heat Island E-module is a book containing enriched textual materials for primary and secondary educations. Urban Heat Island can be introduced to students through Geography in essential competences of atmospheric dynamics. Urban Heat Island is not included in any textbooks, so Urban Heat Island knowledge can be

presented through Urban Heat Island E-modules under the Regulation of Minister of Education. The Urban Heat Island E-modules may improve students' thinking skills and broaden their horizon of the environment based on latest knowledge. Besides a suitable substance, Urban Heat Island E-modules should also be presented excellently to foster students' reading interest. Urban Heat Island e-modules are needed to open students' insight of any Urban Heat Island s around them. Urban Heat Island e-modules are to be compiled through design and development research. Research and development are a method used to produce specific product and test its effectiveness (Sugiyono, 2017).

Table 1.1

Basic Competency of Atmospheric Dynamic on Senior High School Syllabus

Basic Competency	Indicators
1. Analyzing humans-environment relationship as a result of atmospheric dynamics 2. Presenting the results of analysis on human-environment relationship as the impacts of atmospheric dynamics in narratives, tables, charts, graphs, illustrated, and concept maps.	1. atmospheric layers 2. weather and climate 3. climate type classification 4. climate characteristics in Indonesia 5. impacts of global climate change 6. research on climate and its utilization.

Source: Kemendikbud, 2013

Therefore, this study will develop Urban Heat Island e-module for school students' achievement, collaborative skills, and awareness in Surakarta.

1.3 Problem Statement

City is region with both administrative and morphological boundaries. City's morphology is characterized by dominance of land built due to population concentration, driving its life in the city's activities and dynamics. Surakarta city's overgrowth now leads to agglomeration (Iqbal & Basuki, 2017). Surakarta city's density was 11,530.99 people/km2 in 2015, increasing the need for urban space (Putri et al., 2016). Land-use change in Surakarta is overgrowing, as indicated with the increase in built-up land from 1999-2000 to 2000-2017 of 340%. Surakarta's temperature surface in 1994, 2000, and 2017 continuously changed from about 21°C-24°C (lowest) to 34°C-37°C (highest), and such temperature changing indicated Urban Heat Island in Surakarta (Baroroh, 2017).

Meanwhile, (Susilawati, 2016) reported that her analysis result using the Normalized Differentiation Vegetation Index (NDVI) and Land Surface Temperature (LST) indicated that Urban Heat Island threatened Surakarta. Surakarta's NDVI was categorized of low level of 0.491 from 2003 to 2011. This shows that the land use was dominated by settlement and low vegetation density. Meanwhile, LST analysis using Landsat TM 8 Satellite Imagery illustrated Surakarta's average surface temperature increased from 33.1^{o}C – 35^{o}C in 2003 to 36^{o}C – 37^{o}C in 2011. The micro-climate changes in Surakarta City caused the people there, including students at School, to face the rising Urban Heat Island. Students are one vulnerable group of the vulnerability factors, not to mention students are also one education component in the community, as part of the assets of the nation's generation that may be involved in disaster mitigation, such as Urban Heat Island mitigation.

Rapid urban sprawl and growth leads to substantial urban thermal environment changes and influences local climate, environment, and residents' quality of life (Xiong, Peng, & Zou, 2019); (Silva, Silva, & Santos, 2018; Yan, Wu, & Dong, 2018) Land use change will inevitably lead to urban reshaping and alter urban environment's temperature (Pan, Wang, Hu, & Cao, 2019); (Qiao, Tian, Zhang, & Xu, 2014). In general, some urban parts (building surfaces, roofs, and impervious fractions) are identified as the warmest zones, while water and vegetated area are identified as the coolest zones (Quan, 2019); (Bartesaghi Koc, Osmond, Peters, & Irger, 2018)(Geletič, Lehnert, & Dobrovolný, 2016). Overheating urban environment is of an important concern with consequence on residents' comfort and energy consumption. Surface albedo represents the most influencing parameters of local temperature. Therefore, functional and large-scale detection could significantly contribute to urban microclimate assessment (Baldinelli & Bonafoni, 2015). Higher temperature and thermal discomfort in local urban area are known as Urban Heat Island's effects (Lee et al., 2017; Qaid, Bin Lamit, Ossen, & Raja Shahminan, 2016); (Hien & Ignatius, 2016). Urban Heat Island is a modern local zone with a much higher temperature than those within its region, and is an everyday phenomenon in the exceedingly developed zone, such as large cities. This impact encompasses negative effects on the administrative vitality of building features that collectively affect human well-being, particularly for old individuals (Seebacher et al., 2019).

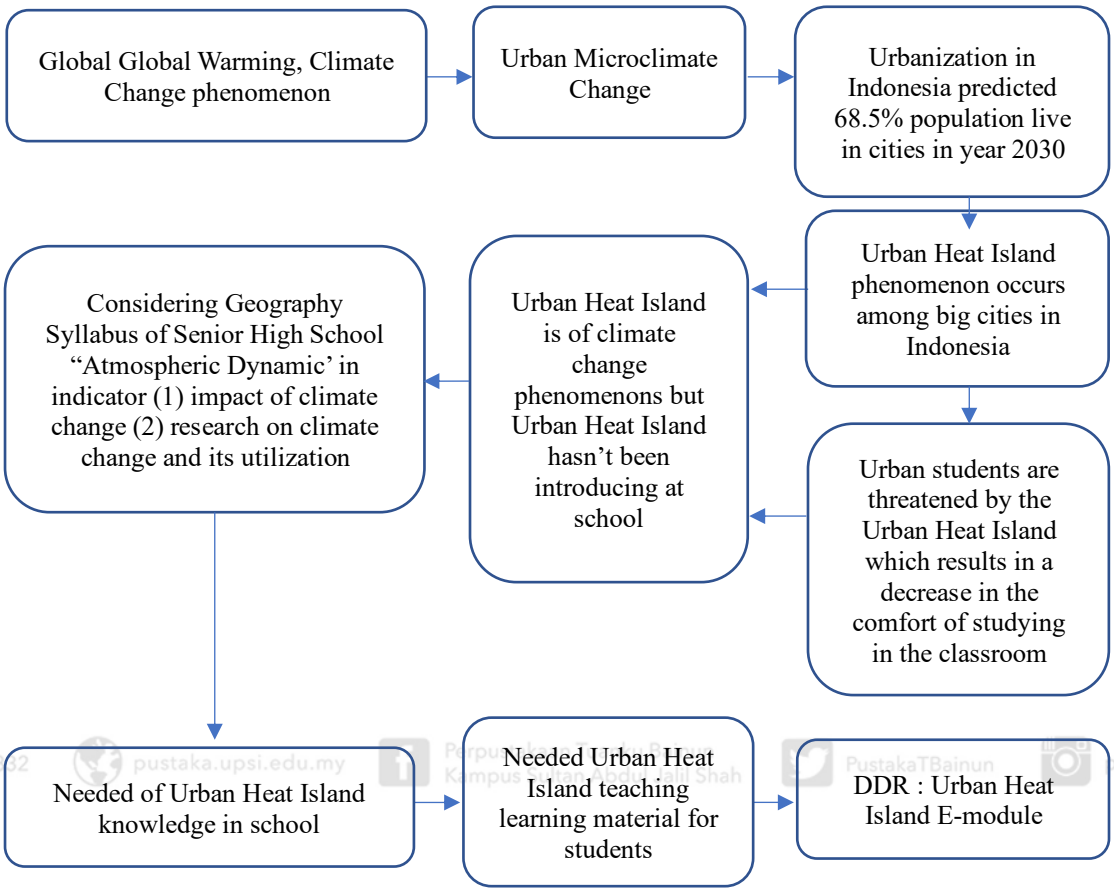
Urban heat is a natural stress that significantly influences human health and well-being. Urban Heat Island, exacerbated by increasing urban temperature and as climate change is in progress, will affect vulnerable populations at a neighborhood or census block group level (Voelkel, Hellman, Sakuma, & Shandas, 2018)(Taylor et al.,

2015). Children are a population at a risk of extreme temperature, and 0-18 years old students are a group vulnerable to the climate change effects (Guevara Sanches, Nunez Peiro, & Neila Gonzalez, 2017)(Vanos, 2015; Zivin & Shrader, n.d.), (Räsänen, Heikkinen, Piila, & Juhola, 2019). Climate change decreases schools' existing environmental health issues (Sheffield et al., 2017). Urban sprawl affects local climate, which then affects microenvironment, such as plants, people, and buildings, including external and internal school environments, causing discomfort for teachers and students during classroom teaching and learning process (Puteh et al., 2015).

Urbanization in Surakarta results in a fragmented urban sprawl pattern in several districts that keeps growing close to one another (Mardiansjah, Handayani, & Setyono, 2018). Urbanization in Surakarta drives increase in urban temperature and raises Urban Heat Island phenomena, but the phenomena have not been introduced to students as a vulnerable group. The Urban Heat Island learning materials that Surakarta students need are explained in figure 5. Urbanization in Surakarta results in a fragmented urban sprawl pattern in several districts that grows close to one another (Mardiansjah et al., 2018). Learning media for Urban Heat Island are needed in Indonesia and the world. Based on 65 papers' Urban Heat Island literature review, there is no research on Urban Heat Island teaching-learning.

Figure 1.3

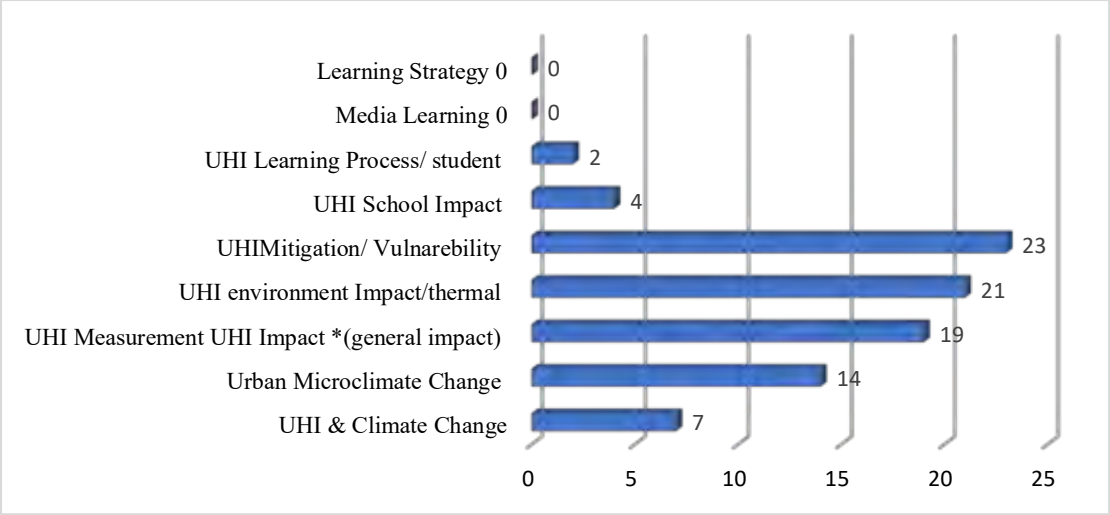
Flowchart of Urban Heat Island E-module is Needed for Surakarta Students



Source: Author

Figure 1.4

Urban Heat Island E-module Research Gap Graph



Source: Author

Based on the literature review, the majority examines mitigation related Urban Heat Island, Urban Heat Island vulnerability, Urban Heat Island impacts, Urban Heat Island measurement, and Urban microclimate change. At the same time, in education, four papers are about Urban Heat Island's school impacts and two papers are about Urban Heat Island process learning, but there is no paper exploring Urban Heat Island learning media and Urban Heat Island learning strategy.

(Susilawati & Sekartaji, 2019) reported that students' knowledge of the threat of disasters in Surakarta City was explored through information on Urban Heat Island knowledge at school. The study's population was Grade Seven students of SMP 1 Muhammadiyah Surakarta and Grade Seven students of SMP 10 Muhammadiyah Surakarta, totally 216 students. The exploratory research's results were that the students' knowledge of Urban Heat Island in Surakarta City was still low, thus introduction to

Urban Heat Island phenomena at school was needed. Even 93% of the students agreed that Urban Heat Island learning materials were needed at school. Based on the preliminary studies above, we may conclude that knowledge of Urban Heat Island threat is needed for urban students, including students in Surakarta.

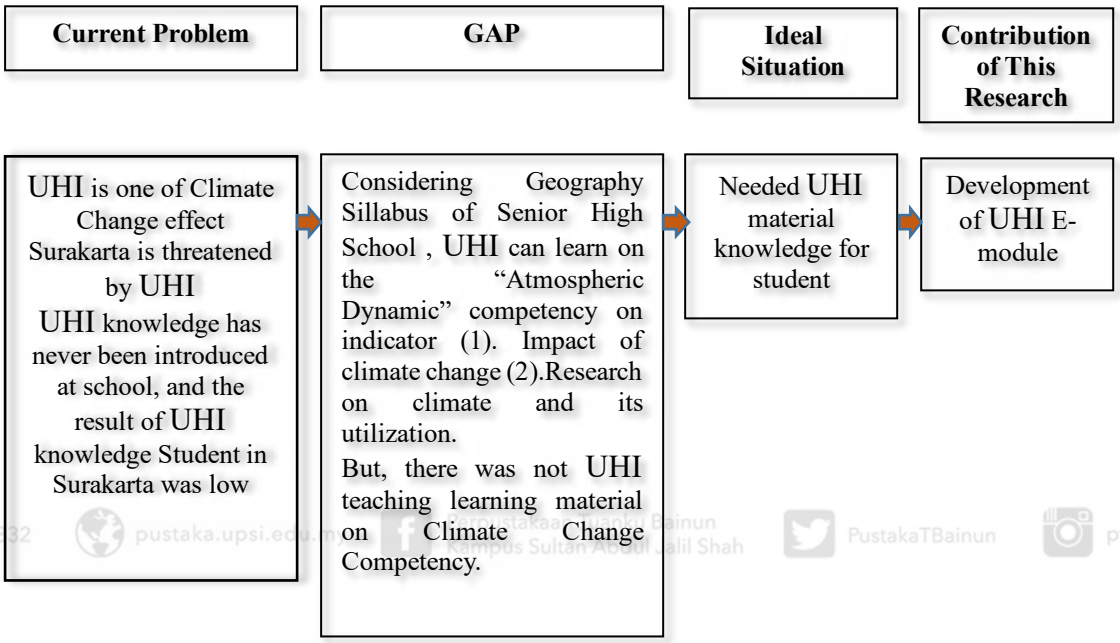
The OECD 2030 Learning Framework states that environmental problems (e.g., climate change and depletion of natural resources require urgent action and adaptation) are the first problem: the need for new solutions to rapidly changing world and economic and social issues. Furthermore, the (OECD, 2017) the OECD 2030 Learning Framework explains that Education plays a vital role in developing knowledge, skills, attitude, and values enabling people to contribute to and benefit from inclusive, sustainable future. Education needs more than preparing young people for the working world; it needs to equip students with the necessary skills to become active, responsible, and engaged residents. According to the OECD 2030 Learning Framework, Urban Heat Island E-module needs to open students' insights into surrounding Urban Heat Island threats.

Mitigation of Urban Heat Island, which threatens Surakarta residents, can be made through Urban Heat Island e-module by engaging students to get actively involved in projects, implementing projects, and assessing the project under collaborative activities. Learning has to be founded on the constructivist concept. Students get the opportunity to interact with the environment through well-organized tasks, dialogues, and reflections on their conceptions; thus, the solutions agreed on can be reached through various senses and in building multiple-intelligence. Students'

assessment of the activities is based on achievement, collaborative skills, and Urban Heat Island awareness.

Figure 1.5

Research Gap



Source: Author Illustration

Referring to Regulation of Minister of Education Number 23 of 2016, Students' achievement is carried out to measure and determine the students' Urban Heat Island competences based on learning process through the Urban Heat Island e-module developed. At the same time, Collaborative skills actively encourage students' interaction and communication. Partnership for 21st Century Learning proposes the 21st Century Learning Framework that highlights the 4Cs (Critical thinking, Communication, Collaboration, and Creativity). The '4Cs' model asserts that 21st-century challenges will demand a broad set of skills, emphasizing individual's core subject and social and cross-cultural skills. Based on the systematic review by

Chalkiadaki (2018), the 21st Century social skills include communication and collaboration, oral and written communication, team work, especially in heterogeneous environments, open-mindedness, and conflict management). Furthermore, CCR (2015) stated that with the world's increasing complexity, the best approaches to solving multifaceted problems encourage collaboration among people and agencies with different skills and backgrounds. Collaboration enables a group to make better decisions than individuals personally. In comparison, Collaboration skills encourage students' active interaction and communication.

Referring to the I-change model (de Vries, 2017), awareness is the result of knowledge, cues to action, and individual's risk perceptions, while awareness factor is determined by predisposing (behavioral, psychological, biological, and social-cultural factors) and information factors (message, channel, source). Awareness is formed by individual's knowledge and realized cues to action, and individuals will then be responsible for their risk perception. Students' Urban Heat Island awareness needs to be measured since Urban Heat Island threat is around them daily. Measuring Urban Heat Island awareness describes students' knowledge, cues to action, and risk perception of Urban Heat Island phenomena. Most Urban Heat Island studies are on Urban Heat Island measurement regarding Urban Heat Island identity and the relation of urbanization impact to Urban Heat Island. There are few studies on the relationship between school and the learning process, but there is no study on the development of Urban Heat Island teaching materials.

This study's scenario to meet the variables aims to design and develop a Urban Heat Island E-module for teaching-learning at school. This Design and Development

Research (DDR) study used Borg and Gall's model consisting of 10 stages. The three main phases of DDR (C. R. Richey & Klein, 2014), are: 1) needs analysis phase, 2) design and development phase, and 3) implementation and evaluation phase. This study's independent variable is Urban Heat Island E-module, and the dependent variables are students' achievements, awareness, and collaboration skills of Urban Heat Island. The basic conceptual framework is given in figure 5. According to the preliminary research, Urban Heat Island phenomenon was identified in Surakarta based on existing conditions.

1.4 Purpose of the Study

This research aims to design and develop a Urban Heat Island E-module in Surakarta through Borg and Gall's DDR model.

1.5 Objective of the Study

The research objectives are Urban Heat Island module's design, which is divided into 3 phases: this study's research objectives are explained below:

1. To identify the needs for Urban Heat Island E-module development
2. To design and develop a Urban Heat Island e-module for school students
3. To examine the effectiveness of the Urban Heat Island e-module for students' achievement, collaborative skills, and Urban Heat Island awareness

1.6 Research Questions

Based on the research objectives above, the research question is described below:

1. Is there a need to develop the Urban Heat Island e-module for school students?
2. How to design and create a Urban Heat Island e-module for school students?
3. How is the Urban Heat Island e-module's effectiveness for students' achievement, collaboration skills, and Urban Heat Island awareness

1.7 Research Hypothesis

This study's research hypotheses are as follow:

1. H01 : There is no difference in students' pretest Urban Heat Island achievement between the control and experiment groups
2. H0 2 : There is no difference in students' posttest Urban Heat Island achievement between the control and experiment groups
3. H0 3 : There is no difference in student's pretest and posttest Urban Heat Island achievement in the control class
4. H0 4 : There is no difference in student's pretest and posttest Urban Heat Island achievement in the experiment class
5. H0 5 : There is no difference in students' Urban Heat Island awareness between the experiment and control groups.

6. H0 6 : There is no regression between students' collaboration skills and achievement
7. H0 7 : There is no regression between students' Urban Heat Island awareness and achievement
8. H0 8 There is no difference in Urban Heat Island achievement between urban and rural students

1.8 Operational Definitions

This research's operational definitions cover Urban Heat Island, Design Development Research, three domains of objective learning, and preparedness.

1.8.1 Urban Heat Island

(T R Oke, 1973) stated that Urban Heat Island is a phenomenon of city warmer than surrounding areas all day long. Also, as Oke explained, Urban Heat Island is one of the clear examples of unintentional urban modification by humans. Stewart explained that "Urban Heat Island" was first declared by Balchin and Pey in 1947, referring to the atmospheric warmth of a city compared to the countryside (Stewart & Oke, 2012). Urban Heat Island phenomenon occurs in almost all large or small urban areas in all climatic regions. Urban Heat Island is a phenomenon of warmer urban temperature than rural or underdeveloped surroundings. Urban Heat Island is an atmospheric modification that can be found in settlements of all sizes in all climatic

regions and alter the radially aerodynamic, radioactive, moisture and thermal properties in an urban area compared to its surroundings (Roth, 1991). Based on the previous arguments, we may conclude that Urban Heat Island is a specific urban phenomenon by which the temperature rises in an urban area compared to its surroundings.

1.8.2 Design Development research

Design and development research studies the design, development, and evaluation processes by systematically establishing an empirical basis for creating instructional and non-instructional products and instruments and new or enhanced models. Richey explained that Design Development Research is a unique inquiry type of the Instructional Design and Technology (IDT) field that results in new knowledge and validation of the existing practice (C. R. Richey & Klein, 2014).

1.8.3 Students Achievement

The American Psychological Association defined achievement as the competence an individual has in an area of content, and competence is the result of many intellectual and non-intellectual variables (Association, 1999). Algarabel explained that achievement is an individual's competence in a knowledge domain (Algarabel & Dasi, 2002). Student's achievement in this research means student's competence in Urban Heat Island knowledge through the learning processes presented in the Urban Heat Island e-module.

1.8.4 Collaboration Skills

The collaboration ability in this research is related to PISA 2015's definition of collaborative problem-solving skills. Individuals are effectively involved in some process and problem solving attempt through an understanding to reach a solution. This ability combines knowledge and skills to achieve problem-solving (OECD, 2017). In addition, the collaboration skills in this research refer to Fiore, with two main areas of collaborative problem-solving. The two main areas are collaborative (for example, communication or social aspects) and knowledge or cognitive aspects (for example, domain-specific problem-solving strategies), often called "teamwork" and "task work." (Fiore et al., 2017). This research aims to assess collaborative skills to measure the students' collaboration in Urban Heat Island learning using the Urban Heat Island e-module.

1.8.5 Students' Urban Heat Island Awareness

Students' Urban Heat Island awareness refers to "environmental" and "awareness" based on Collins English Dictionary. As indicated in Collins English Dictionary 2009, environment means the 'external conditions or surroundings, especially those in which individuals live or work' or 'external surroundings in which a plant or animal lives, which tend to influence its development and behavior.'

Furthermore, Collins English Dictionary 2013 defines awareness as 'the state or condition of being aware; knowing; consciousness.' Thus, environmental awareness

can be described as being aware, having knowledge about, and being conscious of the external surroundings in which individuals live and work, which tend to influence people's development and behavior. As a result, student's Urban Heat Island awareness can be defined as being aware of Urban Heat Island, having knowledge on Urban Heat Island, and being conscious of the external surroundings in which individuals live and work, which tend to influence people's development and behavior in Urban Heat Island phenomena.

1.9 Limitation of Study

The research indicates urban school students' need for Urban Heat Island e-module. Urban school students are affected by Urban Heat Island phenomenon directly. Urban Heat Island e-module provides information on such phenomena occurring around students. Urban school students are affected by Urban Heat Island phenomena presently. The Urban Heat Island e-module provides information on the phenomena emerging around students. Urban Heat Island e-module was designed and developed for learning outcomes in the form of student's achievement, effectiveness, collaboration skills, and Urban Heat Island awareness. The Urban Heat Island e-module was designed and developed based on Borg and Gall's Model, consisting of 10 steps. The data were collected in the first step involving the students in identifying and measuring Urban Heat Island in Surakarta and identifying Urban Heat Island phenomena in Surakarta city and its suburban area by interpreting the Landsat TM 8 Satellite Imagery for NDVI and LST. The students involved were from Senior High Schools in Surakarta who were selected by school location's spatial distribution.

1.10 Importance of Research

The research provides teaching materials on Urban Heat Island in an e-module. The e-module's Urban Heat Island knowledge provides new information of the global warming effects, which obviously threatens urban students. The Urban Heat Island e-module's development results in learning outcomes of students' cognitive, affective, psychomotor, and Urban Heat Island awareness.

1.11 Summary

Constant urbanization from time to time leads to global warming and climate change worldwide. Besides, this effect causes urban microclimate changes in the form of higher temperature than that in rural areas, commonly known as an Urban Heat Island (Urban Heat Island) phenomenon. The literature review shows that Urban Heat Island occurred in several big cities in Indonesia. In dealing with the climate change issues, based on the Sustainable Development Goals (SDGs) by 2030, education is essential to actualize all of these goals, including Goal 13 on climate actions. Urban Heat Island is one of the phenomena of climate change effects, but has not been introduced to students at school. Based on Senior High School's Geography Syllabus, global warming and effects have been studied in grade X of Indonesian high schools. Global warming does exist in the essential atmospheric dynamics competences, but there is no Urban Heat Island. As one impact of climate change, Urban Heat Island can be covered as indicators of climate change phenomena. Urban Heat Island phenomena must be introduced at schools,

especially for urban schools. Meanwhile, Urban Heat Island has threatened several big cities in Indonesia, including Surakarta.

Urban Heat Island can be introduced to students through Geography in the essential competences of atmospheric dynamics. Urban Heat Island is not included in any textbook; thus, Urban Heat Island knowledge can be accessed through Urban Heat Island E-module based on the Regulation of Minister of Education. Urban Heat Island E-module may contain textbook enriching material on primary and secondary education level. Urban Heat Island e-module may enhance students' thinking skills and broaden their horizons of the environment based on latest knowledge. In addition to good substance, Urban Heat Island e-module should also be presented with fun to raise student's interest in reading it. Urban Heat Island e-module is needed to open students' insights of Urban Heat Island occurring in their surroundings.