LEBANESE AMERICAN UNIVERSITY

Science Teachers' Pedagogical Content Knowledge of Plastic Waste

By

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Dedication

To my loving parents

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Science Teachers' Pedagogical Content Knowledge of Plastic Waste

Rozan Dakroub

ABSTRACT

The purpose of this research study was to explore the pedagogical content knowledge (PCK) of science teachers in Lebanon regarding teaching about plastic waste and plastic waste as a socio-scientific issue (SSI). SSIs are open-ended and controversial issues connected to science content. Efficacious SSI teaching is indispensable for developing scientific literacy (SL). Plastic waste, with its links to science, politics, ethics and economics, can be classified as an SSI. For the purpose of the current study's investigation, the five PCK components from the PCK-BSSI model of Han-Tosunoglu and Lederman (2021) were considered. This research employed a case study design. Participants were ten science teachers. Data sources included interviews, classroom observations, and teachers' lesson plans. Data were analyzed through qualitative thematic analysis. Results were compared and triangulated to increase credibility and trustworthiness of the study findings. Findings showed that science teachers' PCK of plastic waste was characterized by low-order practices, inadequate scientific knowledge, ineffective teaching strategies, and traditional forms of assessment. The results also showed that science teachers' PCK reflected minimal aspects of SSI. The science teachers sought to integrate disciplines, make connections to real-world problems, engage students in questioning, and involve them in discussions. Nevertheless, higher-order thinking, scientific argumentation, inquiry-based learning, and understanding the nature of science were rarely part of their lessons. In addition, the science teachers did not incorporate the political, social, ethical, and economic aspects of plastic waste into their science instruction. Although this study is limited to science teachers in Lebanon,

the findings raised new questions for future research. Recommendations are provided to science educators, policy-makers, and curriculum designers.

Keywords: Pedagogical content knowledge, Plastic waste, Science teachers, Scientific literacy, Socio-scientific issues.

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Chapter One

Introduction

1.1. General Research Area

The purpose of this research study is to explore the pedagogical content knowledge of science teachers in Lebanon regarding teaching about plastic waste and plastic waste as a socio-scientific issue. Socio-scientific issues (SSI) are multidisciplinary (Forbes & Davis, 2007; Kara, 2012) and complex real-world situations at the interplay between science and society (Ratcliffe & Grace, 2003; Sadler et al., 2007). Since SSI represent modern science problems that are tightly linked to social, political, and economic concerns (e.g., Oulton et al., 2004), they cannot be solved by depending merely on scientific knowledge (Oulton et al., 2004; Ratcliffe & Grace, 2003; Sadler et al., 2007). Choi et al. (2011) indicate that the 21st century skills include citizens' acknowledgment of how science is connected to society, along with acknowledging their duties towards SSI.

Over the last three decades, one essential argument of science education has been about emphasizing what is indispensable to scientific literacy (SL) (Karışan & Zeidler, 2017). Roberts and Bybee (2014) call for differentiating between Vision I and Vision II of SL. While the former stresses on the alignment of the features of academic content within science disciplines, the latter stresses on incorporating personal decision-making on contextually deep-rooted science and social issues (Roberts & Bybee, 2014). The author of this study adopts perspectives consistent with Vision II of SL. This perspective puts forward that a scientifically literate citizen must be able to confront, debate, and undergo decisions in daily situations that contain science (Sadler, 2011). SL

is regarded to be crucial to an individual's profound participation in society (Bybee, 2008). In other words, the mutual dependence of science and society lies at the heart of SL, which is an enduring goal of science education (Karışan & Zeidler, 2017).

One example of a socio-scientific issue that can trigger students to undergo decision-making are issues related to the environment (Rizal et al., 2017), such as global climate change or the loss of worldwide biodiversity (Oulton et al., 2004). Several studies state that environmental problems are an SSI (e.g., Wang et al., 2018; Weinberger & Dreyfus, 2013), since they are shaped by social, cultural, political norms, and public opinions (Wang et al., 2018). Environmental issues contain values — and are ill-structured and controversial (Weinberger & Dreyfus, 2013). More specifically, one current socio-scientific issue related to the environment is the issue of plastic waste and how humans are dealing with it.

The United Nations defines waste as "materials that are not prime products […] for which the generator has no further use in terms of his/her own purposes of production, transformation or consumption, and of which he/she wants to dispose" (Department for Economic and Social Information and Policy Analysis, 1997, p. 76). Likewise, the European Union describes waste as "any substance or object which the holder discards or intends or is required to discard" (European Union, 2008, p.9). In either case, the intention to discard an object is principal to define waste (Kedzierski et al., 2020). Kedzierski et al. (2020) claim that the transition of plastic from object to waste is incompletely understood, despite the shift being one of the central sources to plastic pollution. Therefore, since the term plastic waste is the dominant cause leading to plastic pollution, plastic waste in specific will be adopted in this study.

According to Nxumalo et al. (2020), plastic waste pollution is a multifaceted issue. The problem of mismanaged and unmanaged plastic waste is attributed to a lack of infrastructure (Browning et al., 2021; Jambeck et al., 2018), absence of equitable distribution of economic resources, environmental injustice due to the disposal of plastic waste produced by the developed world, along with the frequent absence of an accountable, equitable, and effective political governance (Browning et al., 2021).

Nevertheless, in attempts to deal with the critical plastic waste issue, education on plastic waste management is becoming progressively dominant across the globe (Chow et al., 2017). Chow et al. (2017) indicate the following four major educational approaches for educating about the plastic waste problem: community-based, government-based, business-based, and school-based education. In the school-based educational approach, the topic on plastic waste may fall under environmental education or may be integrated within different subjects.

Shortland (1988) questions whether, how, when, and where lay people should have a more direct voice in scientific matters. There has been growing research worldwide required from teachers, governments, and employers on the skills and abilities by future citizens to thrive in life, profession, and citizenship (Barth, 2009). These skills project beyond basic reading, writing, and calculation to incorporate skills of critical thinking, problem-solving, cooperation, communication, creativity, and digital proficiency (Barth, 2009). The fundamental challenge for teachers is to recognize these skills and implement strategies for their development in science education (Barth, 2009). According to Bybee (2008), understanding the environment is critical and being

scientifically literate about the environment is indispensable to all citizens in the global community. Citizens must act responsibly in a global plastic waste crisis.

Inspired by Shulman's (1986) report, several researchers have concentrated on teachers' knowledge and how it is developed (e.g., Borko & Putnam, 1996; Calderhead, 1996). The report presented the concept of pedagogical content knowledge (PCK) as a distinct body of knowledge for teaching (Park & Oliver, 2008). The concept of PCK was initially presented by Shulman during a discussion to the meeting of the American Educational Research Association in the 1985 Presidential Address (Shulman, 1986). Following that, a significant amount of research has been produced to examine PCK in various subjects (Abell, 2007; Grossman, 1990; Park & Oliver, 2008; You, 2011).

According to Shulman (1986), PCK is a combination of content and pedagogical knowledge. PCK is believed to induce an influence on the practices of teaching, since it is tightly related to "the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, p. 9). PCK goes "beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" (Shulman, 1986, p.9). It has been represented as the knowledge required to transform subject matter content into forms more understandable to students (Geddis et al.1993; Grossman, 1990; Marks 1990; Shulman 1986, 1987). The foundation of science PCK impacts teachers by ways that would effectively enhance students' science learning to understand subject matter, explain it in novel ways, and invest it in activities and feelings to be embraced by students (Shulman, 1987).

Shulman (1986) reveals three components of PCK: (1) knowledge of topics taught in the subject area, (2) knowledge of forms of representation of those ideas, and

(3) knowledge of students' understanding of the topics. Later, Gudmundsdottir and Shulman (1987) have further developed the components of PCK into: (1) knowledge of the topics and concepts of the subject matter that can exist and are taught to students, along with the knowledge of analogies, similes, examples and metaphors to justify subject matter to students, (2) knowledge of the various approaches that topics can be taught, along with their advantages and disadvantages, and (3) knowledge of students' preconceptions or misconceptions about the topics they learn, along with the knowledge of the subject of the topics that students find interesting, hard, or easy to learn.

Moreover, Bullough (2001) indicates that upon Shulman's notion of PCK, a movement was about to occur in how teachers think about the knowledge foundation of teaching. Many studies on PCK have been carried out, where most of the researchers examined the elements of PCK exhibited by teachers, while concurrently teaching with Shulman's concepts of PCK in the background (Kim et al., 2015). Similarly, Han-Tosunoglu and Lederman (2021) confirm that most studies in the field have elaborated and developed on Shulman's work (1986, 1987).

Although Shulman's concept of PCK has been explained in various ways, it remains to provide meaningful insight into enhancing teaching of science (Loughran et al., 2004). The subsequent researchers have further expanded the PCK components and their sub-components. With respect to Shulman's (1987) clarification, Grossman (1990) adds one component related to the conceptions of purposes for teaching. Accordingly, Grossman (1990) puts forward the following four components of PCK: (1) knowledge of instructional strategies and representations, (2) knowledge of students' understanding, conceptions, and misconceptions, (3) knowledge and beliefs about the purposes for

teaching, and (4) knowledge of curricula. Similarly, extending from Shulman's (1987) clarification, Tamir (1988) adds one component related to knowledge of evaluation, which is not present in Grossman's (1990).

Furthermore, to conceptualize PCK for science teaching, Magnusson et al. (1999) build on the work of both Grossman (1990) and Tamir (1988). Magnusson et al. (1999) present five components of PCK: (1) orientations toward science teaching, (2) knowledge and beliefs about science curriculum, (3) knowledge and beliefs about students' understanding of specific science topics, (4) knowledge and beliefs about assessment in science, and (5) knowledge and beliefs about instructional strategies for teaching science. Later, Bayram-Jacobs et al. (2019) are found to adopt four PCK components from the PCK model of Magnusson et al. (1999).

Scarce studies from the literature are related to teachers' PCK on plastic waste as an SSI. Yet, with the available literature, teachers vary considerably in their PCK to develop an adequate context to teach on plastic waste and plastic waste as an SSI. For instance, pre-service teachers in a study adopt the inquiry-based learning approach to engage students in recycling plastic bags, as well as to develop communication and critical thinking skills on the plastic pollution issue (Sang, 2010). In other instances, the fundamentals of proper plastic disposal are established through non-teaching time (So & Chow, 2019). Consuming students' free time in a meaningful way is a pedagogically crucial aspect of education. In other words, informal education permits students to carry on and apply their developed habits of mind to unstructured situations and settings.

Based on what has been presented before, studies from the literature mainly cover the PCK of teachers on plastic waste to raise awareness on the dangers of plastic

waste to the environment and promote an understanding on the importance of an adequate disposal of plastic waste (e.g., Sang, 2010; So & Chow, 2019). In contrast, the PCK of teachers on plastic waste as an SSI means that students create innovative solutions to diminish plastic waste, critique the policies related to plastic production, evaluate the consumption methods of plastic, and design alternatives of plastic to reduce their use. The literature lacks enough studies that reflect on the PCK of teachers regarding teaching about plastic waste as an SSI.

On the other hand, the number of published articles in the fields of environmental science and environmental studies on plastic are rising yearly (Nielsen et al., 2020). Plastic has been one of the most researched matters, with the literature mostly covering marine pollution and relatively scarce studies on plastic pollution about land or soil (Nielsen et al., 2020). Specifically, marine plastic pollution — the umbrella that covers plastic litter and micro-plastic — has long been one of the most researched topics (Nielsen et al., 2020). Kazour et al. (2019) indicate that plastic pollution in the marine environment is becoming a global problem. Yet, the argument has earned more recognition lately, magnified by the increasing political and social awareness to micro-plastic (Nielsen et al., 2020). Also, other studies find it necessary to emphasize the environmental and economic values of plastic pollution (e.g., He & Kua, 2013; Thondhlana & Kua, 2016). The next section gives information about plastic waste being an environmental challenge all over the globe.

1.1.1. Plastic Waste as an Environmental Challenge

The adequate disposal of plastic waste has been an environmental challenge over

the globe. Browning et al. (2021) set forward that due to its chemical composition, plastic cannot decompose naturally. Drzyzga and Prieto (2019) explain that the degradability of plastic significantly relies on the type of molecular bonds present in the polymers. Plastic with hydrolysable bonds in their backbone (e.g., ester or urethane bonds) can be depolymerized by enzymes (Wierckx al., 2018). While the non-biodegradable nature of plastic leads to a huge environmental problem (Seghiri et al., 2017), Drzyzga and Prieto (2019) reveal that engineering enzymes for degrading plastic are developing as a new field.

Nevertheless, plastic breaks down into micro-plastic and accumulates in landfills due to their non-biodegradable nature (Cressey, 2016). Similarly, Andrady (2011) finds that the defragmentation of larger plastic on coasts — due to oxidation, heat, and radiation — releases micro-plastic in the aquatic environment. Additives can be crucial for the functionality and preservation of plastic material throughout its use (Hahladakis et al., 2018). However, due to the weathering conditions in the environment, plastic decomposes discharging portion of their additives (Andrady, 2011). The next section shows how the breakout of the coronavirus disease of 2019 (COVID-19) has induced changes in the standards of living and altered consumer behavior, thereby increasing plastic waste.

1.1.2. Plastic Waste amid the COVID-19 Pandemic

At a first glance, the COVID-19 pandemic is assumed to have positive impacts on the environment as the breakout has ceased industrial and economic activities (Muhammad et al., 2020). Nevertheless, recent studies have found that the COVID-19 outbreak has contributed to an increase in plastic waste in the environment (e.g.,

Ahmadifard, 2020; Silva et al., 2021). For instance, hospitals in Wuhan produced more than 240 tons of plastic medical waste each day during the pandemic climax — six folds more than the daily average prior to the pandemic (Adyel, 2020; Zuo, 2020). Silva et al. (2020) explain that masks and gloves must not be put on for more than a couple of hours and must be properly thrown away to inhibit cross-contamination. Moreover, throughout an eight-week lockdown in Singapore, packed meals and home supplied items led to an increase in 1,400 tons of plastic waste (Bengali, 2020).

While COVID-19 remains spreading, the haphazard utilization of plastic and improper disposal of plastic waste by numerous citizens is swiftly growing into a global issue (Silva et al., 2021). Disposable face masks that are reachable to landfills, freshwater, oceans, or public spaces could result in a new source of micro-plastic fibers — upon degrading into smaller fragments of plastic known as micro-plastic (Fadare & Okoffo, 2020). As a result of the COVID-19 pandemic, the global proliferation in the production and consumption of face masks has led to a novel environmental challenge increasing the massive plastic and plastic particle waste in the environment (Fadare & Okoffo, 2020).

Hence, the global pandemic did not reduce the challenge of the growing plastic pollution (Fadare & Okoffo, 2020). COVID-19, a worldwide health emergency, weighs additional pressure on the standard practices for waste management, resulting in unsuitable management strategies, such as incineration, landfills, and local burnings (Silva et al., 2020). The COVID-19 pandemic has further exposed the existing vulnerability of the global waste management system. The next section gives information on the state of the plastic waste crisis in the global south.

1.1.3. Plastic Waste in the Global South

According to the Central Pollution Control Board (2013), plastic pollution challenge has become a major issue in many countries located in the global south. Similarly, Bashir (2013) indicates that some countries located in the global south are incapable of providing appropriate waste management strategies. More recently, Browning et al. (2021) highlight that the most severe costs will be heavier in developing countries as the plastic waste crisis is accelerating and demands instantaneous action. Also, underdeveloped nations are at a greater risk for exposure to health hazards and environmental degradation resulting in long-lasting severe influences on livelihood security and economic growth (Yang et al., 2018). In relation to the purpose of the study, the next section will reveal the state of plastic waste in Lebanon specifically, being a global south nation in the Arab state.

1.1.4. Plastic Waste in Lebanon

In recent years, a competition has largely increased in the plastic industry in Lebanon, a country located in the Eastern Mediterranean (Nassereddine & Wehbe, 2018). The Lebanese plastic industry is resilient due to enhanced operational and manufacturing practices, despite being regarded as a large producer of waste with respect to other industries (Nassereddine & Wehbe, 2018). Analysis of waste composition in Lebanon indicates that plastic is the third highest waste fraction (Abbas et al., 2017).

Nevertheless, Lebanon is a significant source of micro-plastic in the Mediterranean basin (Kazour et al., 2019; Sherlock, 2018), and more specifically, a potential sink of plastic in the Eastern Mediterranean (Duncan et al., 2018). Kazour et

al. (2019) reveal that the levels of micro-plastic present are higher than other Mediterranean regions. The significant difference may be due to the mismanagement of waste along the Lebanese coast, in which high plastic materials are visible to the naked eye (Kazour et al., 2019). In Lebanon, all kinds of micro-plastic shapes are present: square, rectangular, spherical and cylindrical (Kazour et al., 2019). Kazour et al. (2019) reveal that the white color of micro-plastic is dominating in Sidon (south of Lebanon) and Tripoli (north of Lebanon), while the blue color of micro-plastic is the most abundant in Beirut (capital of Lebanon).

1.2. Research Problem

Most of the research on PCK has concentrated on content knowledge rather than on issues that foster SL, such as SSI (Han-Tosunoglu & Lederman, 2021). Very little is known about what happens to the knowledge of teachers, particularly PCK during SSI instruction (Bayram-Jacobs et al., 2017; Han-Tosunoglu & Lederman, 2021). Teachers should develop a specific PCK for teaching about SSI, since SSI varies over areas of subject matter (Forbes & Davis, 2007; Han-Tosunoglu & Lederman, 2021) and there are challenges faced in teaching it (Forbes & Davis, 2007). For instance, Han-Tosunoglu and Lederman (2021) highlight that measuring PCK for biological SSI is much more complicated than measuring PCK for traditional content knowledge. Teachers who teach SSI must occupy appropriate knowledge on the subject matter, be effective in linking the issue to the curriculum, have skills for dealing with argumentation in the classroom, and possess knowledge of assessing students' skills in reasoning (Han-Tosunoglu & Lederman, 2021).

In this respect, PCK development includes a substantial shift in teachers'

understanding “from being able to comprehend subject matter for themselves to becoming able to elucidate subject matter in new ways, reorganize and partition it, clothe it in activities and emotions, in metaphors and exercises, and in examples and demonstrations, so that it can be grasped by students” (Shulman, 1987, p. 13). Hence, what differentiates novice from expert teachers is the display of such knowledge, whereby “the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by students” (Shulman, 1987, p. 15).

Furthermore, to include any conceptual models proficiently, the pedagogical nature of the model should be consistent with the teachers’ nature of PCK (Han-Tosunoglu & Lederman, 2021). While the key aspects of instructional quality are determined by PCK (Kleickmann et al., 2013), Saunders and Rennie (2013) indicate that a lack of pedagogical knowledge and a weak understanding of ethical frameworks contribute to teachers’ lack of confidence in addressing SSI. Moreover, with the concept of PCK being substantially personal (Gess-Newsome, 2015), teachers’ attitudes towards encountering SSI enhance student's SL influence teaching practices (Sadler et al., 2006). Han-Tosunoglu and Lederman (2021) explain that teachers develop the PCK components by using personal experiences and knowledge. Personal PCK constantly changes and reconstructs to develop into a firm aspect of a refined PCK (Gess-Newsome, 2015).

After inspecting the literature and with respect to the PCK of teachers regarding teaching about plastic waste, some teachers are found to merely rely on haphazard means of verbal instruction to influence students’ behavior (e.g., Dalu et al., 2020; Ko &

Lee, 2003). According to Kempton et al. (1995), many people do not sufficiently know about environmental issues to behave in an environmentally responsible way. More recently, according to the United Nations Environment Program (2018), more than 50% of the world population have inadequate knowledge regarding the effects of plastic waste on people and the environment.

With respect to Lebanon, inadequate public awareness is one of the main problems of solid waste management (SWM) in the country (Abbas et al., 2017). Only a small percentage of the public knows where domestic waste goes once it has been collected or how much the waste collection and disposal service cost (Abbas et al., 2017). Browning et al. (2021) reveal that one of the constraints through which many developing countries are unable of handling generated waste is due to lack of education. Similarly, according to Abbas et al. (2017), education is one way to promote public involvement to develop citizens' awareness for an enhanced SWM.

One remarkable solution to the problem of the plastic challenge is by modifying attitudes towards waste disposal (Nxumalo et al., 2020). Similarly, Chow et al. (2017) set forward that to diminish plastic waste, the state of plastic waste management among the public must be enhanced through altering individual's knowledge, attitudes, and behaviors toward plastic waste management. However, Mironenko and Mironenko (2020) contend that there are gaps in school education that lead to an inability for students to face the crisis beyond the classroom. The gaps in school education reveal that the global formal educational system has not picked up the urgency of the plastic waste crisis (Mironenko & Mironenko, 2020). Even more, Nxumalo et al. (2020)

contend that plastic waste management issues remain one of the poorly researched topics.

Hence, teachers' use of plastic waste as an SSI remains a far-fetched goal for engaging students on science-based social issues. Shortland (1988) puts forward that "If the general public is to have a voice in scientific decision-making, then it had better know something about the science whose future it is helping to decide" (p. 313). Not only does a greater comprehension of science increase the likelihood that people will apply their democratic rights, but also it increases the likelihood that they will apply these rights intelligently (Shortland, 1988). There should be an urgent need to invest in education on the plastic waste management challenge that can turn the crisis into a growth opportunity and assist lives that rely on its sustainability. Teachers should incorporate plastic waste as an SSI to induce a sociocultural view essential to a functional SL. The integration of SSI in teaching reveals the importance of science to society and helps students become better critical thinkers and citizens (Cross & Price, 1996; Dolan et al., 2009; Driver et al., 2000).

To elaborate further, a proficient teaching of SSI demands not only acknowledging the related content, but incorporating the content into political, social, and ethical dimensions of the issue (Romine et al., 2017). Teachers from the study of Kitagawa et al. (2018) conducted a field trip, where students collect waste along the shore. Students constructed a collection container that provokes people to recycle their plastic bottles (Kitagawa et al., 2018). Students also donated the financial gains from the recycled bottles and engaged in collaborative committees (Kitagawa et al., 2018). They are encouraged to write persuasive letters addressing the local community officials and

are motivated to initiate recycling at home and clean local areas (Kitagawa et al., 2018). The more citizens develop a greater comprehension of science, the more they are likely to apply their democratic rights intelligently (Shortland, 1988).

Nevertheless, Mironenko and Mironenko (2020) find that there is a lack of stakeholders collaboration, specifically on a united vision of an approach to tackle the plastic problem on all levels of the global education community. Along with stipulating the development of critical thinking, problem solving, and decision-making skills in the context of issues related to the well-being of individuals and societies (Stevenson, 2007), the Tbilisi Declaration stresses that students must 'be actively involved at all levels in working toward resolution of environmental problems' (Tbilisi Declaration, 1978, p. 18, as cited in Stevenson, 2007). In their study, Kitagawa et al. (2018) proficiently exemplify students' engagement in the social, economic, and political structures. A scientifically literate individual goes beyond the development of skills to apply their knowledge by engaging in decision-making. PCK on plastic waste as an SSI permits students to transform communities, jobs, and nations, as well as to develop adequate plastic waste management strategies.

Successful plastic waste management necessitates planning, economic and political ability, along with the development of physical and technical infrastructure from a national level to a local level in developing countries (Wilson et al., 2013). Addressing the challenge of unmanaged plastic waste must consider not only the technical, but also the ecological, political, social, and economic aspects specific to each area to which they are brought in (Browning et al., 2021). Students should be active participants at different levels, since only then can they engage in resolving

environmental issues. As the public supports a great deal of science, citizens have the right to criticize developments and to desire changes in policy or practice (Shortland, 1988).

In democratic societies, citizens have the right to impact decisions that are taken on an extensive range of issues in which they have an interest (Shortland, 1988). Teachers should aim towards shaping future citizens who are precautious and who make informed decisions. Exposing students to SSI as a context for empowering them and supporting citizenship assists in situating learning in meaningful contexts (Dagher, 2020). According to Han-Tosunoglu and Lederman (2021), an efficacious SSI teaching is indispensable for developing SL. SSI, a crucial context for SL, develops scientifically literate individuals who can undergo informed decisions. Thus, to investigate how science teachers are responding to the plastic waste disposal challenge, the following research study aims at exploring the PCK of science teachers in Lebanon regarding teaching about plastic waste and plastic waste as an SSI.

1.3. Research Purpose

The purpose of the following study is to explore the pedagogical content knowledge (PCK) of science teachers in Lebanon regarding teaching about plastic waste and plastic waste as a socio-scientific issue (SSI).

1.4. Research Questions

The following research questions aim to guide the study:

1. How can science teachers' PCK of plastic waste be characterized?
2. How do science teachers use plastic waste as a context to teach about SSI?

1.5. Rationale

Of the publications on the COVID-19 pandemic, only about 20% tackle the influence of COVID-19 disease on plastic pollution (Silva, et al., 2020). On the other hand, prior to the pandemic, Giesler (2018) indicates that environmental topics tend to be extremely subjective and that conducting research on these topics is minimal. Also, the United Nations Environment Program (United Nations Environment Program, 2018) reveals that there is a scarce discussion on the plastic waste management challenge on a local scale, along with limited evidence that uses data to understand plastic management issues in a geographical point of view.

To the author's knowledge, there are no studies from literature that address the PCK of teachers regarding teaching about plastic waste in the wake of COVID-19. Besides the pandemic, Mironenko and Mironenko (2020) contend that the gaps in school education reveal that the global formal educational system has not picked up the urgency of the plastic waste crisis yet. There is a lack of stakeholder collaboration, specifically on a united vision of an approach to tackle the plastic problem on all levels of the global educational community (Mironenko & Mironenko, 2020).

Concerning the Lebanese context, the following databases of the Lebanese American University (LAU) were searched: EBSCO, ERIC, JSTOR, and Shamaa, in order to identify Lebanese studies related to teachers' PCK regarding teaching about plastic waste and plastic waste as an SSI. No research is found about the topic in the Lebanese context that the present study seeks to investigate.

In Lebanon, waste production has significantly increased, and the country has experienced waste management conflict (Kazour et al., 2019). The regulated dumping

sites could no longer control the massive amount of waste produced, and hence, many unregulated and open dumping sites were generated mainly along the coast (Khalil et al., 2018). Hence, the present study will add to the literature, since pollution in Lebanon is at alarming levels, the country still lacks a coherent waste management plan, and COVID-19 is not in control yet. The positive cases of coronavirus in Lebanon soared dramatically after the explosion in the port of Beirut, the country's capital, on August 4, 2020 (Translated by ContentEngine, 2020).

Furthermore, Vlaardingerbroek and Taylor (2007) reveal that pre-service Lebanese teachers lag their Australian fellows in relation to their knowledge of global environmental issues and exhibit limited awareness of national issues with respect to the environment. Only less than a quarter of pre-service Lebanese teachers from the study recognize garbage management and absence of recycling as environmental issues (Vlaardingerbroek & Taylor, 2007). Consequently, it can be assumed that pre-service Lebanese teachers have limited knowledge and scarce awareness on local environmental problems.

Also, pre-service Lebanese teachers are more prone than their Australian fellows to be skeptic about the influence of environmental education on students' environmental attitudes and behaviors (Vlaardingerbroek & Taylor, 2007). Vlaardingerbroek and Taylor (2007) suggest that the hesitance may result from the hasty treatment of environmental topics in many schools. In addition, the pre-service Lebanese teachers from the study are less likely to recognize the need for people to alter their ways of living in favor of the environment (Vlaardingerbroek & Taylor, 2007). Therefore, the

target population in the current study was in-service teachers in Lebanon, which contributed to an assessment of their PCK in addressing plastic waste as an SSI.

Despite the growing number of research studies that explore how pre-service and in-service science teachers can use different topics as contexts to teach SSI, such as genetically modified foods (Kılınç et al., 2013), evolution (Borgerding & Dagistan, 2018; Hermann, 2013), climate change (Borgerding & Dagistan, 2018; Hestness et al., 2011), nuclear energy, and reproduction (Borgerding & Dagistan, 2018), how in-service science teachers teach about plastic waste as an SSI needs further inquiry. Most of the literature on SSI focuses mainly on students and how they form conclusions on such issues (e.g., Fowler & Zeidler, 2016; Sadler et al., 2007; Simonneaux & Chouchane, 2011; Tayne et al., 2018; Zangori et al., 2017).

On the other hand, according to Saunders and Rennie (2013), only a few research studies have tackled teachers and teachers' pedagogy, and still teachers have an important role to play. In other words, there is lack of research regarding the strategies and approaches for which educators are using to teach plastic pollution (Dalu et al., 2020). Even more, Fadare and Okoffo (2020) question whether plastic pollution may be the upcoming world pandemic.

Also, several studies from literature have used case studies to provide a detailed picture of teachers' values and motivations for teaching about SSI (e.g., Lee, 2006; Lee & Witz, 2009; Reis & Galvao, 2004). Nevertheless, these studies still lack the practices of these teachers. More recently, Chan and Hume (2019) indicate that studies that focus on capturing the nature of the integration between science teachers' PCK components are limited. More research should be done to 'understand how they [the components]

interact and how their interaction influences teaching' (Magnusson et al., 1999, p. 115). Hence, there is a great need for in-depth case studies that would concentrate on teachers' practices of planning for and teaching in SSI-based learning environments, along with their deeper beliefs and motivations for teaching about SSI.

Han-Tosunoglu and Lederman (2021) developed an instrument for biological socio-scientific issues (PCK-BSSI) to assess science teachers' understanding of SSI and PCK-BSSIs. For the sake of their assessment, Han-Tosunoglu and Lederman (2021) employ a survey approach. Han-Tosunoglu and Lederman (2021) consider that one of the limitations in their study is the lack of teacher interviews and observations regarding their planning and instructional decisions. The researchers set forward that although the instrument is topic specific, it can be used equally and adequately on other topics or disciplines to assess teachers' PCK. Hence, the following study adopted and modified the instrument developed by Han-Tosunoglu and Lederman (2021).

A case study design was used to explore how ten science teachers in Lebanon teach about plastic waste and plastic waste as an SSI. The researcher of this study found difficulties in securing ten participants, since there were challenges in finding current science teachers who teach about plastic waste. Due to the limited data set obtained from the participants, the recruited science teachers were considered altogether as one case study.

1.6. Significance

The current study should be conducted, since researchers and practitioners must be conscious of the various strategies to be used in Lebanese classrooms, in order to address the indiscriminate use and lack of proper disposal of plastic waste. To the best

of the author's knowledge, the present study is the first in Lebanon that explores the PCK of science teachers regarding teaching about plastic waste and plastic waste as an SSI; hence, the results will contribute to compelling evidence regarding the target context.

1.6.1. Significance for Research

While there is currently no unified international regulation on plastic regulation and pollution management, very rare countries place strict measures to restrain the unabated increase of plastic waste (Fadare & Okoffo, 2020). Hammami et al. (2017) highlight that there is lack of research regarding the consumption of plastic, which raises several questions concerning society's awareness and whether they are prepared to modify their behaviors of plastic consumption. Hence, it is important to educate future generations about preventing indiscriminate use and practicing the proper disposal of material in favor of the environment, particularly during a future epidemic.

Furthermore, due to the numerous realities and perspectives, along with the uniqueness of situations, the results from the following case study can be part of a growing pool of data. A case study can contribute to greater generalizability. Also, case studies can alert one to similar possibilities in other situations. Future research can benefit from the findings of this study as it will allow for cross-cultural comparative studies to be conducted.

1.6.2. Significance for Practice

The current study can benefit practitioners, such as teachers and schools globally that are concerned in developing scientifically literate citizens who can make decisions upon global challenges, such as in the current environmental crisis. Environmental

education continues to face serious restrictions and implementation problems (So & Chow, 2019), which is mainly from the absence of appropriate and useful environmental attitudes by teachers (Molstad et al., 2018; So & Chow, 2019). To ensure efficient implementation, teachers must be completely conscious of environmental aspects in education, as only then can they permit upcoming generations to be aware of these environmental challenges and their probable solutions (So & Chow, 2019). Students should be knowledgeable of and competent about plastic waste control and the preventive measures in order to minimize its' increase.

The present study will benefit practitioners by permitting them to develop knowledge on the plausible strategies and approaches that they may implement in the future with the rise of global environmental issues. In their study, Fadare and Okoffo (2020) indicate that the acknowledgment on the prevention of COVID-19 is extreme across the globe. For instance, precautionary actions such as staying at home, avoiding going out and gathering, wearing masks, and refraining contact with symptomatic people have been and are still being recurrent on the media, such as newspapers, television, radio, and Internet. There are posters in public spaces that also highlight the precautions on COVID-19. Yet, awareness regarding the aftermath of consuming plastic on health and the environment should be studied in schools.

Fadare and Okoffo (2020) stress that it would be worthy if awareness on protecting the environment by minimizing, eliminating, and properly managing disposable face masks can also be carried out. The study can benefit in designing the science curriculum and in including authentic environmental problems. For example, Li et al. (2019) reveal that The Marine Waste Project of the National Oceanic and

Atmospheric Administration (NOAA) seeks to raise awareness on the pollution of plastic particles through the public education program. Hence, this study is an additive to international literature, because it can provide knowledge on how teachers can effectively make use of difficult times, such as in environmental crises or global challenges to influence students' habits.

Chapter Two

Literature Review

The purpose of this chapter is to present an insight review of the literature on the components of pedagogical content knowledge among various scholars for integrating science knowledge with SSI. It also outlines the practices of science teachers on teaching about plastic waste and plastic waste as an SSI. While this chapter reviews the emergent literature on the science teachers' PCK regarding teaching about plastic pollution, it sheds light on the gaps that exist in this area of research.

2.1. Socio-scientific Issues (SSI)

Deriving out of the 1950s and 1960s on, an international awareness has been developing out of the need to be competent in the implementation of scientific and technological policies, citizens who can take part in discussions and in making decisions on SSI (Adúriz-Bravo & Pujalte, 2020). SSI are characterized as controversial issues that encompass ethical, moral or legal dilemmas consisting of multiple viewpoints with no palpable consensus (Walker & Zeidler, 2007). In the past years, SSI has become a noticeable theme within the literature on science education (Sadler, 2011). Knowing how students handle issues is related to the debate of the public understanding of science, since it presents information on the use and the need of science by novice people (Kolstø, 2001). If developing citizenship is a primary goal for science teachers, then there should be an examination of the contexts created for students to experience science (Sadler, 2009).

Sadler (2011) reveals a range of contexts and instructional approaches to engage students in decision-making on SSI. The development of SSI has scaffolded upon other approaches, which aim at better readying students to engage in discussions and decisions on science-based social issues (Sadler, 2011). For instance, context-based science education (Forbes & Davis, 2007; Sadler, 2011), science-technology-society (STS, Yager, 1996), and science-technology-society-environment (STSE) are among the approaches that overlap with the SSI approach (Sadler, 2011). Other approaches for discussing SSI include the cooperative and collaborative learning approaches (Bryce & Day, 2014). Moreover, SSI-based learning environments permit students to engage in higher-order practices, such as argumentation (Ratcliffe & Grace, 2003; Sadler, 2009; Saunder & Rennie, 2013; Zeidler & Nichols, 2009). For instance, one type of argumentation in science education incorporates science in a social setting that encompasses decision-making, political debate, or any kind of implications for society and individuals (Christneson et al., 2017).

Another approach for tackling science-based social issues is through using a framework based on critical thinking (Yacoubian, 2015), which is crucial to contribute to an informed decision (Yacoubian, 2018). Students should be skeptical, recognize bias in scientific arguments, and critically reflect on the reporting of science findings (Bryce & Day, 2014). In the weak sense, critical thinking is an attitude based on self-centered and prejudiced beliefs, in which individuals are critical to others without reflecting or interrogating one's own presumptions or actions (Paul, 1994). In other words, a critical person would be someone who points out the flaws and weaknesses in their surrounding world, yet not in one's own self (Paul, 1994). However, in the strong sense, critical

thinking begins from self-criticism, in which one's personal assumptions and beliefs are reflected on, re-inspected, and interrogated (Paul, 1994).

Similarly, Payne (2010) sheds light on the importance of critical theories to direct human action, as in the attainment of social justice and the proper management of human interaction. The philosophy of being critical should be embedded in science education to permit students to delve into science-based social issues. Science education should concentrate on developing citizens who are eager and ready to critically appraise systems of power, recognize injustices or harms, and respond accordingly to amend situations (Bencze & Carter, 2020). Bencze (2017), Bencze and Alsop (2014), and Hodson (2011) contend for science education as a way of readying students to intervene on societal issues in their responsibility as citizens. Students should be able to explore the different facets of identity rather than being tied up blindly and superstitiously in society.

Furthermore, according to Hansson (2020), the nature of science (NOS) assists students to understand the limitations of science and how science can lead to decisions made on SSI. Similarly, Driver et al. (1996) view that understanding NOS is essential for citizens to become aware of science and technologically related issues and to participate in the decision-making process in a democratic society. In addition, understanding NOS leads to SL along with citizenship (Erduran et al., 2020).

The previous paragraphs have explored the prominent contexts and instructional approaches to engage students in decision-making on SSI. The awareness of the social features of science can contribute to engage citizens with SSI (Kolstø, 2008). SSI — being a valuable context — plays a significant role in stimulating SL in school (Zeidler

& Sadler, 2011). SSI can be global in nature, such as climate change or can be local, such as addressing a neighborhood environmental crisis (Sadler, 2011). Human activities such as the accumulation of waste, the damage of ecosystems, and the exhaustion of resources significantly influence the global environment (Bybee, 2008). Consequently, citizens of each nation are progressively faced with the urge to comprehend complex environmental issues (Bybee, 2008). In the next section, plastic waste is discussed as an SSI in which the environmental, social, economic, and political aspects of the issue are addressed.

2.2. Plastic Production and Consumption

Plastic is composed of polymers that are formed through a process known as polymerization (Halden, 2010; Koushal et al., 2014). Polymers are chains of molecules — where each link of the chain is made of carbon, hydrogen, oxygen, and/or silicon (Halden, 2010). The chain is produced after the several links are polymerized, i.e., combined (Halden, 2010). The structure of the repeating units and kinds of atoms play a major role in deciding the characteristics of the plastic (Koushal et al., 2014).

Plastic is regularly used in daily life and in numerous ways (Koushal et al., 2014). The development of modern plastic expanded in the first 50 years of the twentieth century, in which a minimum of 15 new classes of polymers have been produced (Andrady & Neal, 2020). Koushal et al. (2014) indicate that plastic has become a crucial asset for humankind, mainly ensuring functionality that cannot be easily or economically substituted by other materials. The characteristics of plastic make it a convenient material as they are lightweight, low-priced, and long-lasting (Thompson et al., 2009). Also, Andrady and Neal (2020) reveal that plastic has shown versatility for

use in a variety of types and forms, such as: natural polymers; modified natural polymers; thermosetting plastic; thermoplastic; and biodegradable plastic.

Plastic has brought benefits to society in terms of economic activity, jobs, and quality of life. The swift urbanization and economic development in various countries have resulted in an extreme increase in plastic production and consumption across the globe (Chow et al., 2017). The production of plastic has been multiplying due to the global needs in the domestic, business, and health sectors (Amélineau, et al., 2016; Dalu, et al., 2020; Kumar & Singh, 2018). For instance, plastic deliberately produced in small sizes (Galafassi et al., 2019) are added to products, such as cleansers or fertilizers to provide a desirable property (Andrady, 2011; Foster & Environment, 2017; Sherrington et al., 2016; Wang et al., 2020). Other types of plastic may be used in automotive, electronics, and buildings (Seghiri et al., 2017).

Plastic can play a significant role in hospitals and the medical field (Koushal et al., 2014), whereby disposable syringes, intravenous **(**IV) sets, glucose bottles, plastic aprons, etc. are disposed of daily (Koushal et al., 2014). More recently, to inhibit the transmission of COVID-19, the use of Personal Protective Equipment (PPE), such as medical masks and gloves has become necessary (Silva et al., 2021). In response to the COVID-19 pandemic, plastic-made material such as PPE are considered as preventive strategies to protect the mouth, ears, and hands, thereby, preventing or minimizing a pathway for infection.

2.3. Plastic Waste and SSI

Environmentally, the production of plastic and the incineration of plastic waste produces around 400 million tons of CO_2 per year (Nielsen et al., 2020). Plastic

production results in global warming and air pollution (Verghese et al., 2006). Each year, about five to thirteen million tons of plastic end up in the ocean (Geyer et al., 2017). Moreover, plastic burning releases poisonous chemicals and contaminates the atmosphere, thereby leading to air pollution (Nxumalo et al., 2020). On the other hand, the degradation of plastic in landfills leads to the emission of methane — a main contributor to the greenhouse effect (Brydson, 1999).

Plastic waste can last for prolonged periods of time (Andrady, 2003). Kazour et al. (2019) explain that the fragmentation and dispensation of micro-plastic is a long-term process. Some plastic is not affected by the sun or microorganisms and can remain in the environment for years, thus intensifying the potential of their accumulation (Stevens, 2002). The precise lifespan of the discarded plastic relies on the chemical characteristic of the material, conditions of the environment in which it exists in, and on how breakdown is set out (Andrady & Neal, 2009).

Furthermore, plastic waste has increased largely in the last decades not only due to the production of plastic products in high volumes, but also since more than 40% of plastic is intended for single-use (Geyer et al., 2017; Mason et al., 2018; Parker, 2018) and just 20% to 25% for long-term use (Geyer et al., 2017; Hopewell et al., 2009). For instance, plastic bags are a major source of single-use plastic worldwide (Browning et al., 2021). Globally, a trillion single-use plastic bags are used yearly — approximately two million per minute (Larsen & Venkova, 2014). Stevens (2002) highlights a key point asserting that most plastic bags are resistant to degradation under the effect of the sun and/or microorganisms and can remain in the environment for years.

Since plastic remains in the ecosystem, almost all the plastic ever generated is

still existing (Geyer et al., 2017). Scientists have lately discovered micro-plastic in all places from the lowermost of the Mariana Trench (Chiba et al., 2018) — being the deepest oceanic trench on Earth — to human placentas (Ragusa et al., 2021). Less than 2% of the plastic waste generated since the 1950s has been recycled, less than 6% incinerated, and nearly 92% has been landfilled or disposed of in the natural environment (Geyer et al., 2017). It is noteworthy to highlight that plastic waste is not restricted to continents, since around 4.8 to 12.7 million tons of plastic ends up in the oceans every year (Agamuthu et al., 2019).

Socially, plastic embodies a crucial element of a scope of materials used in contemporary society (Andrady & Neal, 2009). For instance, plastic has been useful in clothing manufacturers, construction sectors, food industries, healthcare systems, and transportation vehicles (Andrady and Neal 2009). According to Halden (2010), the yearly production of plastic worldwide has exceeded 300 million metric tons. More recently, according to Ellen MacArthur Foundation (2016), by 2040, the production of plastic is expected to double. Yet, human health complications are among the problems found to be associated with plastic bag wastes (Adane & Muleta, 2011). Rochman et al. (2015) indicate that humans may as well suffer from potential harm upon consuming shellfish and fish with plastic litter. Also, European anchovies are eaten completely (without being degutted) by the Lebanese people that are delivered in several Lebanese restaurants, thus bringing up the concern on the ingestion of these contaminated seafood (Kazour et al., 2019).

Koushal et al. (2014) reveal that human beings are to be blamed for the misuse. Many nongovernmental organizations, notable reports (Ellen MacArthur Foundation,

2017; United Nations Environment Programme, UNEP, 2016), and civil society movements have contributed to increase the global attention of the complications accompanied with plastic (Nielsen et al., 2020). According to Fadare and Okoffo (2020), population sensitization can largely aid in the management of waste. Still, only a few countries have implemented strict actions to restrain the continuous growth of plastic waste (Fadare & Okoffo, 2020). For instance, The Marine Waste Project of the National Oceanic and Atmospheric Administration (NOAA) aims to stimulate awareness towards plastic pollution by the public education program (Li et al., 2019).

Economically speaking, plastic is inexpensive and a durable material that has been consumed worldwide in all the forms of everyday life and has enhanced the progression of society (Andrady & Neal, 2009). Most of the plastic is robust and lasts for hundreds of years. Plastic has replaced metals in the components of most manufactured goods and has often made the products cheaper, lighter, safer, and stronger (Koushal et al., 2014). Still there is currently no united international regulation on the regulation of plastic due to the controversy of economic interests (Fadare & Okoffo, 2020).

Diverse approaches have been applied by governments against single-use plastic, such as efforts to diminish plastic carrier bags (Kedzierski et al., 2020; Xanthos & Walker, 2017). For instance, Fadare and Okoffo (2020) indicate that Ireland imposes tax on consumers of single-use bag, whereas China and South Africa include ban and levies on retailers. In other instances, placing ban on face masks remains the least option, while considering its positive impacts in the persisting global fight against COVID-19 (Fadare & Okoffo, 2020). Nevertheless, adverse economic impacts on aquaculture and

tourism may arise upon the mismanagement of plastic waste (Newman et al., 2015). Several studies perceive that summer tourists are inclined to avoid beaches polluted by plastic waste (e.g., Free et al., 2014; Retama et al., 2016; Stolte et al., 2015).

While the circular economy (CE) is considered as a potential solution in which materials are repeatedly reused and recycled (Nielsen, et al., 2020), not all types of plastics can be recycled (North & Halden, 2013). With all attempts to separate and collect plastic waste, the percentage of plastic that is adequately recycled does not exceed five percent of the entirely plastic that is produced (Velis, 2014). Transitioning to CE demands the creation of products that permit ease of recyclability (Nielsen, et al., 2020). North and Halden (2013) suggest that plastic should be adequately separated, which raises the cost. The CE has also increased the challenges of making the collecting, sorting, and recycling of plastic waste economically feasible (Nielsen et al., 2020).

Politically, there is an absence of an established consensus on how to accurately define the plastic problem (Nielsen et al., 2020). Nielsen et al. (2020) expose that the entire plastic life cycle is political. Despite attempts created within marine plastic pollution, there is centrally no recognized global scientific or political authority tasked with addressing the plastic problem (Nielsen et al., 2020). For instance, plastic bottles remain the subject of a great deal of political debate (Nielsen et al., 2020). When the European Commission in recent times suggested compulsory tethered caps on plastic bottles, it was firmly rejected by Coca-Cola, Danone, Nestlé, and PepsiCo (Morgan, 2018). The purpose of the tethered caps is to ensure the caps remain firmly attached to

the plastic bottle from manufacture to disposal, and thus do not produce any separate waste.

Azar (2016) contends that the garbage crisis in Lebanon is an exemplary of the political bargains that occur behind the scenes there and somewhere else, whereby politicians exchange favors at the cost of citizens. Kazour et al. (2019) show the presence of high micro-plastics pollution in areas located in proximity to Lebanese coastal landfills. Although some landfills are no longer active, their waste continues to enter the sea due to mismanagement and lack of adequate treatments (Kazour et al., 2019). Azar (2016) asserts that the political bargain is not unique to Lebanon, but also to governments in the world who are unsuccessful in providing effective solutions to deal with garbage (Azar, 2016).

With respect to public health, plastic remains in the natural environment and continuously break into smaller pieces, thereby risking the life of humans and animals (Barnes et al., 2009; Cuthbert et al., 2019; Dalu, et al., 2020). Plastic and micro-plastic are often consumed by an extensive variety of organisms (Lusher et al., 2013) and nearly 100 species in the Mediterranean have been hurt either by consumption or entanglement (Deudero & Alomar, 2015). Also, some studies reveal the presence of micro-plastic in several Mediterranean fish species (e.g., Bellas et al., 2016; Giani et al., 2019; Rios-Fuster et al., 2019).

Plastic consumption by livestock can lead to digestive tract blockages and internal injuries (National Solid Waste Management Strategies for Swaziland, 2000). The issues relating to the death of livestock due to mistaking plastic bags for food have been reported by countries such as India, Kenya, South Africa and Somaliland (Ellis et

al., 2005). Plastic bag pollution is a threat to wildlife and livestock (Nxumalo et al., 2020). Plastic bags can block storm drains and sewage systems, leading to flooding and increased spread of disease (Nxumalo et al., 2020). Water stuck in plastic bags also presents an ideal breeding ground for mosquitoes, increasing the threat of malaria transmission (Nxumalo et al., 2020).

Furthermore, Hammami et al. (2017) indicate that the accumulation of plastic waste creates several problems to marine life. Plastic waste influences a vast range of marine life by being strangled, drowned, starved, or choked (Laist, 1987). The piling of debris poses a threat to marine mammals, seabirds, turtles, fish, (Laist, 1987; Van Franeker et al., 2011), and reptiles (Laist, 1987). Animals can become entangled, unable to catch food, powerless to run from predators, and suffer from wounds due to the abrasive action of the attached debris (Laist, 1987). For instance, Kazour et al. (2019) reveal that Anchovies caught in the Western Mediterranean Sea have ingested micro-plastics less than those caught in the Eastern and Central Mediterranean, thereby confirming the higher pollution of these regions.

Nevertheless, several studies notify that micro-plastic may pose a larger threat than macro-plastic (Browne et al., 2011; Henderson & Green, 2020; Thompson, 2015). The impact of micro-plastic on the eco-system is "…one of the most intensely discussed issues in environmental science..." (Haegerbaeumer et al., 2019). Micro-plastic has been identified in all forms of marine life (Wang et al., 2020), from tiny organisms, such as phytoplankton and zooplankton, up to supreme predators, such as larger fish and mammals (Cole et al., 2013; Haegerbaeumer et al., 2019; Romeo et al., 2015; Set¨ al¨ a et al., 2014; Tanaka & Takada, 2016). Microorganisms are extremely significant to the

sea food chain, and a decrease in numbers may contribute to issues in food safety (Cole et al., 2013).

Humans can inhale, swallow and ingest micro-plastic directly through air (Gasperi et al., 2018), bottled water (Zuccarello et al., 2019), table salt and seafood (Nelms et al., 2018) respectively. Recent studies have found that micro-plastics is present in the feces of humans (Yan et al., 2020; Zhang et al., 2021), thereby proving its ingestion (Anagnosti et al., 2020). Human tissue studied from patients with Alzheimer disease, associated toxicity and neural damage with lifetime exposure to micro-plastic (Manivannan et al., 2019). Even more, smaller nanoparticles have the capability interact with tissues (Raj et al., 2012), and can be distributed in the circulatory (Rothen-Rutishauser et al., 2006) and lymphatic system (Wright & Kelly, 2017). The next section reviews studies from the literature related to the components of PCK for teaching about SSI.

2.4. Pedagogical Content Knowledge for Teaching about SSI

As stated before, an efficacious SSI teaching is indispensable for developing SL (Han-Tosunoglu & Lederman, 2021). Han-Tosunoglu and Lederman (2021) indicate that to effectively teach about SSI, teachers need to be qualified with the dimensions of PCK for SSI. For instance, Lee (2016) conceptualizes an SSI-PCK framework to foster science teachers' confidence and knowledge on teaching about SSI. The framework includes six central components. According to Lee (2016), SSI-PCK includes orientation for teaching SSIs, which shapes the knowledge of instructional strategies for teaching SSIs, knowledge of assessment of SSIs, knowledge of curriculum, knowledge

of learning context, and the knowledge of students' SSI learning. The full text of Lee's article was not obtainable in an English version.

To carry on SSI instruction in science classrooms, teachers should occupy skills and understandings regarding teaching about SSI (Zeidler et al., 2011). Levinson (2006) indicates that teaching about SSI demands a comprehension of higher order cognitive skills, such as proficiency to evaluate an issue from several perspectives. Also, while SSI are affected by economic, political, and social ideologies, a proficient teaching of SSI demands not only acknowledging the related content, but incorporating the content into political, social, and ethical dimensions of the issue (Romine et al., 2017).

Furthermore, PCK is the knowledge required to convert subject knowledge such as science or mathematics in a way that students can comprehend (Magnusson et al., 1999). Hence, PCK is subject-specific depending on the content of every subject curriculum (Chang & Park, 2020). PCK may as well be domain or topic specific, since it demands different inquiry methods or instructional strategies depending on the subject (Magnusson et al. 1999). Similarly, Veal and Makinster (1999) classify different types of PCK as the general PCK, domain-specific PCK, and topic-specific PCK. The general PCK includes specific pedagogy of ideas and approaches in disciplines (Veal & Makinster, 1999). The domain specific PCK includes one of the different domains or subject matters within a particular discipline (Veal & Makinster, 1999). Some researchers have performed studies about the domain specific PCK of biology: photosynthesis and heredity (Park & Chen, 2012), genetic testing (Van der Zande et al., 2012), and evolution theory (Stasinakis & Athanasiou, 2016; Van Dijk, 2009). The topic specific PCK is the most precise level of pedagogy belonging to all ideas, terms,

approaches, metaphors, and misconceptions that a teacher must have to teach a specific topic of a science domain (Veal & Makinster, 1999). The construct of topic specific PCK (TSPCK) has been endorsed by Loughran et al. (2008), Mavhunga and Rollnick (2013), and more recently by Han-Tosunoglu and Lederman (2021).

On the contrary to Gess-Newsome's model of Teacher Professional Knowledge and Skill (TPK&S), which demonstrates the construction of subject-specific PCK (Gess-Newsome, 2015), Shulman's model is found to be entirely topic specific (Han-Tosunoglu & Lederman, 2021). Like PCK's topic-specific nature, SSI have a unique nature that is different from the traditional subject matter (Han-Tosunoglu & Lederman, 2021). Han-Tosunoglu and Lederman (2021) explain that "SSIs are topic specific, such as chemical bonds, the respiratory system, and Newton's laws" (p. 3).

Furthermore, teaching of the open-ended and controversial SSI is associated with the context of the school (Han-Tosunoglu & Lederman, 2021). A measure of PCK calls for awareness to the school context aspect particularly for expressing context-dependent subject matters, which is absent in Gess-Newsome's (2015) model. Knowledge of school is straightforwardly connected to context dependent subject matter knowledge, such as SSI (Han-Tosunoglu & Lederman, 2021). In addition, SSI are examined as valuable contexts in aiding students to acquire a diversity of new perspectives and to make decisions from what is learnt (Han-Tosunoglu & Lederman, 2021).

Hence, to assess teachers' PCK for biological socio-scientific issues (PCK-BSSIs), Han-Tosunoglu and Lederman (2021) conceptualize PCK for teaching science by adopting Shulman's model. Shulman's model is perceived as the favorable exploratory and topic-specific model to assess PCK for any topic (Han-Tosunoglu and

Lederman, 2021). The framework on which PCK-BSSI is based includes the five components of PCK: (1) subject matter knowledge, which is crucial for adequate teaching of BSSIs, (2) pedagogical knowledge, which includes teaching approaches, assessing BSSIs, and addressing students' misconceptions concerning BSSIs, (3) curricular knowledge, which specifies the awareness of the present BSSI curriculum and knowledge on linking BSSIs with the curriculum, (4) awareness and understanding of the students' weaknesses and difficulties about the BSSI, and (5) school context, which includes knowledge of the instructional context and learning environment for teaching of BSSIs (Han-Tosunoglu & Lederman, 2021).

Moreover, Han-Tosunoglu and Lederman (2021) indicate that knowing about teachers' understanding and perspective of teaching SSI is necessary. According to Shulman (2015), the crucial missing piece in PCK is related to the affective domain of the understandings and actions of teachers. Shulman (2015) explains that what teachers "know and do" is related to their own emotional and motivational modes, and their competence to impact the emotions, motives, resilience, and character formation means of students (p. 9).

Hence, Han-Tosunoglu and Lederman (2021) seek to investigate teachers' understanding and perception of SSI. Han-Tosunoglu and Lederman (2021) ask "Should SSI be a part of the science curriculum?" and "If you think it is important, what do you think is the best way to integrate SSI into your science instruction?" (p. 4). Individual attitudes play a crucial role in their curiosity, awareness, and reaction to science and technology in general and to issues that influence them in specific (Bybee, 2008). How

teachers consider teaching and learning is related to how students learn, and as a result influences students' conception and learning strategies (Igwebuike et al., 2013).

The current study aims to explore the pedagogical content knowledge (PCK) of science teachers in Lebanon regarding teaching about plastic waste and plastic waste as an SSI. Therefore, for the purpose of the current study's investigation, the five PCK components from the PCK-BSSI model of Han-Tosunoglu and Lederman (2021), which followed Shulman's ideas, will be considered. The five PCK components that will be used to explore teachers' instruction about plastic waste are: (1) subject matter knowledge, (2) curricular knowledge, (3) knowledge of students' understanding, (4) pedagogical knowledge, and (5) school context.

Furthermore, Han-Tosunoglu and Lederman (2021) developed an instrument for biological socio-scientific issues (PCK-BSSI) to assess science teachers' understanding of SSI and PCK-BSSIs. For the sake of their assessment, Han-Tosunoglu and Lederman (2021) employ a survey approach. Survey studies aim to collect broad surface-level information about a topic (Lapan et al., 2011). The PCK-BSSI is found to have three sub-scales: demographic background, understandings/ beliefs about SSI, and teachers' PCK about BSSI (Han-Tosunoglu & Lederman, 2021).

On the other hand, several studies from literature are found to apply a case study approach in an investigation on how science teachers deal with SSI (Hancock et al., 2019; Owens et al., 2019; Reis & Galvão, 2009). For instance, Owens et al. (2019) implement a case study to determine the practices that a secondary biology teacher employs while enacting SSI on antibiotic resistance. Owens et al. (2019) have relied on the SSI Framework for Teaching and Learning pioneered by Sadler et al. (2017). On the

other hand, the PCK for teaching SSI in the current study have been previously considered from the PCK-BSSI model of Han-Tosunoglu and Lederman (2021), which followed Shulman's ideas. Also, Han-Tosunoglu and Lederman (2021) set forward that although the instrument is topic specific, it can be used equally and adequately on other topics or disciplines to assess teachers' PCK.

Furthermore, Han-Tosunoglu and Lederman (2021) consider that one of the limitations in their study is the lack of teacher interviews and observations regarding their planning and instructional decisions. The interview obtains data on what the respondent thinks, knows, likes, values and believes (Tuckman, 1972). Hence, besides understanding teachers' PCK to teaching about plastic waste and plastic waste as an SSI, interviews will also aid in determining the teachers' attitudes towards teaching about it. Interviews will provide a close-up reality and a thick explanation on teachers' attitudes, content knowledge, curricular knowledge, knowledge of students' understanding, pedagogical knowledge, and school knowledge towards teaching about plastic waste.

The section has revealed that many studies from the field have developed on Shulman's notion of PCK. Although the concept of PCK by Shulman has been justified in many ways, it remains meaningful to promote teaching of science. Also, several studies have focused on PCK for content knowledge rather than on SSI. SSI remains a crucial element to foster SL. Teachers who teach about SSI should have sufficient content knowledge, be successful in forming connections to the curriculum, occupy argumentation skills, and be able to assess students' reasoning skills. The next section

provides a review on the available literature related to the pedagogical content knowledge of science teachers regarding teaching about plastic waste.

2.5. PCK of Science Teachers Regarding Teaching about Plastic Waste

As stated previously, for the purpose of the current study's investigation, five PCK components from the PCK-BSSI model of Han-Tosunoglu and Lederman (2021), which followed Shulman's ideas will be considered. Up to the author's knowledge, no studies from literature are found to cover teachers' instruction on plastic waste regarding students' knowledge and the school context. Therefore, the next section covers studies from the literature about teachers' instruction on plastic waste regarding the following components: (1) subject matter knowledge, (2) curricular knowledge, and (3) pedagogical knowledge. Also, since attitudes play a role in determining the PCK of teachers, then, a section on the attitudes of science teachers towards teaching about plastic waste is also presented.

2.5.1. Attitudes of Science Teachers towards Teaching about Plastic Waste

While several studies reveal that teachers hold positive attitudes towards teaching about plastic pollution (e.g., Dalu et al., 2020; Molstad et al., 2018; So & Chow, 2019), others are found to hold negative attitudes (e.g., Dalu et al., 2020; Ko & Lee, 2003). For instance, some teachers seek to enhance students' recycling behavior and aim for greater convenience in more recycling actions by the students (So & Chow, 2019). On the other hand, according to Dalu et al. (2020), teachers' own behaviors appear to oppose their beliefs. Although the teachers from the study tackle the potential threats of pollution, they tend to litter frequently (Dalu et al., 2020).

According to Kaur (2013), when teachers have a positive attitude towards the environment, they exhibit an inclination towards obtaining greater knowledge concerning the environment, its issues, and their solutions. One of the solutions to plastic waste might include developing a greater awareness among future generations. Yet, to do so, teachers should occupy a stiff body of knowledge regarding the causes and effects of plastic waste, along with adequate methods of disposing of the waste. Derived from the existing literature, the next section presents the subject matter knowledge component of science teachers regarding teaching about plastic waste.

2.5.2. Subject Matter Knowledge of Science Teachers Regarding Teaching about Plastic Waste

Some studies reveal that teachers have adequate content knowledge regarding teaching about plastic waste (e.g., Dalu et al., 2020; Molstad et al., 2018). Dalu et al. (2020) reveal that primary and secondary schools are aware of the influence of plastic waste in the environment, and the challenges that emerge from the use of plastic. Teachers exhibit knowledge related to the trouble of plastic disposal, the threats to aquatic and terrestrial organisms, the unfavorable outcomes on aesthetics, and the emission of poisonous gases (Dalu et al., 2020).

On the other hand, some teachers have inadequate content knowledge regarding teaching about plastic waste (e.g., Dalu et al., 2020; Oztas & Kalipci, 2009). For instance, most in-service teachers from primary and secondary schools are not knowledgeable, proactive, and conscious of the possible risks of plastic pollution (Dalu et al., 2020). The in-service teachers are unable to teach students and deal with the improper use, purchase, and disposal of plastic in the environment (Dalu et al., 2020).

Besides subject matter knowledge, teachers should have curricular knowledge. Curricular knowledge encompasses teachers' awareness of the presence of plastic waste or plastic-waste related topics in the curriculum. Teachers should also be knowledgeable about linking the issues with the curriculum. The next section presents the curricular knowledge component of science teachers regarding teaching about plastic waste.

2.5.3. Curricular Knowledge of Science Teachers Regarding Teaching about Plastic Waste

Some science teachers from a study report that there is no aspect of plastic pollution that is taught within the curriculum (Dalu et al., 2020). However, only grade seven teachers from the study report that there is certain content in the curricula that covers manufacturing of plastics and their environmental effects (Dalu et al., 2020). In another study, the rigid subject curriculum did not prevent teachers from teaching about environmental issues in non-class time, such as weekly assembly, co-curricular activities, lunch breaks, and recesses (So & Chow, 2019).

Science teachers must be proficient in connecting the curriculum to the lives of the students to form real world connections and engage students with society and culture. Besides curricular knowledge, teachers must have pedagogical knowledge that includes: the teaching approaches, assessing students' learning of plastic waste, and addressing students' misconceptions on plastic waste. The next section presents the different approaches, methods, and strategies used by science teachers to teach about plastic waste.

2.5.4. Pedagogical Knowledge of Science Teachers Regarding Teaching about Plastic Waste

One study reveals that a package of extensive plastic resources learning materials is developed for a program on Plastic Resources Education (PRE, So & Chow, 2019). Students are motivated to bring plastic waste from their homes to school, implement the recycling steps, and improve their hands-on experiences of plastic recycling and sorting (So & Chow, 2019). Teaching resources that deal with controversial issues expose students to opportunities in which they inspect the richness of the connections between science and society (Cross & Price, 1996).

Moreover, other studies report that when teaching about plastic waste, teachers use worksheets, teaching plans, guidelines, presentation files (So & Chow, 2019), videos (Kitagawa et al., 2018; So & Chow, 2019), picture books, and online websites (Kitagawa et al., 2018). Also, teachers in a study arrange recycling competitions with reward schemes to amplify the use of the recycling facility (So & Chow, 2019). Other teachers use questioning to trigger students' thinking about plastic-related issues (Kitagawa et al., 2018).

Furthermore, several studies have reported that teachers consider involving parents during their instruction on plastic waste by asking them to aid on banning plastic (Molstad et al., 2018), classifying plastic waste (So & Chow, 2019), and constructing plastic waste containers (Kitagawa et al., 2018). Parental involvement in a child's education has an influence on student learning, since parents are looked up to as role models in the eyes of their children. Other teachers assigned a green ambassador during non-class timeslots to inform students about the categorization of the seven plastic types

(So & Chow, 2019). Also, through informal education, teachers from a study utilize informal methods to pass on green messages over the school campus, such as using recesses and lunch breaks to promote PRE in creative and innovative ways (So & Chow, 2019). Teachers put posters in the classrooms (So & Chow, 2019) and in the hall to educate students on the need to preserve the environment from plastic waste (Dalu et al., 2020).

Despite the variety of attempts that several teachers use to teach about plastic waste, they merely promote a common understanding on plastic waste and raise awareness on the dangers of plastic waste to the environment. Although the teachers promote an understanding on the importance of an adequate disposal of plastic waste, they do not encourage students to assess present policies related to the consumption of plastic material, design alternatives of plastic to minimize their use, or construct future social and environmental solutions to dispose plastic. The next section presents studies from literature related to the pedagogical content knowledge of science teachers regarding teaching about plastic waste as a socio-scientific issue.

2.6. PCK of Science Teachers on Plastic Waste as an SSI

After a thorough inspection of the literature, it is found that there are scarce studies that tackle the pedagogical content knowledge of science teachers regarding teaching about plastic waste as an SSI. To the knowledge of the researcher, Kitagawa et al. (2018) is the only study found to have explored the PCK of science teachers regarding teaching about plastic waste as an SSI — even though the study does not explicitly state so. Teachers in the study adequately exemplify students' engagement in the social, economic, and political structures.

More specifically, the literature lacks studies in the Lebanese context that address the PCK of teachers regarding teaching about plastic waste as an SSI. The PCK of teachers on plastic waste as an SSI must permit students to transform communities, jobs, and nations, as well as to develop adequate plastic waste management strategies. Addressing the issue of unmanaged plastic waste must consider not only the technical, but also the ecological, political, social, and economic aspects. Students should be active participants at various levels, since only then can they engage in resolving the plastic waste issue.

2.7. Refocusing the Discussion

While most research on PCK focused on content knowledge rather than issues that promote SL, Han-Tosunoglu and Lederman conceptualize PCK for teaching SSI by adopting Shulman's model. For this study, the five PCK components from the PCK-BSSI model of Han-Tosunoglu and Lederman (2021), which followed Shulman's ideas, will be considered. The five PCK components that were used to explore science teachers' instruction about plastic waste are: (1) subject matter knowledge, (2) curricular knowledge, (3) pedagogical knowledge, and (4) knowledge of students' understanding, (5) school context. Chan and Hume (2019) indicate that studies that focus on capturing the nature of the integration between science teachers' PCK components are limited. More research should be done to 'understand how they [the components] interact and how their interaction influences teaching' (Magnusson et al., 1999, p. 115). Hence, there is a great need for studies that would concentrate on teachers' practices of planning for and teaching in SSI-based learning environments, along with their deeper beliefs and motivations for teaching about SSI.

More specifically, there is lack of research regarding the strategies and approaches for which educators are using to teach plastic pollution (Dalu et al., 2020). Despite the growing number of research studies that explore how pre-service and in-service science teachers can use different topics as contexts to teach SSI, how in-service science teachers teach about plastic waste as an SSI needs further inquiry. Therefore, the purpose of this research study is to explore the pedagogical content knowledge (PCK) of science teachers in Lebanon regarding teaching about plastic waste and plastic waste as a socio-scientific issue (SSI).

Chapter Three

Methodology

The purpose of this chapter is to present the research method used in this study, which aims to explore the PCK of science teachers in Lebanon regarding teaching about plastic waste and plastic waste as an SSI. This chapter also describes the study's research paradigm, methodology, methods, context, participants, instruments, data collection and analysis, validity and reliability, ethical considerations, and table connecting procedures to research questions.

This study is guided by the following two research questions:

1. How can science teachers' PCK of plastic waste be characterized?
2. How do science teachers use plastic waste as a context to teach about SSI?

3.1. Research Paradigm

A qualitative paradigm was used to address the study's research questions. A qualitative approach touches on research concerning individuals' lives, lived experiences, behaviors, and emotions (Strauss & Corbin, 1998). In other words, a qualitative approach provided an understanding of how the selected science teachers interpret their experiences, how they construct their worlds, and what meanings they attribute to their experiences. Hence, for the purpose of this study, the qualitative approach provided a deeper understanding of the PCK of science teachers regarding teaching about plastic waste and plastic waste as an SSI.

3.2. Methodology

This study aimed at catching the close-up reality, plenteous detail, and heavy explanation of science teachers' PCK in Lebanon regarding teaching about plastic waste and plastic waste as an SSI. Methodologically, a case study was used for the purpose of this research to investigate a phenomenon (the PCK of science teachers) in a real-life context, i.e., in their science classrooms (Roehrig & Karahan, 2018). Merriam (2009) defines a case study as an in-depth description and analysis of a bounded system. In this respect, this research is a case study in which the investigator explored how science teachers teach about plastic waste in Lebanon. This case study provided a holistic description and explanation of how the science teachers in Lebanon integrated plastic waste in their science lessons and whether they integrated plastic waste as an SSI into their teaching practice.

According to Loughran et al. (2004), every new topic carries new demands, such as comprehending the difficulties of the content and pedagogy. PCK is a complex idea and has proven difficult to measure (Morrison & Luttenegger, 2015). Moreover, SSI are controversial in nature and exploring the PCK of science teachers with the matter would require an investigation from a micro-level, in order to understand the different elements that intertwine. Therefore, the research design is a qualitative case study.

3.3. Methods

To explore science teachers' PCK regarding teaching about plastic waste and plastic waste as an SSI, I used interviews and observations to contribute to the triangulation of the case. The mixed use of interviews and observations delivers a considerable amount of data about how the teacher thinks and acts (Reis & Galvão, 2009).

In other words, it allowed me to discover whether the science teachers' responses from the interviews refer to the reality in the class or to common insights of what good practice should entail. Also, besides conducting interviews and observations, teachers' lesson plans were collected and analyzed.

3.4. Participants

The major criteria for selecting participants were that they (a) hold at least a Bachelor in science-related degrees (biology, chemistry, biochemistry, and medical lab) or arts (elementary science education), (b) teach science, chemistry and (or) biology, (c) spend at least one session per year teaching about plastic waste or plastic waste as an SSI, (d) teach in private schools in Lebanon, and (e) teach in schools with English being used as the language of instruction of science.

Criterion (c) above made it hard to recruit participants, because the Lebanese science curriculum does not provide space for science teachers to teach at least one session per year. Most science teachers do not teach about plastic waste at all. The target participants of the study consisted of ten science teachers from six private schools in Beirut, Lebanon. The number of participants was obtained by purposeful convenience sampling and is unrepresentative of schools in Lebanon. In this section, I summarized the school context and provided a detailed description of each science teacher. To maintain anonymity a pseudonym was assigned to each science teacher and a letter was assigned to the corresponding school.

The first participant, teacher Mary (pseudonym), has a bachelor's in Agricultural Engineering, a master's degree in Ecosystem Management, along with an educational diploma in Management and Leadership. Mary has twenty two years of teaching

experience. She uses the Next Generation Science Standards (NGSS) to teach in her science classrooms. At the participant school, the framework from the NGSS is adopted to build their own curriculum. Mary teaches science in middle school (grades six, seven and eight). Mary is confident implementing the project-based learning (PBL) approach. She seeks to give her students a realistic challenge they might face in the future and have them find background information, research, and come up with creative solutions. She has had a big sum of experience in PBL over the years in different topics, such as in units of electricity, ecology, and the impact of humans on the environment. Nevertheless, Mary believes that going a step further to make connections with expertise on the ground is an area that could be strengthened within science. Mary characterizes effective science teaching as authentic, where students are given real cases and are challenged to think outside and inside the box to design solutions. The participant believes that students will recall the challenges on the long term. In the participant school, Mary does not specialize in physics, chemistry, or biology, but rather teaches all three subjects in a more general manner. In any given topic, Mary digs in and always tries to make a link somewhere to create an interest in the students, to motivate them and make their learning meaningful. Mary has taught about plastic waste for the past ten years, as it has always been shown in ecology and in the impact of humans on the environment. She usually spends at least a month per year to teach about plastic waste. During the academic 2021-2022 school year, Mary had also spent over a month teaching about plastic waste and ocean plastic.

The second participant, teacher Sally (pseudonym), holds a degree in Biomedical Engineering. Sally uses the Lebanese science curriculum to teach science and biology

for grades five, six, and nine at School B. She has twenty years of teaching experience, which makes her confident about the knowledge she holds; however, she believes that learning about strategies to apply in a flipped classroom is an area that she needs to strengthen. The participant characterizes effective science teaching by having enough knowledge about science concepts, along with expertise in using technology and teaching aids for science experiments. Sally has been teaching about plastic waste over the past ten years. She spends three to four sessions per year teaching about this topic.

The third participant, teacher May (pseudonym), has a B.S. in biology and a Master's in Animal Biology from a university in Lebanon. She uses the Lebanese science curriculum to teach science for grade four, as well as biology for grades eight and nine at School B. May is currently a science coordinator at the school. She has been teaching for the past eighteen years. May stays up to date with respect to the latest research in the field. The participant believes that one of the weaknesses students face is the lack of research skills. Moreover, May characterizes effective science teaching through the integration of hands-on activities in the classroom. She has been teaching about plastic waste over the last ten years. The number of sessions she spends teaching about plastic waste depends on the class, but ranges between three to six sessions.

The fourth participant, teacher Carol (pseudonym), has a biochemistry degree from a Lebanese university. She currently teaches science for grades four, five, and six along with physics and chemistry subjects for grades seven, eight, and nine at School B. Sally, May and Carol are co-workers at School B. Moreover, Carol has up to ten years of teaching experience. Besides providing her students with scientific content knowledge, Carol strongly believes that she can help them develop ways of thinking that

can benefit them in the future. She seeks to teach beyond the curriculum and expose students to issues they might deal with in their everyday lives. The participant is determined to form connections between the curriculum and the outside world to prepare her students for real life. Nevertheless, Carol feels the need to strengthen her technology-related teaching skills to optimize her science teaching. Carol characterizes effective science teaching as that of which is student-centered. The participant perceives that the students must witness real life problems, while aligning between the curriculum and the books. Furthermore, Carol has been teaching about plastic waste over the last ten years. She teaches about this topic in every grade level for a total of ten sessions every year.

The fifth participant, teacher Abby (pseudonym), holds a degree in biochemistry from a Lebanese university. She uses the Lebanese science curriculum to teach science for grade six, chemistry and biology for grade nine, and biology for grades ten and eleven at School C. School C is a sister school to School B; it has a different name and is located in a different area. Abby has seven years of teaching experience and keeps herself informed with the latest research in the field by reading scientific articles. She encourages her students in grades ten and eleven to read by exposing them to such articles and explaining to them about their importance and relevance to their lives. However, Abby is afraid to expose younger students to scientific topics since they might lack the required scientific background due to online learning during the COVID-19 pandemic. Abby characterizes effective science teaching by incorporating novel teaching strategies and engaging students in laboratory experiments rather than using traditional teaching methods. The participant has been teaching about plastic waste over

the last six years, in which she spends one week, approximately five sessions, teaching about this topic.

The sixth participant, teacher Sophia (pseudonym), has a B.S. in Chemistry and a master's degree in molecular and inorganic chemistry. Sophia uses the Lebanese science curriculum to teach science to grade six along with chemistry to grades seven and eight at School C. Sophia and Abby are coworkers at School C. Sophia has two years of teaching experience. She has also private tutored before. Sophia perceives that following a student-centered approach is one of her strengths with respect to the science area and specific content topics as it permits her students to become independent and curious learners. She believes that having students undergo experiments and hands-on activities in the laboratory is what characterizes effective science teaching. On the other hand, the participant believes that she needs to frequently update her scientific knowledge. Sophia has taught about plastic waste in grades six and seven over the past two years. The participant spends between two to three sessions in each grade teaching about plastic waste.

The seventh participant, teacher Victoria (pseudonym), has a B.A. in elementary science education in science and mathematics from a Lebanese university. She is currently pursuing her master's degree in education with a specialty in Science, Technology, Engineering and Mathematics (S.T.E.M.) education at a Lebanese university. Victoria unifies the Lebanese science curriculum and the IB curriculum for her science instruction in elementary school. She currently teaches science from grade one up until grade six at School D. Victoria has two years of teaching experience and is dedicated to reflecting her passion in teaching science to her students. Victoria perceives

that attending to her students' needs is an area that could use more strengthening. She thinks that learning how to use different teaching strategies with respect to each student's weakness could help strengthen her scientific area. The participant characterizes effective science teaching as teaching beyond the scope of memorization. In other words, effective science teaching implores students to think freely and learn by incorporating all levels of Bloom's taxonomy to cover the entire circle of science. By doing that, students can analyze, evaluate, and think critically as they create solutions on their own. Victoria has taught plastic waste in her two years of teaching in various grade levels. She spends between two to three sessions in each grade level.

The eighth participant, teacher Nina (pseudonym), holds a B.S. in chemistry and a teaching diploma for teaching science in secondary education. Nina unifies the Lebanese science curriculum and the IB curriculum for her science instruction in elementary school. She currently teaches science for elementary classes from grade one up until grade six at School D. Nina and Victoria teach in the same school (School D) but different campuses. Nina has four years of teaching experience and sees that her knowledge in chemistry is a point of strength. Her confidence and solid foundation in chemistry empowers her in teaching the subject. On the other hand, Nina believes that she could work a little bit more on classroom management as it affects the scientific knowledge the students might gain. She believes that effective science teaching involves the continuous development of the scientific body of knowledge, as science is prone to change with time. Nina has taught about plastic waste in her four years of teaching since their curriculum includes topics related to waste, recycling, and pollution. In each grade level, she teaches between one to two sessions per year.

The ninth participant, teacher Rose (pseudonym), has a B.S. in biochemistry and a teaching diploma. She uses the Lebanese science curriculum to teach biology and chemistry for grades eight and nine at School E. She has nine years of teaching experience. Rose is passionate about teaching science and believes that it gives her strength with respect to teaching topics in biology and chemistry. Moreover, Rose is confident in integrating technological tools in her teaching, such as videos, PowerPoint, Ed puzzle, and Teams. She believes that professional development, specifically on using technological tools, will help teachers develop themselves and their teaching. Furthermore, Rose characterizes effective science teaching by incorporating hands-on activities rather than virtual labs or videos. Also, effective science teaching incorporates experiential learning, where students produce their own hypothesis and either validate or reject it. Students need to take part in their own learning as opposed to traditional teaching, which marginalizes the role of the students. Rose has been teaching about plastic waste all throughout her nine years of teaching. Outside the classroom, students in the participant school have a health club where they tackle this issue. The health club works on collecting caps of plastic bottles, which are donated to a Non-Governmental Organization (NGO) in Lebanon. Rose spends between two to three sessions per year teaching about plastic waste. In the participant school, plastic waste is presented more as an activity in a club rather than as a topic taught in class.

The tenth participant, teacher Jason (pseudonym), has a B.S. in biology, a master's degree in microbiology and immunology, and a teaching diploma in education management. Jason uses the International Baccalaureate (IB) curriculum to teach biology and chemistry for middle and high school students. He teaches from grades

eight till twelve at School F. The participant has six years of teaching experience. Jason is passionate about teaching science and believes that both his background in biology and his master's degree contributed to his scientific knowledge. He also refers to his teaching diploma as an additive to his expertise in teaching the subject, because it exposed him to methods in teaching sciences. Nevertheless, Jason perceives integrating more experimental procedures and techniques throughout the lessons is an area that could use more strengthening with respect to the science area. He believes that by doing this, students will apply their theoretical knowledge in real life and hence, science teaching would become more authentic. Furthermore, Jason considers that effective science teaching must be based on the scientific method. The participant has superficially taught about plastic waste before when teaching about solid pollution, sand pollution and pollution in general. He accumulates two sessions for teaching about plastic waste per year.

3.5. Plastic Waste as a Curricular Topic

In this section, I introduced the different curricula used by the participants to teach about plastic waste. Despite the absence of this topic in the Lebanese science curriculum, six teachers (Sally, May, Carol, Abby, Sophia, and Rose) that use this curriculum still integrate it within their lessons. Related topics to plastic waste are found in the Lebanese science curriculum. Specifically, pollution as a curricular topic is present in science, life science, and chemistry subjects across different grade levels (Center for Educational Research and Development, CERD, 1997).

At the elementary level of the second cycle (year six) in the Lebanese Science Curriculum, there exists a unit on "Man and the Environment". The following two

subtopics emerge from the unit: sustainable development of resources in Lebanon, along with the various features of pollution in Lebanon and its effects. At the intermediate level in the chemistry (grade nine), there exists a unit on “Chemistry and Environment”. The following two subtopics emerge from the unit: pollution of air, water, and soil (pollutants and their sources, along with the effects of pollution) and pollution problems. Furthermore, in the first year of the secondary education for life science, there exists a unit on “Control and Protection of the Environment”. The following two subtopics emerge from the unit: pollution, conservation and protection of fresh water, as well as degradation, conservation and protection of soil (CERD, 1997).

Moreover, in the secondary education for the chemistry curriculum of the Lebanese Science Curriculum, there exists a unit on “Pollution”. In the first year of the secondary level, the topic “atmospheric pollution” is present. In the second year for the General Sciences and Life Sciences sections, the topic “pollution and treatment of wastes” is present. In the third year for the Sociology and Economics section, the following subtopic is present: treatment of wastes. In the third year for the General Sciences and Life Sciences sections, the topic “pollution due to polymers” is present (CERD, 1997).

Hence, environmental-related topics are taught across the elementary, intermediate, and secondary levels. The subjects and grade levels include sciences from grade six, chemistry subject from grade nine, life science and chemistry subjects from grade ten, chemistry subject from the ‘Scientific’ section in grade eleven, and chemistry subject from the ‘Sociology and Economics’, ‘General Sciences’, and ‘Life Sciences’

sections in grade twelve. According to CERD (1997), students will develop an awareness about their responsibility towards the protection of the environment.

Furthermore, at the two campuses of School D, Victoria and Nina unify the Lebanese science curriculum and the IB curriculum for their science instruction in elementary school. Additionally, Jason uses the International Baccalaureate (IB) curriculum for his science instruction about plastic waste. Through the IB curriculum, students will develop commitment to make a positive impact on the lives of others and the environment. Students will be curious about the natural and physical environment. They will evaluate actions that benefit or threaten the environment. Students will be exposed to reduce waste through reusing and recycling different materials. They will engage in higher-order thinking through reflection and self-assessment of their own personal use of natural resources. They will explore ethical issues in science-related contexts and use their learning in science to plan realistic actions to enhance their welfare and that of other living things. Students will explore how human activities, including waste disposal, can have positive or negative effects on the environment (International Baccalaureate Organization, 2007).

Also, to teach in her science classrooms, Mary uses the Next Generation Science Standards (NGSS). The NGSS presents the unit "An Ocean of Plastics" to help students promote public awareness and to take actions against the global challenge of plastic pollution. Throughout the unit, students learn to reduce their individual impact, educate their family and communities, as well as suggest plausible solutions to minimize the influence of marine plastic pollution. Furthermore, students develop an in-depth understanding of how the water cycle and ocean circulations permit plastic to

accumulate in ocean gyres, along with the influence of plastic pollution on marine ecosystems. Throughout the unit, students research alternatives to plastic and design recycled plastic. They are encouraged to raise public awareness at a local level about the causes and effect of plastic pollution, and the plausible solutions (NGSS Lead States, 2013).

3.6. Research Instruments

3.6.1. Semi-Structured Interviews

The semi-structured interviews aimed at exploring deeply science teachers' PCK regarding teaching about plastic waste and plastic waste as an SSI, to see how they construct their ideas. The interviews were guided by a set of questions that were obtained and modified from Han-Tosunoglu and Lederman (2021). The author Han- Tosunoglu has given the researcher of this study approval to adopt and modify the PCK-BSSI instrument.

The interview began to collect demographic information related to the level of education, science background, teaching subject, years of teaching experience, and motivations of the interviewees related to teaching science. In part II of their survey, Han-Tosunoglu and Lederman (2021) present questions that revolve around teachers' understanding about SSI in general. The questions were adopted. See Appendix A.

In part III of their survey, Han-Tosunoglu and Lederman (2021) present scenario passages on several SSI. The passages are followed by a list of questions related to teachers' PCK on several specific BSSIs. For the sake of the current study, the scenario passages were not considered. Instead, only the questions from the scenario passages in Part III of the survey were adapted and presented with respect to the five PCK components

(from the PCK-BSSI model of Han-Tosunoglu and Lederman), i.e.: (1) subject matter knowledge, (2) curricular knowledge, (3) knowledge of students' understanding, (4) pedagogical knowledge, and (5) school context. In each component, the questions were modified and centralized around plastic waste in specific. For instance, under the curriculum component, one question is as follows: "What learning objectives in the curriculum are related to diet and obesity?" I modified it into "What learning objectives in the curriculum are related to plastic waste?" and so on. Also, the question "How would you use this scenario instructionally in this classroom?" was modified to "What teaching strategies would you use to teach about plastic waste in the classroom?" See Appendix A.

3.6.2. Lesson Plans

The science teachers' lesson plans on plastic waste were considered as a second data source to complement what is observed by the researcher on the teacher's PCK. The teacher's lesson plans served for collecting the timeline of teaching about plastic waste. Moreover, this helped the researcher to have a deeper insight into what the teachers aim to teach irrespective of what is only observed in class time. Because the researcher might not observe all the sessions of teaching about plastic waste, particularly if the teacher refused to be observed, the lesson plans close the gaps of what is not observed during class time. The researcher acquired an in-depth idea about the objectives and procedures of the lesson. The observed classes were selected based on the lesson plans. The chosen sessions were based on the relevance of the lesson to the research questions of the study.

3.6.3. Classroom Observations

After holding interviews and collecting the lesson plans, the researcher further collected data via structured classroom observations. Observations provide the opportunity to collect first-hand live data from the classroom and validate the information. Hence, the classroom observations yielded information pertaining to the first and second research questions. The observation protocol specific to SSI instruction (SSI-OP) developed by Topçu et al. (2018) was used. This protocol helped explore whether the topic of plastic waste was tackled as an SSI or not. The SSI-OP presents five dimensions of SSI-based instructional activities, "focus of instruction, teaching moves, role of teacher, role of students, and classroom environment" (Topçu et al., 2018, p. 302).

The researcher did not adopt the SSI-OP in the same format. Only the first and third sections were adapted from the SSI-OP since it is concerned with observing the classroom of the science teacher. The second section consists of inserting data about the space and size of the class, which are not relevant to the research questions of this study. The first section of the SSI-OP is concerned with background information, which contains the name of the observer, teacher (a pseudonym has been used), and the school (a letter has been used). The section also collected information related to the grade level, topic, observation data, and the duration of the classroom observation.

Furthermore, the third section of the SSI-OP has two columns. The first column is called observation categories and the other is scale (0= not observed, 1= observed one time or 2= observed two or more times). Every phrase under the observation categories column was scaled. Adaptations from the SSI-OP protocol included deleting some phrases that do not relate to this study. The phrases were rephrased for clarity. Since this

questionnaire is of a quantitative nature, the researcher added a third column to explain the choice of each scale. A column is added to the rubric on the left entitled "Observation Journal" to justify the chosen scale for each category. In the observation journal, the researcher recorded notes to give examples and reasons of the scale choice. See Appendix B for the classroom observation protocol.

3.7. Data Collection

Before collecting data, a pilot study was conducted. The researcher interviewed a science teacher who has eight years of teaching experience. She currently teaches biology for grades seven, eight and nine. The interview took 30 minutes and was held online via WebEx, as per the participant's request. The interview was also recorded upon the participant's approval. After data collection from the teacher, the researcher modified some information regarding the interview questions. By the end of May, the consent forms from the six participating schools were secured from Beirut area in Lebanon. The participants and the school principals approved and signed the received consent forms and school letters respectively. The researcher then scheduled a meeting with each participating teacher to collect the lesson plans, as well as set a date and time for the interview and classroom observation.

First, the researcher conducted nine online interviews in English. Only one interview was conducted in person as per the participant's request. Charmaz (2014) provided suggestions for tips to entirely understand the responses from the interviewer, such as: avoid interrupting the interviewee, be a good listener, and only interrupt the interviewee if the answer to the question deviates from the path designed or if more explanation is needed. Those suggestions were considered upon conducting the ten

interviews. During the interview, interviewees were informed about the duration of the interview (30 minutes). The interviewer clarified the questions when needed and responded to any concern the interviewee asked about. The researcher took in-depth responses for each question. The interviews were audio-recorded and transcribed before analysis. Some of the teacher's words or sentences that passed in Arabic within the interview were translated upon transcription.

Then, lesson plans were collected on the plastic waste topic. All participants provided lesson plans. Since Sally, May, Carol, Abby, and Sophia work in schools that belong to the same institution, there is a unified lesson plan provided to them by the science department. Similarly, since Victoria and Nina worked in the same institution but on different campuses, there was a unified lesson plan provided to them by the department.

Due to the participants' preferences, all interviews were held remotely on WebEx and recorded, except for the interview with the participant teacher Sally, which was held in person at school and recorded using a recorder. The online interviews were limited to audio meetings to inhibit any possibility of discomfit by the interviewees. Each participant was interviewed individually once.

The interview was in English knowing that all the participants teach in the English language at schools in Lebanon. The interviewee and I agreed on the commencement of the interview. I fully clarified to the interviewee as to what will occur during and after the interview. I familiarized myself with the interviewee and justified the purpose of the interview. I also talked about the structure and organization of the interview, and how the responses were recorded.

Then, after conducting the interview, lesson plans were collected from all ten participants. To explore the implemented instructional approaches, I observed a range of sessions in which the science teachers practiced teaching about plastic waste and plastic waste as an SSI. With each of Sally, May, Carol, Abby, Rose, and Jason, I conducted one session of classroom observation that lasted for 45 minutes. However, I had conducted six classroom observation sessions with Mary, with 45 minutes for each session. It is noteworthy that I was not able to conduct observations in Sophia's, Victoria's, and Nina's classrooms, since they had taught about this topic at an earlier point during the academic year.

During science classroom observations, I took the role of a complete observer or a non-participant observer. I observed classes without taking part in the instruction that happened, and without interacting with the teacher or students. I sat at the end of a classroom and filled the classroom observation protocol and transcribed notes. I attended the held science classroom sessions in person.

3.8. Data Analysis Method

Deductive and inductive coding were applied. Han-Tosunoglu and Lederman (2021) associate a pre-determined rubric to their instrument. The rubric was adopted and modified to fit the previously adapted interview questions. See Appendix C for the rubric. For example, the category responses for the question "What learning objectives in the curriculum are related to diet and obesity?" are "fails to recognize the learning objectives related to diet and obesity in the curriculum" for the first category, "write the objectives but not exactly" for the second category, and "write all the objectives related to diet and obesity in the curriculum" for the third category. Because the questions were implemented

in an interview and not a survey, the word “write” was changed. As stated before, the question was modified to “What learning objectives in the curriculum are related to plastic waste?” The category responses were modified to “fails to recognize the learning objectives related to plastic waste in the curriculum” for the first category, “recognizes the objectives but not exactly” for the second category, and “recognizes all objectives related to plastic waste in the curriculum” for the third category.

Each question was analyzed using the rubric and codes emerged. For instance, the code “LO” emerged from the question “What learning objectives in the curriculum are related to plastic waste?” The code “LO +” was given if the teacher recognized all the objectives related to plastic waste in the curriculum. The code “LO –” was given if the teacher recognized the objectives related to plastic waste in the curriculum, but not adequately.

Although the rubric assumes that all codes are determined prior to data collection, inductive coding was also used as this study follows a qualitative research paradigm, where the worldviews and experiences of participants are important. In order to confirm the pre-determined codes, data that was collected underwent inductive analysis.

Thematic analysis was used to analyze the results obtained from the interviews, observations, and lesson plans. Analysis was carried out in several phases, recommended by Brown and Clark (2006). First, for each science teacher, the researcher repeatedly read data from the interview transcriptions, lesson plan artifacts and observation protocols to identify meaningful units (words, phrases, and sentences) and label them with initial codes. The inductive analysis sought to explore the codes that were particularly revealing about the science teachers’ PCK on plastic waste and plastic waste as an SSI.

Then, the initial coding in all data sources were reviewed across the ten participants to confirm the codes (see Table 1). Similar codes were grouped into potential sub-themes, i.e. patterns (see Table 2). Then, candidate themes emerged from the patterns. The obtained themes from thematic analysis were revised numerous times by comparing them to their collated extracts, in order to check for coherence. If the themes were not coherent, they were modified and reconsidered. The final stage was revising the themes to their final candidate's name. Finally, the themes were reviewed and refined according to the research questions. Results were then reported and compared in the chapter of findings for each teacher. The analysis of the ten teachers produced hypotheses for future research upon comparing those of the participants from the study.

Table 1. Codes Generated from the Qualitative Thematic Analysis.

Codes	**Definitions**	**Examples**
High	high awareness level on the importance of content knowledge to teach about plastic waste	"I believe I need to learn a lot about this topic myself. I don't know I may be wrong, but this is where I feel. […] If I had more info, especially from a person of expertise in that regard to better develop my students' knowledge. I would know more about it. I feel that I am still a learner in this area." (Mary, interview)
Weak	weak rationale on the importance of content knowledge to teach about plastic waste	"We must read more, because this lesson we don't explain it a lot ... Only for one week. Of course, the information is not as other lessons. We must read more." (Abby, interview)
Low	low awareness level on the importance of content knowledge when teaching about plastic waste	"I am pretty sure I have good information about that." (Sally, interview)
App	mention having students applying solutions is a challenge to teach about plastic waste	"The difficulty lies in the application of students' understandings […] How to apply their knowledge in real life remains a challenge." (Sally, interview)
Inf	mention that the influence of the environment is a challenge to teach about plastic waste	"I am telling them to recycle, to clean up, but this is not what they are getting from people around them. They are being influenced by people around them. I am telling them

		something and they are seeing something else." (Victoria, interview)
Tim	face time constraints for teaching about plastic waste	"We must spend time on such issues; however, we are tight on time. There must be time allotted to such issues." (Carol, interview)
Des +	adequate description of plastic waste in detail in connection with environmental, social, economic, and political aspects	"Plastic waste is the plastic that we throw, that we do not need anymore… We should take into consideration the pollution, how much it is harmful, the climate change. And at the same time, we need plastic, many things that are used are made out of plastic. We cannot replace plastic with another material yet, yet if someday we find a substitution that would be great." (Sophia, interview)
Des –	inadequate description of plastic waste in detail in connection with environmental, social, economic, and political aspects	"Plastic waste… we use a lot of plastics in our lives, for example, cups, plates, bottles, like this and these will, some people will throw them for example in rivers." (Sally, interview)
Rel +	mention the relationship between plastic waste and climate change in detail	"This cause of plastic waste, its disposal throughout the environment generates greenhouse gases. And generating such greenhouse gases […] would increase the CO_2 emission and trapping the heat from the atmosphere in the earth's surface and increases the temperatures of the earth, hence causing climate change." (Jason, interview)
Rel –	inadequate explanation how plastic waste influences climate change in detail	"I don't know" (Abby, interview)
Eff +	confidently states the effects of plastic waste	"A major one besides the littering and ugly looks is that it gets broken down into micro-plastic that eventually end up in our food chains and I am sure we are eating them right now […] Micro-plastic can […] kill organisms in marine ecosystems, because they can mistake it for actual food or they might swallow it by mistake. […] when we come to eat them, we are eating plastic as well." (Mary, interview)
Eff –	states few effects of plastic waste	"The effects, we have pollution, because these bottles for example, they will give toxic substances and this will harm the air. So, we will have air pollution." (Abby, interview)
AIL	use art-integrated learning as a teaching strategy to teach about plastic waste	"I wanted them to rage through their art. So, I wanted them to express themselves and their furiousness through this paper that they see in front of them and through the recycling material that they prepared. So they did a … very small artistic figure." (Victoria, interview)

CBL	use case-based learning as a teaching strategy to teach about plastic waste	"I have chosen an article […]. Learners are supposed to read the article in order to analyze what is written, and I have a couple of questions where we will be making a discussion like a debate on it in order to reach the final conclusion." (Rose, interview)
CL	use cooperative learning to teach about plastic waste	Each group was assigned a task to determine solid wastes in Lebanon, identify their effects, classify them as biodegradable and non-biodegradable, or come up with possible solutions. (May, classroom observation)
Deb	use debate to teach about plastic waste	"I love to use debates, I like this strategy in class. Two groups debate in front of each other. So, this, I believe this is a very good strategy to work on SSI in class." (Sophia, interview)
Dis	use discussion to teach about plastic waste	Student: "People do not want to find solutions in Lebanon." Mary: "It is a fallacy. Who told you that people in Germany want to? They have to pay fines if they pollute." (Mary, classroom observation)
EDC	implement the engineering-design cycle to teach about plastic waste	"Students start from imagine, to brainstorming to planning, to creating the actual solution, to trying it out. They can modify and eventually there is a sharing part." (Mary, interview)
IBL	use inquiry-based learning as a teaching strategy to teach about plastic waste	"We had a project this year with, with a Non-Governmental Organization (NGO). So, basically students had to collect recyclable items. […] they did a project where they had to build something out of the recyclable materials." (Sophia, interview)
PBL	use problem-based learning as a teaching strategy to teach about plastic waste	"Anything that has to do with project-based learning, I love to give my students a challenge, whether it is a problem I throw or a challenge I give them or something they have to find out that is authentic happening now in the world and they need to be engaged you know in finding out background info, researching, being creative, coming up with solutions, etc." (Mary, interview)
Res	use research as a teaching strategy to teach about plastic waste	"Research in groups about ideas that one can implement to minimize plastic consumption and the production of solid waste in general." (Carol, interview)
Ref	use reflection as a teaching strategy to teach about plastic waste	Students were asked to determine the main idea of a recent article on plastic waste, do wonderings, and extract information. (Mary, lesson plan)
Tech	incorporate the use of technology to teach about plastic waste (students use computers/ iPads)	"Most of the time when you are with me you will see them working in groups, tackling a specific issue, doing their own research, collecting their own data." (Mary, interview)

Vis	use visualization (PowerPoint, video, article) to teach about plastic waste	"I also make them watch a video about the polluted beach and lands in Lebanon, for example, humans, animals or any kind of living "things…" (Victoria, interview)
AES	use authentic evaluation strategies to assess students' understanding of plastic waste	"For the assessment, I would focus on students' decision-making skills that include the use of evidence, argument, and counterargument." (Mary, interview)
OB	formally and informally observing student behavior in the long term to assess their understanding of adequate disposal of plastic waste	"In this year we have been trying to make statistics to see how many students are still using plastic bags, […] and we gave advice for using […] Tupperware, […] And this has really been successful." (May, interview)
OP	use oral presentation to assess students' understanding of plastic waste	"We would go for a small research, because it is not something you can assess by just a paper and pen work […] They can do it as group work and then they can finalize or present their work and what conclusion did they reach." (Rose, interview)
PAP	use traditional paper-and-pencil assessment to evaluate students' understanding of plastic waste	"For fourth graders, we start giving written assessments. […] We give them matching. We give them fill in the blanks. We give them true or false, and correct the false statements. But also […] some fun questions: color the plastic waste […] or draw solutions for plastic waste. They might draw the sign of recycling or someone throwing plastic in a plastic recycling bin." (Victoria, interview)
LO +	recognize all the learning objectives related to plastic waste in the curriculum	"So students develop a greater understanding to using resources efficiently, students will also value the importance of efficiently disposing plastics and consuming less plastics, they will also understand the threats and the harmful sides of using plastic wastes. Or they will gain more understanding of the adverse effects of plastic waste on the environment, wildlife and humans as a result." (Sophia, interview)
LO –	inadequately recognize the learning objectives related to plastic waste in the curriculum	"Distinguish between biodegradable and non-biodegradable. Know the effects of plastic waste, know suitable solutions." (Carol, interview)
Con +	mention all concepts related to plastic waste	"Pollution definitely, waste, responsible consumption, recycling, reusing, reduce, effect on organisms whether marine or terrestrial, […] Whereas in ecology, concepts related also to how it affects the food chains, how it affects the survival of organisms, polluting the environment as well." (Mary, interview)
Con –	unsuccessful to recognize the concepts related to plastic waste or mentions few	"We focus on recycling". (Sally, interview)

Rec	mention plastic being recyclable material is considered as a student's misconception	"Some students think that plastics which are recyclable, which go in recycling bins, are recycled, but that isn't true. […] Another is also concerning recycling. So whenever they see the sign, the chasing arrow sign, they think that the container is recyclable." (Sophia, interview)
Bio	mention plastic being biodegradable material is a student's misconception	"On the internet we have some types of plastic made from bacteria, so some students think all the types of plastics are biodegradable." (Abby, interview)
Eco	mention that plastic is ecofriendly is a student's misconception	"They think that plastic is a very good thing to be used in their life, easy, it is something that you can use and throw, and it is ecofriendly. This is what they always say." (Rose, interview)
DT	refer to direct teaching as an approach to address students' misunderstandings of plastic waste	"I would implement direct teaching to further explain about … for example the importance of creating better methods to dispose plastic waste and the harmful effects on the environment if we did not…" (Carol, interview)
IQ	use inquiry questions as a teaching approach either to avoid creating misconceptions on or address misunderstandings of plastic waste	"I would always like to start with, with inquiry questions. I like them to figure out what we are talking about by themselves...." (Jason, interview)
Res TA	use research as a teaching approach to address misunderstandings of plastic waste	"One of my students thought it was okay to throw plastic waste in the environment, because he thought plastic is biodegradable. But I asked him to go home, research about this specific idea, come up with a presentation to make sure that everybody in class knew that plastic is non-biodegradable." (Sophia, interview)
SPK	refer to the importance of students' prior knowledge either to avoid creating misconceptions on or address misunderstandings of plastic waste	"I start from the beginning, so we can just jot the ideas and from here we can start splitting, which one can just be as a misconception, and which one is a good thing, and we can continue with it." (Rose, interview)
VA	use visual aids to avoid misconceptions on or address misunderstandings of plastic waste	"I show students videos about how the sea level is really rising, the icebergs are melting… What I've noticed is that when they see animals suffering, this affects them the most." (Nina, interview)
Sup	school and community environment are supportive to teach about plastic waste	"The school plays a very important role in identifying how these future generations need to relate what they learn to their surrounding environment. The school plays a very important role." (Rose, interview)
Opi	feel free to express opinion about plastic waste in school	"In my school we are free to give our opinion […] I can't say according to me, plastic … pollutes and litters. It is a scientific fact that it

		does. […] It could be my opinion whether I recycle or not […]. But if I really want to live the mission of my school… is littering a way to serving the community? I doubt. It is either you fit in the mission or vision or you don't fit it." (Mary, interview)
Conn +	teacher made a successful connection between functional SL and plastic waste	"Is this the future you want to have not for your kids, but yourself? To swim in water that is filled with plastic?" (Mary, classroom observation)
Conn –	teacher made an unsuccessful connection between functional SL and plastic waste	"Students could practice some behaviors that will lead to the decrease in pollution related to plastic waste." (May, interview)
HOP	teacher focused on higher-order practices	Mary focused on higher order practices, such as argumentation and reasoning. Students also collected and analyzed scientific data from articles. (Mary, classroom observation)
LOP	teacher focused on lower-order practices	Students were engaged in lower-order practices, such as recognizing, understanding and classifying. (Sally, classroom observation)
Multi +	students adequately confront the multi-dimensions of plastic waste	"As you design a solution, keep in mind the price. You can't design an expensive solution that is not affordable." (Mary, classroom observation)
Multi –	students hastily confront the multi-dimensions of plastic waste	Rose asked her students if there is a process to get rid of the plastic waste or if it is not feasible. "Rose: What is needed to get rid of the patch? Student 1: Human interference Student 2: Cost." (Rose, classroom observation)

3.9. Validity and Reliability

This qualitative research began with a pilot study that sought to improve, investigate, and amend the data collection approaches and the instruments and organize the initial coding list along with the data analysis procedure. Furthermore, the interview questions were derived from the research questions and the reviewed literature; therefore, the validity of the research study is to be increased. I administered highly structured interviews with the exact format and arrangement of words and questions for every interviewee to establish reliability in interviews. Since nine interviews out of ten

were not held face-to-face, then their reliability might be strengthened as the interviewee might expose information that may not be accessible in a face-to-face situation.

To establish reliability in observations, I was consistent without any variation in interpretation. I aimed to have the maximum number of observations to ensure a greater reliability of data; thus, permitting the emerging themes to be verified. In addition, I recorded notes during the classroom observation, because the memory neglects and selects data if this was done later. To establish validity, I ensured that the indicators were fair and operationalized. In addition, I involved multiple investigators to detect whether different observers find similarities. Also, minimizing bias is an effective way of increasing validity, whether in interviews or during observations.

I promoted trustworthiness of results by triangulation and member checking. Besides aiding in the triangulation of the results, the use of different procedures and instruments to collect data promotes the validity and reliability of the study (Patton, 1997). The data analyzed from interviews, lesson plans, and observations was returned to participants to look for precision and resonance with their experiences. The participants revised and clarified my interpretations of their teaching practices.

3.10. Researcher's Bias and Assumptions

In this study, it is assumed that the participants in the interviews answered the questions honestly. As an interviewer, I assumed a neutral stance with respect to the interviewees' knowledge, opinions, beliefs, and attitudes. Moreover, I did not include personal interpretations or opinions as the interviewees' answers were audio-recorded. Cohen et al. (2018) indicate that reducing bias in interviews requires careful formulation of questions, along with matching the characteristics of the interviewer with those of the

sample being interviewed. The researcher sought to build rapport with the interviewees by listening carefully and acknowledging their answers. Also, as an observer, I did not interact or communicate with neither the teacher nor the students in the classroom.

3.11. Research Ethics

Initially, ethics approval for the study was granted by the LAU's Institutional Review Board (IRB). For each method of data collection tools, a consent form was implemented to obtain the participants' approval of conducting interviews, observing them, and collecting their lesson plans. The consent form ensured safety and security of participants, confidentiality of information, and the right to withdraw at any time and to skip any question. The school principals also received a letter to obtain their approval of conducting the classroom observations. At the beginning of the interview script, a brief introduction was included informing the participants about the researcher and the institution that the study belongs to. Then, there was a justification for why the participant had been chosen to take part in the study. At the end of the consent form, the contact information of the researcher and the IRB office were included, if participants would require additional information on the current study.

Chapter Four

Findings

The study aimed to explore how science teachers in Lebanon teach about plastic waste and plastic waste as a socio-scientific issue. Semi-structured interviews, lesson plans, and classroom observations were used to explore how ten science teachers teach about plastic waste. This chapter provides the descriptive and qualitative analysis of the findings of each teacher alone, which serves to answer the two research questions. Data were coded and then patterns were derived from these codes. The frequency of each code was also presented to show how each pattern developed. The codes with high frequencies were considered for further analysis into potential patterns. The codes that were identified from one or two science teachers only were excluded. See Table 2. The results showed that four themes emerged from the patterns and are presented in Table 3. The themes reported in this chapter are the following: scientific competency to teach about plastic waste, interpretation of students' knowledge for teaching about plastic waste, pedagogy used to integrate plastic waste, and addressing plastic waste as a socio-scientific issue. Discussion of results is provided in the last chapter of this thesis.

Table 2. Patterns Generated from the Codes.

Patterns	**Codes**	**Frequency**
inadequate awareness level on the importance of content knowledge to teach about plastic waste	Weak Low	4 3
inadequate subject matter knowledge on plastic waste	Des – Rel – Eff –	8 5 5

use of teaching strategies to teach about plastic waste	Dis Res Vis	8 4 7
traditional assessment to evaluate students' understanding of plastic waste	OP PAP	4 7
students' misconceptions and difficulties about plastic waste	Bio Eco Rec	2 3 3
teaching approaches to avoid creating misconceptions and address students' misunderstanding	IQ Res TA VA	3 3 5
challenges for teaching about plastic waste	App Inf Tim	8 5 2
unsuccessful connection between functional SL and plastic waste	Conn –	8
focus on lower thinking skills	HOP LOP	5 5
inadequate focus on the social dimensions of plastic waste	Multi –	9

Table 3. Themes Generated from the Patterns.

Themes	**Patterns**
scientific competency to teach about plastic waste	inadequate awareness level on the importance of content knowledge to teach about plastic waste inadequate subject matter knowledge on plastic waste
pedagogy used to integrate plastic waste	use of teaching strategies to teach about plastic waste

	traditional assessment to evaluate students' understanding of plastic waste
interpretation of students' knowledge for teaching about plastic waste	students' weaknesses and difficulties related to plastic waste
	students' misconceptions about plastic waste
	use of teaching approaches to avoid creating misconceptions and address students' misunderstanding
	challenges for teaching about plastic waste
addressing plastic waste as a socio-scientific issue	unsuccessful connection between functional SL and plastic waste
	focus on lower thinking skills
	inadequate focus on the social dimensions of plastic waste

4.1. Teacher 1: Mary

4.1.1. Scientific Competency to Teach about Plastic Waste

Mary demonstrated having high awareness level on the importance of content knowledge and explained how content knowledge affects the quality of plastic waste teaching. She expressed having moderate levels of self-efficacy with respect to her knowledge on plastic waste and its disposal. The science teacher stated confidently the

definition of plastic waste, its effects, and the relationship between plastic waste and climate change (Mary, interview).

4.1.2. Interpretation of Students' Knowledge for Teaching about Plastic Waste

The participant perceived that the most challenging in teaching about plastic waste is having students unleash their creativity to create novel solutions and apply them in real life. She explained that:

> *"Walking the talk, applying these things in our life, not simply keep it as a video I made and I play it on social media and my cousin saw it, and it was nice and they clapped for me, but I never applied it in my life." (Mary, interview)*

Furthermore, Mary gave details about her students' misconceptions on plastic waste. For instance, one misconception is related to recycling plastic waste.

> *"They might think I'm recycling, but I am throwing it in the bin. […] Can we recycle it as it is? I do not think so. […] Are we just simply telling the students we recycle, and it just simply goes into the same bin as everything else?" (Mary, interview)*

Another misconception is related to how ocean currents move waste around globally.

> *"I show them two beaches: one that is polluted and one that is not. Then, I ask them: which one you think is close to a city? They all pick the one that is polluted. Whereas the one that is polluted with plastic litter is remote like in a very faraway place […] because the ocean currents carry the plastic there..." (Mary, interview)*

During the interview, Mary inadequately explained the teaching approaches used to avoid creating misconceptions on plastic waste. In her opinion, misconceptions are viewed as opportunities for learning. Nevertheless, she revealed using discussions, research and inquiry questions to guide her students upon facing misunderstandings on plastic waste (Mary, interview). Congruently, during classroom observation, the

researcher noted the following discussion between Mary and her student.

Student: "People do not want to find solutions in Lebanon."

Mary: "It is a fallacy. Who told you that people in Germany want to? They have to pay fines if they pollute."

4.1.3. Pedagogy used to Integrate Plastic Waste

Mary emphasized the use of the engineering design cycle to teach about plastic waste. She explained that students begin from "imagine, to the brainstorming, to the planning, to creating the actual solution, trying it out, […]. They can modify …. And eventually there is sharing. The sharing part is very important" (Mary, interview). This was in accordance with the classroom observation, where Mary's students designed solutions to plastic by reusing or recycling plastic waste for various purposes (Mary, classroom observation).

In accordance with the lesson plan, Mary asked her students in class: "What solutions would you suggest to tackle the problem at hand? Be creative and clear in your explanation". She also noted the following:

> *"Your solutions should be practical and feasible. It is highly preferable if you already do apply them in your life to design your poster around them or solutions you are willing to start to apply in your life and discuss your experience in your poster." (Mary, classroom observation)*

Also, Mary reported assessing students' decision-making skills that include the use of evidence, argument, and counterargument. She focused on the process and product. In other words, assessment of students' understanding of plastic waste occurred using authentic evaluation strategies (classroom observation). Also, Mary had included in the

lesson plan the requirements that must be present for students' posters (Mary, lesson plan).

4.1.4. Addressing Plastic Waste as a Socio-Scientific Issue

Mary formed a connection between functional SL and plastic waste. She explained that teaching about plastic waste improves understanding of content knowledge and NOS, and enables students to engage in discussion based on scientific evidence. Mary indicated that exposing students to plastic waste helps them develop higher-order thinking skills and prepares them for real life to become active citizens. She believed that raising awareness to create understanding is crucial to undergo informed decisions about plastic waste. Mary asked her students: "Is this the future you want to have not for your kids, but yourself? To swim in water that is filled with plastic?" (Mary, classroom observation).

Mary was the only participant to consider plastic waste as a socio-scientific issue with links to various disciplines. She demonstrated that plastic waste involves forming opinions and undergoing choices at the personal or societal level (Mary, classroom observation). She also indicated that plastic waste is media reported and addressed at local and global dimensions. Mary considered that the plastic waste issue lacks information due to the incomplete scientific evidence and reporting about it (Mary, interview). Similarly, during classroom observation, Mary revealed that plastic waste involves benefit-cost analysis, as well as values and ethical reasoning (Mary, classroom observation).

During the interview, the participant adequately described plastic waste in detail in connection with environmental, social, economic, ethical, aesthetic, and political aspects. Similarly, during classroom observation, Mary had her students confront the different

dimensions of plastic waste. For instance, on the economic dimension of plastic waste, the researcher noted the following during classroom observation:

> *"As you design a solution, keep in mind the price. You can't design an expensive solution that is not affordable." (Mary, classroom observation)*

Besides focusing on the social dimensions of plastic waste, Mary promoted the conceptual scientific understanding on the topic. For instance, students are aware that plastics are made from fossil fuels (Mary, classroom observation).

Furthermore, Mary adequately implemented the PBL approach to teach about plastic waste in the classroom. The students performed an engineering task to minimize the amount of plastic wastes. Students communicated their findings about the sources of plastic waste, its effects, and plausible solutions. They raised public awareness at a local level by inviting the community environment of School A (classroom observation) and presenting to them their solutions. The PBL approach helped Mary's students confront the social dimensions of the issue on plastic waste.

Furthermore, Mary focused on higher order practices, such as argumentation and reasoning. For instance, she implemented debates upon dividing her students into three groups. Each group was assigned a type of bag: plastic, cotton and paper. Mary provided scaffolding for higher order practices using various techniques. Students collected and analyzed scientific data from articles that were associated with guiding questions, such as "How much energy is used to make the bag during manufacturing?", "How many times can the bag be used?" (Mary, lesson plan), and "How do I decide if I will take paper, plastic, or cotton bags? Based on what criteria do I choose?*"* (Mary, classroom observation). The questions sought to have students assess the risks and benefits of plastic waste. They also negotiated the social dimensions of plastic waste.

Mary had also encouraged her students to check further embedded links she provided or conduct research on their own if they wished to (Mary, lesson plan). She acted as a learning facilitator instead of an authority. The classroom environment was collaborative and interactive. For instance, during classroom observation, she stated the following: “John is playing the devil’s advocate and I love it, because we should be able to recognize other points of view”. (Mary, classroom observation). She would also cultivate motivation in her students. “We need a great system for recycling. Yes, you are leaders. Those leaders, the ministers, etcetera, they work for us. Wake up and make them realize...” she argued (Mary, classroom observation). Although she revealed to her students that dealing with plastic waste is difficult, she encouraged them to act regarding their school’s cafeteria.

> *“We are part of the problem. By just being, we are part of this. Think of solutions in our cafeteria. We pollute a lot in our cafeteria with respect to our community. We need to come up with a plan to recycle in our own cafeteria.” (Mary, interview)*

During classroom observation, the researcher noted that Mary has conducted formative assessments before students went on to design their posters and prototypes. Students were asked to determine the main idea of a recent article on plastic waste, do wonderings, and extract information (Mary, lesson plan). The teacher has also provided opportunities for students’ reflections about their learning, whether it was after watching a video or reading a scientific article. Mary also related what students learned to prior knowledge. When playing a video, Mary paused and asked: “What is the Giant Island called?” (Mary, classroom observation). The use of current media, whether articles or videos, helped Mary connect content to plastic waste. This was evident during classroom observation and the lesson plans.

4.2. Teacher 2: Sally

4.2.1. Scientific Competency to Teach about Plastic Waste

Sally implied having low awareness levels on the importance of content knowledge. She failed to acknowledge how content knowledge influences the quality of teaching plastic waste. Bearing that in mind, it was found that Sally lacks subject matter knowledge required to define plastic waste and determine its effects. She also provided an inadequate explanation of the relationship between plastic waste and climate change In consideration of that, she failed to recognize and define plastic waste as a socio-scientific issue (Sally, interview).

4.2.2. Interpretation of Students' Knowledge for Teaching about Plastic Waste

Sally believed that having students apply solutions can be quite challenging. According to her, "students already know the information. I explained the information or they researched the information. But, how to apply their knowledge in real life remains a challenge" (Sally, interview). She set forward that her students' misconceptions included overlooking that plastic is non-biodegradable and misperceiving the real effect of plastic waste in nature. Sally would use case studies as a teaching approach in order to avoid creating misconceptions on plastic waste (Sally, interview).

4.2.3. Pedagogy used to Integrate Plastic Waste

During the interview, Sally revealed engaging students in research as a teaching strategy to teach about plastic waste. She would pose a problem and have students conduct research. Students would be provided steps and a procedure to follow. Sally believed that the instruction on plastic waste is contextually related to the school and

community environment. She was also given freedom to express her opinion about plastic waste in school. An example on how Sally uses plastic waste with respect to the school context is provided next.

> *"I always let the students calculate the number of plastic bottles in each day for one class. Then, we multiply the number of classes. Then, we multiply the number of schools, and we calculate the number. And we start to solve the problem, if we reduce using plastic and/ or reuse the plastic more than one time, the number will be decreased." (Sally, interview)*

However, the researcher noted during classroom observation that Sally implemented classroom discussion. She started the lesson by asking her students to recognize the types of pollutants present in class, such as looking through the window and in the waste basket. This was compatible with what was stated in the lesson plan. Nevertheless, after further inspection of the lesson plan, it was stated that a grouping strategy would be implemented to determine solid wastes in Lebanon, identify their effects, classify them as biodegradable and non-biodegradable, and come up with possible solutions (Sally, lesson plan). During classroom observation, the researcher realized that there was no cooperative learning among students. The pollutants recognized by the students were listed on the board during a classroom discussion.

Regarding assessing students' understanding of plastic waste, Sally revealed in the interview that she conducts a project presentation in which students present a solution. The teacher added that the solution must always be an updated one instead of a traditional one. During the classroom observation, Sally asked students to solve an exercise in their workbook related to sorting plastic waste. There was no implementation of a PBL approach in which students created solutions to plastic waste disposal.

4.2.4. Addressing Plastic Waste as a Socio-Scientific Issue

Sally failed to establish a relationship between plastic waste and SL. The science teacher emphasized the importance of teaching about plastic waste in the classroom in attempts to inform her students about the advantages and disadvantages of plastic consumption. In other words, she believes that plastic waste should be part of the science curriculum as it can develop students' awareness.

At School B, Sally is encouraged to focus on the scientific and religious aspects of plastic waste. She revealed confronting the ethical and religious dimension of plastic waste by relating the issue to the students' Islamic beliefs (Sally, interview). Similarly, during classroom observation, Sally started her lesson with a verse from the Holy Quran, which says: "Eat and drink from the provision of Allah, and do not commit abuse on the earth, spreading corruption." She explained to her students that "this verse shows the importance of God's blessings on us. Therefore, you must appreciate and respect it. Also, God wants us to protect the Earth rather than destroy it" (Sally, classroom observation).

Sally guided the students to explore a document in the book, whereby various kinds of solid pollutants were present. Students did not collect and analyze scientific data related to plastic waste. The students were engaged in low order practices, such as recognizing, understanding and classifying. At the end of the session, students reached solutions like reduce, reuse, and recycle (Sally, classroom observation). Although Sally helped students negotiate the social dimensions of plastic waste, such as the effects on the environment and marine life, her instruction was only limited to a classroom discussion (Sally, classroom observation). She insignificantly promoted conceptual

scientific understanding, despite relating plastic waste to real life. With respect to assessing students' conceptual understanding, Sally focused on the learning product rather than the learning process. Sally inadequately used plastic waste to promote SL; instead, she would merely use plastic waste to promote awareness about the issue.

4.3. Teacher 3: May

4.3.1. Scientific Competency to Teach about Plastic Waste

May inferred having low awareness levels on the importance of content knowledge. The participant provided weak rationales on how content knowledge affects the quality of teaching plastic waste. It was found that May lacks subject matter knowledge to define plastic waste and on how plastic waste influences climate change. Nevertheless, she confidently stated the effects of plastic waste. Taking that into account, May was unsuccessful to recognize and define plastic waste as a socio-scientific issue (Mary, interview).

4.3.2. Interpretation of Students' Knowledge for Teaching about Plastic Waste

May provided details about her students' difficulties of understanding plastic waste. She pointed out that her students fail to understand the importance of minimizing their consumption of plastic. May explained that "they are not convinced with the idea that they will have to stop using plastic. They would say that it is only once. What would that affect others?" The interviewee further explained that the essence of the problem lies in modifying the mentality of the whole society rather than just the students.

Nevertheless, she revealed using visual aid to address students' misunderstandings of plastic waste. She believed that students are better at remembering

what they have seen than what they have heard. Furthermore, when asked about students' misconceptions on plastic waste, May reported that her students believe that plastic waste can be recycled after disposing it in bins. Nevertheless, she provided an inadequate explanation of the teaching approaches that she would use to avoid creating misconceptions on plastic waste.

4.3.3. Pedagogy used to Integrate Plastic Waste

May expressed uncertainty in applying hands-on activities with the topic about plastic waste. Instead, she revealed using visual aids to teach about plastic, such as videos that show the effect of the environment on living things. She also mentioned asking students to engage in research when problem-solving case studies (May, interview). Nevertheless, during classroom observation, May implemented a discussion and cooperative learning where students worked in groups. Both strategies were in accordance with the lesson plan. Each group was assigned a task to determine solid wastes in Lebanon, identify their effects, classify them as biodegradable and non-biodegradable, or come up with possible solutions. Each group was given a cardboard, where they designed a poster answering a specific question. Meanwhile, May was moving around conducting informal observation and answering students' questions. Afterwards, each group presented their work.

Regarding assessment, May pointed out doing a formative assessment during and a summative assessment after the lesson. However, she revealed that to assess students, she must observe whether or not will they modify their behaviors on plastic in the long-term. "In this year we have been trying to make statistics to see how many

students are still using plastic bags, […] and we gave advice for using […] Tupperware, […] And this has really been successful" (May, interview).

4.3.4. Addressing Plastic Waste as a Socio-Scientific Issue

May failed to establish an adequate relationship between plastic waste and SL, despite being able to explain plastic waste as a societal issue. In her opinion, teaching about plastic waste is important as it would help her students "practice some behaviors that would lead to the decrease in pollution" (May, interview). May emphasized that the ethical aspects of plastic waste must be highlighted at School B. She explained that the school had collaborated with municipalities and organizations to show students how to reuse plastic bottles. She would shed light on the ethical responsibility her students have towards preserving the environment (May, classroom observation). Although she related plastic waste to the real world, students were inadequately confronted with the multidimensional structures of the issue.

Furthermore, May superficially tapped on the conceptual scientific component of plastic. The teacher focused on low order practices, such as recognizing, understanding and classifying. The participant's use of plastic waste as a context sought to merely develop awareness and alter students' behaviors in attempts to decreasing the consumption of plastic. With respect to assessing students' conceptual understanding, Sally focused on the learning product rather than the learning process.

4.4. Teacher 4: Carol

4.4.1. Scientific Competency to Teach about Plastic Waste

Carol exhibited low awareness levels on the importance of content knowledge. She provided an inadequate explanation on how content knowledge affects the quality

of SSI teaching. In this respect, Carol failed to recognize and define plastic waste as a socio-scientific issue. As she put it, “I believe now, people are more conscious. It is no longer controversial. There is a huge percentage of people working on this” (Carol, interview). The participant lacked subject matter knowledge to define plastic waste and state its effects. Carol also lacked sufficient knowledge on the relationship between plastic waste and climate change.

4.4.2. Interpretation of Students’ Knowledge for Teaching about Plastic Waste

According to Carol, the most challenging about teaching plastic waste is to influence her students. She revealed existing barriers that hinder the effective implementation of solutions. Students believe that “sorting waste at home is a waste of time and it takes room. The parents lack the awareness to begin sorting. This is a huge problem that I find”, argued Carol (Carol, interview). She also revealed that the condensed curriculum minimizes the time allotted to address such issues.

> *“Sometimes the students themselves bring such issues up and we try to address them superficially, because we run out of time, and we need to finish the curriculum. Consequently, some things are left unaddressed and unclear in the minds of the students.” (Carol, interview)*

Furthermore, Carol gave details about students’ difficulties of understanding plastic waste. She perceived that although students know that plastic is non-biodegradable, they are unaware that as they consume plastic, the amount of waste generated increases. The students are also unaware of the actual effect of plastic waste. Nevertheless, Carol pinpointed that explanation helps clarify students’ misunderstandings of plastic waste. She considered that visual aids (videos and

PowerPoint presentations) are effective teaching approaches to avoid creating misconceptions on plastic waste (Carol, interview).

4.4.3. Pedagogy used to Integrate Plastic Waste

During the interview and as noted during the classroom observation, Carol's teaching strategies to teach about plastic waste included brainstorming, classroom discussions, and researching alternatives to plastics. She indicated implementing a summative assessment as a short-term assessment, along with carefully, formally and informally, observing students' behavior in the long-term (Carol, interview).

Before the session was over, Carol gave students an assignment asking them to research in groups about ideas that one can implement to minimize plastic consumption and the production of solid waste in general. Carol encouraged her students to initiate change starting from their home. She asked: "How can you influence your parents to recycle as well?" (Carol, classroom observation).

4.4.4. Addressing Plastic Waste as a Socio-Scientific Issue

Carol sought to make a connection between functional SL and plastic waste. She stressed that plastic waste or related topics are important to include in the curriculum in order to develop a generation that can plan a waste management strategy to solve the current waste crisis in Lebanon. Carol attempted to relate science content to the real world and promote conceptual scientific understanding by asking her students about the most critical environmental challenge in Lebanon. She initiated a discussion on the issue of solid waste disposal. Students deduced the meaning of the terms biodegradable and non-biodegradable through guiding questions. Afterwards, Carol asked the students to propose solutions to the pollution problem. Students' solutions included reusing,

recycling, sorting, and decreasing the consumption of plastic (Carol, classroom observation).

Nevertheless, Carol focused on low order practices, such as recognizing, understanding and classifying. Students did not engage in decision-making at the personal or societal level, nor did they profoundly confront the dimensions of the issue. Also, despite explaining some assessment strategies, Carol did not associate the strategies with the plastic waste learning process. In other words, assessment focused only on the learning product.

4.5. Teacher 5: Abby

4.5.1. Scientific Competency to Teach about Plastic Waste

Abby provided a weak rationale on the importance of content knowledge and how it affects the quality of SSI teaching. Given that, Abby was unable to define plastic waste and provide an explanation on its' effects. She also has inadequate knowledge on the relationship between plastic waste and climate change (Abby, interview).

4.5.2. Interpretation of Students' Knowledge for Teaching about Plastic Waste

According to the science teacher, the heavy reliance on plastic in the society makes it a challenge to teach about it. When asked about her students' weaknesses and difficulties, Abby pointed out that her students do not comprehend the importance of avoiding plastic use especially that it is ubiquitous. She set forward that "even though they know they can use other things like glass, some students still say that all people around us, in stores, […] use plastics" (Abby, interview). She would use visual aids to address students' misunderstandings of plastic waste (Abby, interview).

Furthermore, when asked about students' misconceptions related to plastic waste, Abby indicated that students perceive plastic as a biodegradable material. Abby explains that because some types of plastic are made from bacteria, some students would think that all types of plastics are biodegradable. The participant inadequately explained the teaching approaches that she would use to avoid creating misconceptions on plastic waste (Abby, interview).

4.5.3. Pedagogy used to Integrate Plastic Waste

In congruence with the interview, the researcher noted during classroom observation that Abby implemented a project approach in her teaching about plastic waste. Students were asked to conduct research in groups and present information about the causes, effects and solutions for the plastic waste challenge. Abby also incorporated the use of visual aids as a closure to her lesson. For assessment purposes, Abby would implement a formative assessment (oral presentation) and a summative assessment (paper-and-pencil).

4.5.4. Addressing Plastic Waste as a Socio-Scientific Issue

Abby offered a simplistic connection between SL and plastic waste. She set forward that plastic waste should be part of the science curriculum to help students deal with it in the society. Nevertheless, Abby failed to deal with plastic waste as a socio-scientific issue in her classroom. Abby focused on the ethical component of plastic waste. She revealed that "even when we teach higher grades, we always start with a verse from the Quran or a speech to warm-up the lesson" (Abby, interview).

During classroom observation, Abby began her session with a verse from the Holy Quran saying, *"and We made the sky a protected ceiling, but they, from its signs,*

are turning away." Then, Abby pointed out that this quote is to remind us that God has created the world with the ozone layer to protect living organisms from UV rays. She further explained that God knows that human greed will damage the ozone layer. She concluded on the importance of preserving God's creation to protect ourselves and other living organisms too (Abby, classroom observation).

During classroom observation, Abby revealed to her students that their individual impact is valuable. "Do not ever think that you are insignificant. Your impact will grow on others and eventually, the effect will be magnified. All of us are powerful human beings", she added. The classroom environment was interactive and collaborative. Nevertheless, Abby focused on low order practices, such as recognizing, understanding and classifying. Students did not negotiate the social dimensions of plastic waste. Also, despite explaining some assessment strategies, Abby did not associate the strategies with the plastic waste learning process. In other words, assessment focused only on the learning product.

4.6. Teacher 6: Sophia

4.6.1. Scientific Competency to Teach about Plastic Waste

Although Sophia was able to explain how content knowledge affects the quality of SSI teaching, she provided a weak rationale on the importance of content knowledge. Nevertheless, she adequately defined plastic waste as a socio-scientific issue. She also mentioned in detail how plastic waste influences climate change and confidently stated the effects of plastic waste (Sophia, interview).

4.6.2. Interpretation of Students' Knowledge for Teaching about Plastic Waste

Sophia argued that one of the challenges she faced when teaching about plastic waste is that students do not apply what they learn. Her students find it difficult to consume less plastic, because awareness of minimizing plastic consumption is not raised in younger age groups. Therefore, applying solutions becomes difficult. Speaking from students' perspective, Sophia set forward that plastic waste is not thought of as a critical issue. She mentioned that her students "think it is normal pollution. A normal issue that can be solved like in a blink of an eye. […] When you go a little deeper in the subject, students find it hard to process" (Sophia, interview). Therefore, Sophia would engage her students in research to address their misunderstandings of plastic waste. Furthermore, Sophia explained that recycling plastic after disposing it in bins is a common student misconception. Sophia would resort to visual aids to avoid creating misconceptions about plastic waste (Sophia, interview).

4.6.3. Pedagogy used to Integrate Plastic Waste

During the interview, Sophia revealed using debates, classroom discussions, and research as teaching strategies to teach about plastic waste in the classroom. She also pointed out the use of inquiry-based learning to engage students in higher order practices and create eco-friendly alternatives to plastic.

> *"Well, we had a project this year with, with an NGO. So, basically students had to collect recyclable items. […] they did a project where they had to build something out of the recyclable materials. […] So, for example, some people made a dress out of paper tissues. Other people made use of plastic bottles as pencil cases." (Sophia, interview)*

4.6.4. Addressing Plastic Waste as a Socio-Scientific Issue

Sophia adequately recognized and defined plastic waste as a socio-scientific issue. She explained plastic waste as a societal issue and emphasized the importance of teaching about it in the classroom. Sophia perceived that the integration of plastic waste in the curriculum develops students' critical thinking, decision making, and reasoning. As noted before, the researcher was unable to conduct observations in Sophia's classroom, since the participant had taught about this topic at an earlier point during the academic year. Nevertheless, based on the interview and the lesson plan, Sophia had students confront the multidimensional perspectives of the issue. Students engaged in research to collect data as they created their plausible alternatives to plastic waste disposal.

The science teacher focused on higher-order practices, such collecting data, assessing solutions, and creating useful objects from plastic waste material. Sophia indicated the use of formative assessment to evaluate students' understanding of plastic waste. Nevertheless, the assessment strategy is not associated with the learning process of plastic waste as an SSI. For instance, Sophia does not assess students' higher order practices, which includes decision-making, reasoning, critical thinking, and argumentation. The focus on the assessment was solely on the product.

4.7. Teacher 7: Victoria

4.7.1. Scientific Competency to Teach about Plastic Waste

Victoria exhibited high awareness levels on the importance of content knowledge and explained how content knowledge affects the quality of SSI teaching. She emphasized the importance of teaching about plastic waste in the classroom.

Nevertheless, Victoria inadequately explained plastic waste as a societal issue. Although she inadequately defined the issue, she confidently stated the effects of plastic waste and mentioned how plastic waste influences climate change in detail (Victoria, interview).

4.7.2. Interpretation of Students' Knowledge for Teaching about Plastic Waste

Victoria highlighted struggling to develop eco-friendly habits in her students especially that it disagrees with how most other people in Lebanon act. She explained that when students see adults doing something, even if it was wrong, they will eventually copy.

> *"We are in Lebanon. We do not follow the rules... I am telling them … to recycle, to clean up … but […] they are being influenced by people around them. I am telling them something and they are seeing something else." (Victoria, interview)*

Victoria noted that her students do not have a weakness in the topic on plastic waste. However, what is difficult is that it is unclear what else to do. Students know that it is uneasy to recycle, especially in this country. Victoria added that even if students sorted waste at their homes, the garbage truck will mix everything all together (Victoria, interview). According to the participants, her students do not have misconceptions on plastic waste.

> *"It is very clear to them […] It is not something that is new to them […] and that I have to introduce it from zero. I think it is a universal issue that we know before we even teach it in school." (Victoria, interview)*

4.7.3. Pedagogy used to Integrate Plastic Waste

Victoria described implementing an art-integrated learning strategy to teach about plastic waste in the classroom. She used visual aids to expose her students to the state of marine life upon the disposal of plastic waste in the sea. The participant revealed

that her students were furious, and they enraged through art by expressing themselves. They used recycling material and created artistic figures.

Regarding assessment, Victoria revealed implementing a paper-and-pencil evaluation. She indicated that examinations in grade four are created in an interesting way, where students would color plastic waste in the picture or draw solutions for plastic waste. Students might draw the sign of recycling or someone throwing plastic in a plastic recycling bin. In addition, Victoria stated that grades two and three are assigned oral presentations by creating a digital product (PowerPoint presentation). The teacher further explained that the requirements of the project can be to draw ways to recycle material or create a 3D figure out of recycling waste.

> *"For grade 3 for example they were able to use plastic bottle lids and stick it on very big A4 paper to make a figure of a marine animal. For grade 6, they used plastic bottles to create a recycling bin from scratch sticking them together." (Victoria, interview)*

4.7.4. Addressing Plastic Waste as a Socio-Scientific Issue

Victoria sought to establish a relationship between functional SL and plastic waste as an SSI. Victoria asserted that plastic waste and/ or related topics are important to include in the curriculum, especially that she perceives her students as citizens of tomorrow. "They will grow up and we need them to be the change. So, it is not like we are teaching them just to get grades. No, we are teaching them because we have hope in them for later", Victoria explained (Victoria, interview).

As noted before, the researcher was not able to conduct observations in Victoria's classroom, since the participant had taught about this topic at an earlier point during the academic year. Nevertheless, based on the interview and the lesson plan, Victoria used current media to connect content to plastic waste. She acted as a learning

facilitator instead of authority. The teacher knows the science content related to plastic waste. Students superficially confronted the multidimensional perspectives of plastic waste by focusing on the environmental, aesthetic, ethical, health, and social aspects of the issue. Also, Victoria's use of formative assessment is ineffectively associated with the learning process of plastic waste as an SSI. For instance, Victoria does not assess students' higher order practices, which includes decision-making, reasoning, critical thinking, and argumentation. The focus on the assessment was on the product.

4.8. Participant 8: Nina

4.8.1. Scientific Competency to Teach about Plastic Waste

Nina provided a weak rationale on the importance of content knowledge, but explained how content knowledge affects the quality of teaching about plastic waste. In this respect, Nina was unable to define plastic waste. She also exhibited inadequate knowledge describing its effects and on how it influences climate change (Nina, interview).

4.8.2. Interpretation of Students' Knowledge for Teaching about Plastic Waste

Nina indicated that the existing conflict between what the teachers says in the classroom and society's actions is the most challenging for about teaching plastic waste. When asked about her students' weaknesses and difficulties, Nina revealed that her students are incompetent in implementing practical solutions to the plastic waste disposal problem. Nina provided details about her students' difficulties of understanding plastic waste, such as underestimating the influence they have to induce change. "I cannot do a big change. If I threw a plastic bottle, it won't affect the environment. I am just one person", Nina expressed in the name of her students (Nina, interview).

Nevertheless, she believed that organizing science fairs will help spread more awareness about this topic. If time does not permit, Nina revealed using guiding questions to avoid creating misconceptions. Also, Nina implied using visual aids to address her students' misunderstandings. She explained about a time she introduced global warming. "It's a bit hard. I show them videos about how like the sea level is really rising, the icebergs are melting... What I've noticed is that when they see animals suffering, this affects them the most", Nina explained (Nina, interview).

4.8.3. Pedagogy used to Integrate Plastic Waste

Nina described implementing an art-integrated learning strategy to teach about plastic waste in the classroom. Students created posters in groups and found solutions to plastic waste. They were provided with plastic materials that they used to contribute to reusing plastic.

> *"For example, they used plastic bottles. They made, as I remember, a guitar out of it with rubber bands. […] On the poster, they note the importance of reusing, what is reusing […]." (Nina, interview)*

As her students worked in groups, Nina indicated assessing her students through formal and informal observation. Furthermore, Nina would assess her students' understanding of plastic waste through a paper-and-pencil assessment (Nina, interview).

4.8.4. Addressing Plastic Waste as a Socio-Scientific Issue

Although Nina explained plastic waste as a societal issue and stressed on the importance of teaching it in the classroom, she failed to recognize and define plastic waste as a socio-scientific issue. Nina provided an illogical explanation without considering SL on why plastic waste is important to include in the curriculum. As noted

before, the researcher was unable to conduct observations in Nina's classroom, since the participant had taught about this topic at an earlier point during the academic year.

Based on the interview, the teacher is unconfident with the science content related to plastic waste. Nevertheless, based on the interview and the lesson plan, Nina acted as a learning facilitator instead of authority. Students superficially confronted the multidimensional aspects of plastic waste. Although Nina described some assessment strategies, she did not associate the strategies with the learning process of plastic waste as a socio-scientific issue. The summative assessment would evaluate students' understanding based on their ability to recognize the effects of plastic waste and providing logical solutions to its disposal. The assessment focused on lower order thinking skills.

> *"There was an assessment, mainly direct questions and indirect questions. For example, we mentioned, Sami was on the beach. He saw a child throwing plastic. How should Sami behave? What should he do? If you were at his place, what would you tell the child?" (Nina, interview)*

4.9. Teacher 9: Rose

4.9.1. Scientific Competency to Teach about Plastic Waste

Although Rose provided a weak rationale on the importance of a teacher's content knowledge, still, she explained how content knowledge affects the quality of SSI teaching. Rose inadequately defined plastic waste and stated its effects but mentioned the relationship between plastic waste and climate change in detail (Rose, interview).

4.9.2. Interpretation of Students' Knowledge for Teaching about Plastic Waste

Rose indicated that what makes teaching about plastic waste challenging is the inconsistency between what the teacher says in the classroom and society's actions. She argued that "you feel like you are contradicting yourself. Stop using plastic waste, but we have plastic used everywhere in our life" (Rose, interview). Nevertheless, she admitted spending insufficient time teaching about plastic waste in her classroom due to the packed curriculum. She pointed out closely sticking to the Lebanese science curriculum to teach in her classroom.

Furthermore, Rose provided details about students' difficulties of understanding plastic waste, which included applying the process of sorting waste. Moreover, when asked about her students' misconceptions on plastic waste, Rose revealed that her students viewed plastic material as being eco-friendly.

> *"[…] they think that plastic is a very good thing to be used in their life, easy. It is something that you can use and throw, and it is eco-friendly. This is what they always say. Once you give them the information, you feel that they start questioning. What? They get surprised. What are you saying?" (Rose, interview)*

Rose stated addressing students' misunderstandings of plastic waste by engaging students in research and debating it with the other learners. She also referred to the importance of students' prior knowledge in addressing their misconceptions of plastic waste.

> *"I start from the beginning, so we can just jot the ideas and from here we can start splitting, which one can just be as a misconception, and which one is a good thing, and we can continue with it. The misconception, we can explain why it is considered to be a*

misconception and from here we can start working with our class discussion." (Rose, interview)

4.9.3. Pedagogy used to Integrate Plastic Waste

Rose explained that she would implement a case-based learning, along with effective classroom discussions and debates to teach about plastic waste. Congruently with the lesson plan, the researcher noted during classroom observation that students closely inspected a scientific article related to the effect of plastic waste on Earth's geology. There were guiding questions associated with the article. Nevertheless, in the lesson plan, it is noted that each student must propose one solution or action that he or she can adopt to minimize the use of plastics in his/her daily life. However, this was not evident during classroom observation. During the closure of the lesson, Rose motivated her students to practice recycling plastic waste at their home, which was in congruence with the lesson plan.

Furthermore, to evaluate her students' understanding of plastic waste, Rose stressed that it cannot be assessed by a paper-and-pencil test. Instead, students engage in research to show how they understood the concept of limiting their consumption of plastic waste. "They can finalize or present their work and what conclusion did they reach; how did they do this? Through an experiment? Through recording things over a specific period of time?" questioned Rose (Rose, interview).

4.9.4. Addressing Plastic Waste as a Socio-Scientific Issue

Rose made an inadequate connection between functional SL and plastic waste, perceiving that exposing students to the issue will help them develop awareness about the effects of plastic waste on the environment. She emphasized the importance of enhancing students' scientific knowledge through teaching them about plastic waste.

Congruently with the lesson plan, the researcher during classroom observation noted that the teacher provided opportunities for students' reflections about their learning on the scientific article. Rose asked her students to write the main ideas of the article in their notebooks. Rose used a recent scientific article to connect content to plastic waste. She also implemented guiding questions by tapping on the conceptual scientific understanding of plastic. The questions related science content to the real world and included "Is it better to reuse or recycle plastic?", "Can recycling reduce plastic pollution?", "Why is the Great Pacific Garbage Patch mostly plastic?", "Why should we reuse plastic?", "What are the effects of plastic on the environment?", and "What is the relation between plastic waste and geology" (Rose, classroom observation).

Rose provided scaffolding for higher order practices, such as when explaining how micro-plastics will combine with sediments. She also related to students' prior knowledge when addressing students' misunderstandings. Also, Rose focused on the social dimensions of plastic waste. Students during the debate hastily negotiated the aesthetic, health, political, economic, ethical, and social aspects of plastic waste. For instance, Rose asked her students if there is a process to get rid of the plastic waste or if it is not feasible.

"Rose: What is needed to get rid of the patch?

Student 1: Human interference

Student 2: Cost." (Rose, classroom observation)

4.10. Teacher 10: Jason

4.10.1. Scientific Competency to Teach about Plastic Waste

Jason exhibited high awareness levels on the importance of content knowledge and explained how content knowledge affects the quality of teaching about plastic waste. He confidently stated the effects of plastic waste and mentioned how plastic waste influences climate change in detail. However, he exhibited inadequate knowledge when defining plastic waste (Jason, interview).

4.10.2. Interpretation of Students' Knowledge for Teaching about Plastic Waste

Jason considered that the lack of awareness on the dangers of plastic waste is the most challenging to teach about it. Nevertheless, he argued that because plastic waste is becoming an alerting issue, it must be tackled from elementary school until high school. By doing so, Jason believed that students would become more aware of handling plastic, and this would encourage them to create harmless ways to dispose plastic. According to Jason, the difficulties that he would anticipate when teaching about plastic waste are related to the needs to change students' daily habits. During the interview, Jason set forward that "we use these plastic bottles. We use these plastic bags. They are easier. They are cheaper. So, how could we live without them?"

Jason referred to discussions and students' prior knowledge for addressing students' misunderstandings on plastic waste. He would provide further explanation and real life examples from the context. He also revealed that exposing students to alternatives of disposing plastic waste to instill novel ways of thinking. It may help in understanding how severe plastic wastes are and perhaps they could shift their usages. Also, Jason revealed that believing plastic waste is biodegradable is a common

misconception on plastic waste among his students. He explained that he would address the misconception through inquiry questions (Jason, interview).

4.10.3. Pedagogy used to Integrate Plastic Waste

For active learning to take place, Jason would pose inquiry questions, problems and scenarios with the use of visual aids (PowerPoint presentations and documentaries). In accordance with his lesson plan, Jason began the session tapping on pre-requisite knowledge by asking students to define pollution, pollutants and degradation. During classroom observation, Jason carried on his lesson probing questions, such as "Can you mention some plastic products we use every day? Do these products degrade in soil easily? How can these plastic materials affect living organisms in water and on land?" The researcher also noted that Jason encouraged his students to reduce plastic waste in their small communities. He offered them an alternative solution and drove them with extrinsic motivation.

> *"Do we promise ourselves to do a change? Buy a reusable bag and use it for one month. Who agrees? If you sign up for this, I promise you it will be considered as part of engaging in service learning and it will be deducted from the total number of hours you have." (Jason, classroom observation)*

4.10.4. Addressing Plastic Waste as a Socio-Scientific Issue

Although Jason stressed on the importance of teaching plastic waste in the classroom, he failed to establish a link between plastic waste as an SSI and SL. Nevertheless, during classroom observation, the researcher noted that Jason linked the issue of plastic waste to real life. Jason provided an example on how Japan properly disposes waste by using methane gas to generate electricity. He highlighted to the

students that such an approach is mainly adopted in developed countries. Furthermore, upon introducing the largest dump of plastic in the North Pacific Ocean between Hawaii and California, the teacher asked, “What can we do to address this issue?” (Jason, classroom observation). Also, Jason knows the science content related to plastic waste. He set forward that “the release of methane gas will contribute to the greenhouse gases” (Jason, classroom observation). The teacher related what students know to prior knowledge and provided scaffolding practices.

“Jason: What is the origin of plastics?

Student1: fossil fuels

Jason: that is why it is non-biodegradable” (Jason, classroom observation)

Jason focused on the social dimensions of plastic waste. Students superficially discussed the aesthetic, health, political, economic, ethical, and social aspects of plastic waste. For instance, Jason asked the students to determine the effect of plastic waste on marine life. Students’ responses are presented next.

“Student 1: blocks digestion

Student 2: affect breathing” (Jason, classroom observation)

Nevertheless, Jason described some assessment strategies related to paper-and-pencil assessment, but does not to associate the strategies with SSI learning process.

Chapter Five

Discussion and Conclusions

This chapter discusses the results of the study aligned with the two research questions and their connections to literature. The following headings guide this chapter: "Overview of the Study", "Discussion by Research Question", "Limitations of the Study", "Conclusions", "Implications and Recommendations for Further Practice", and "Perspectives for Future Research".

5.1. Overview of the Study

This study aimed to answer the following research questions:

1. How can science teachers' PCK of plastic waste be characterized?
2. How do science teachers use plastic waste as a context to teach about SSI?

5.2. Discussion by Research Question

The discussion of the results is through the discussion of research questions one and two. While some findings from this study coincided with results from previous research studies discussed in the literature review, there were results that differed from research findings. Findings were compared against the results of other research studies from literature. The data obtained from interviews, lesson plans, and classroom observations were used to answer the first and second research questions.

5.2.1. Research question 1: How can science teachers' PCK of plastic waste be characterized?

Several science teachers perceived that plastic waste must be part of the curriculum as it can develop higher-order cognitive skills in students, such as critical

thinking. These results are in line with several studies reported in the literature, which indicate that teaching SSI permits students to enhance their argumentative thinking, decision making, understanding NOS (Evagorou et al., 2014), and comprehending extremely nested interrelations between distinct aspects of the issues (Muğaloğlu et al., 2016).

Nevertheless, science teachers' PCK on plastic waste was found to be limited to lower order practices, such as differentiating between biodegradable and non-biodegradable, recognizing the effects of plastic waste, and applying the sorting of wastes. Most science teachers did not integrate NOS themes and inquiry-based instructional practices. Although there was an implementation of the student-centered approach to an insignificant extent, students participated mostly in active classroom discussions. The science teachers incorporated questioning to initiate and facilitate the discussion about plastic waste. Besides that, students were not provided with autonomy for their own learning or asked to seek solutions to identified problems. Similar findings from the literature revealed that teachers focused on discussions about plastic and contemporary environmental problems. Aspects of sustainable development, such as empathy and critical thinking were not addressed (Aksland & Rundgren, 2020).

Furthermore, findings from the study revealed that all science teachers reported facing challenges on their teaching about plastic waste that included time constraints, applying students' understandings, altering their mindsets, and developing responsible consumption of plastic among them. Similarly, findings from the literature revealed that science teachers are incompetent upon negotiating the social, economic, and ethical structures of a science-based issue (Forbes & Davis, 2008). According to Cotton (2006),

teaching controversial environmental issues raises a number of pedagogical challenges for teachers. Nevertheless, findings showed that all participants believe that plastic waste or related topics are important to be included in the science curriculum, despite that the reasons varied. Similarly, with respect to a study from the literature, all secondary and primary school teachers perceive that it was necessary for them to teach about plastic pollution, yet the reasons also varied (Dalu et al., 2020).

Moreover, most participants from the study gave details about students' difficulties. The science teachers explained that the excessive consumption of plastic by the society makes it difficult for students to modify their behaviors and minimize the use of plastic. The science teachers also revealed that the students tend to copy the behavior of adults, which hinders their understanding of ceasing plastic use. This finding is consistent with findings in several educational research showing an absence of knowledge and students' misconceptions on water or ocean pollution (Feller, 2007; Hartley et al., 2015; Stavridou & Marinopoulos, 2001). Nevertheless, only Sally failed to recognize her students' weaknesses on the topic. According to Lewis and Leach (2006), misunderstanding of basic science can lead to a failure in recognizing significant issues of relevance, resulting in flawed lines of reasoning and probably inadequate decision-making. For example, students sometimes assume (wrongly) that plastic material is degradable and so fail to perceive the risk to the environment.

Furthermore, none of the science teachers in the study except for Mary and Sophia were able to describe the meaning of plastic waste in detail by forming connections with environmental, social, economic, and political aspects. The teachers either failed to define plastic waste or lacked subject matter knowledge. Also, almost

half of the teachers were able to mention how plastic waste influences climate change in detail and confidently stated the effects of plastic waste. In contrast to this finding, one study from the literature shows that despite the variation in teachers' motivation for teaching about plastic pollution, all of the teachers exhibited knowledge about plastic pollution (Dalu et al., 2020). Teachers must be scientifically informed on these issues to effectively educate their students on them (Mandrikas et al., 2021).

The strategies that the science teachers used to teach about plastic waste varied, but were limited to project-based learning, debates, guided classroom discussions, art-integrated learning, and case-based learning. Nevertheless, most of the teachers implemented a guided classroom discussion, even for Rose who had used a case-based learning. Some of the strategies that were adopted by the science teachers are usually used on traditional content knowledge. To explain more, a study from the literature sought to explore the effectiveness of three teaching strategies (direct teaching, hands-on teaching, and simulation game-based teaching) on change in knowledge, attitude, and behavior in students toward plastic waste management. The researchers found that all these three teaching strategies can considerably develop students' knowledge, whereas the hands-on and simulation game-based strategies can promote attitudes and behavior (Chow et al., 2017). Plastic waste is a topic that cuts across different disciplines and demands the use of teaching strategies that would not only serve the scientific component of the topic.

It also bears mentioning that few teachers had reported in the interview that they do implement a project-based learning approach. Nevertheless, upon conducting classroom observations, the researcher noted that their implementation to this approach

was exclusively limited to students collecting data by undergoing research and presenting it in class. Blonder (2010) explains that teachers do not only need to strengthen their content knowledge on these issues. They also need to be knowledgeable with the required teaching strategies to integrate the social implications of contemporary research, as well as to address the in-built ambiguity of these relatively novel science areas. Similarly, more recently, Mandrikas et al., (2021) highlight that teachers must be qualified with knowledge about appropriate teaching strategies to approach these issues.

Pettipas et al. (2016) set forward that the discharge of waste into the environment could be partially due to an absence of knowledge among the population about the influence of waste on the environment and ecosystems. Hence, individuals must have basic knowledge about environmental issues and the behaviors that cause them to act in pro-environmentally and conscious ways (Kollmuss, & Agyeman, 2002). It can be concluded that science teachers' PCK of plastic waste in Lebanon is limited in terms of effectiveness. Lewis and Leach (2006) recognize that school science cannot begin to teach all the science that an individual might need in their lifetime. Hence, the researcher hypothesizes that teaching a limited number of basic scientific concepts related to plastic, in ways that endorse understanding, would provide a sufficient basis for future engagement with the disposal of plastic and its social consequences.

5.2.2. Research question 2: How do science teachers use plastic waste as a context to teach about SSI?

Findings from this study revealed that only Mary used plastic waste as a context to teach about SSI. Despite their attempts, the remaining science teachers' PCK was merely to raise awareness on the dangers of plastic waste to the environment, promote

an understanding on the importance of an adequate disposal of plastic waste, and to a lesser extent, develop eco-friendly habits. It is worthy to note that the researcher faced challenges in recruiting participants that fit the requirements of the study. One of the major criteria was that science teachers must spend at least one session per year teaching about plastic waste. The mentioned criterion made it difficult to recruit participants, because the Lebanese science curriculum does not provide space for science teachers to teach at least one session per year. The researcher approached many science teachers but only few were motivated to integrate plastic waste into their science instruction. This is consistent with the study of Vlaardingerbroek and Taylor (2007) who infer that environmental topics receive a hasty treatment in many schools.

Presley et al. (2013) emphasize that when an SSI is not central to the curriculum, then the instruction is simply not an SSI-based instruction. The researchers assert that the issue must be the curricular focus and presented at the beginning of the instruction to act as an adequate context for teaching (Presley et al., 2013). Furthermore, textbooks mainly provide examples of how the content is connected to a real-world issue at the end of a section; however, Presley et al. (2013) contend that relatable issues after the instruction happens misses the point of SSI-based instruction.

Moreover, findings revealed that all science teachers agreed that plastic waste instruction is contextually related to the school and community environment, and expressed freedom to share their opinion about the topic in their school. Peripheral influences involving the climate of the school, the expectations of the district and community, along with the national policy will largely play a role on how teachers and students confront controversial issues in the classrooms (Presley et al., 2013). For

instance, Sally and Abby used verses from the Holy Quran to integrate the ethical and religious components of plastic waste. In line with this finding, several studies recommend that students confront the ethical dimensions of an SSI (Gray & Bryce, 2006; Gutierez, 2014; Presley et al., 2013; Zeidler et al., 2006). Exploring the ethical perspective promotes students' interests (Levinson, 2006) and supports them to become socially responsible (Finegold, 2001).

Also, results from this study revealed that teachers' confidence about their understanding and knowledge related to plastic waste and its disposal took on different levels as the teachers' answers ranged from having low or moderate self-efficacy levels to having high self-efficacy levels. According to Presley et al. (2013), teachers must be honest about their knowledge limitations and ready to act as knowledge providers rather than sole experts. Mary was the only participant to explicitly reveal to the students about her limited knowledge. When telling her students that it takes between 400 to 1000 years for a plastic bag to degrade, Mary said: "Listen, it is important. I learned about it two days ago" (Mary, classroom observation).

Teachers must have sufficient knowledge and awareness of the issue to better direct students to resources that will result in new information and understandings (Presley et al., 2013). Nevertheless, teachers must not be expected to know all about a specific issue (Presley et al., 2013). Effective SSI teachers do not position themselves as the sole experts in the classroom (Dolan et al., 2009). SSI-based instruction is constructed around inherently open-ended problems, and hence, it is challenging to foresee exactly what directions classroom discourse linked with SSI will take (Presley et al., 2013).

It was found that none of the teachers from this study except for Mary were able to have students negotiate the environmental, social, economic, and political aspects of plastic waste. Presley et al. (2013) contend that the aim is not essentially to produce students who are experts in economics and politics, but rather, to help students better comprehend the economic and political aspects that fundamentally shape the issue and interact with science. Nevertheless, it was found that none of the teachers from this study except for Mary were able to describe the meaning of plastic waste in detail and in connection with the environmental, social, economic, and political aspects. An effective SSI instruction also relies on the teacher's awareness of the social structures related to the issue (Barrett & Nieswandt, 2010; Sadler, 2011). For example, to assist students in undergoing decisions related to plastic waste disposal, understanding the economic impacts of banning or not banning plastic needs to be considered.

Also, almost half of the teachers were able to mention how plastic waste influences climate change in detail and confidently stated the effects of plastic waste. Similarly, studies from the literature indicated that some teachers have inadequate knowledge and skills for teaching about SSI (Day & Bryce, 2011; Lee et al., 2006). To adequately enable SSI-based instruction in the classroom, Presley et al. (2013) reveal that teachers must be knowledgeable about the science content related to the issue and aware of the social considerations linked with the issue. Similarly, according to Lee and Witz (2006), teachers must understand the underlying content knowledge in order to teach science in the context of an issue. For example, to teach an SSI-based lesson on plastic waste, the teacher must understand the scientific concepts of fossil fuels and greenhouse effect to investigate the relationship between plastic waste and climate change.

Furthermore, only Mary and Rose had engaged their students in reading recent scientific articles. In relation to the study's finding, Klosterman et al., (2012) reveal that incorporating media resources offers teachers with a significant diversity of sources and can help students relate their learning in class with what is happening in the world. However, using technology is also another way to support student learning. Several teachers had incorporated the use of visual aids in their science classes to teach on plastic waste. According to Evagorou (2011), technology can be used in several ways to develop SSI-based instruction and has the potential to be a significant tool for providing access to important social issues.

For instance, through technology, Victoria managed her students' emotional intelligence to allow for greater outcomes. She revealed making her students furious after showing them a video of living things on the seashore trying to take a breath. This finding is in line with the study by Nicolaou et al. (2015), which found that SSI fosters emotions. Similarly, other studies from literature (e.g., Zeidler, 1997; Zeidler & Keefer, 2003) reveal that SSI offers a scope of emotions and that students involve emotions while exploring SSI.

Findings from the study revealed that only Mary and Sophia made a connection between functional SL and plastic waste. Mary engaged students in decision-making based on scientific evidence. Students conducted research at several points when learning about plastic waste. They inevitably confronted the subjectivity and tentativeness of science, in addition to the sociocultural influences on science (Presley et al., 2013). Consequently, Mary was provided with ideal opportunities to engage her students to think about NOS themes. For instance, during classroom observation, the

researcher noted that Mary asked her students: “How do I make a decision if I will take the paper, plastic, or cotton bags? Based on what criteria?” (Mary, classroom observation).

Mary’s students underwent a debate to decide the best choice to use among plastic, cotton, and paper bags. They engaged in argumentation by using evidence to back their claims and offer rebuttals against the evidence given by the opposing group. According to Walker and Zeidler (2007), effective SSI-based instruction engages students in activities that support higher-order practices of argumentation, reasoning, position taking, and decision making. Mary was the only participant who, at several points of her instruction on plastic waste, has engaged the students in undergoing reflections and wonderings about their understandings. This finding is consistent with the assertion of Eastwood et al. (2013), who highlighted that teachers must permit students to reflect on their experiences and to use higher-order practices.

Moreover, the findings in this study showed that while few of the teachers’ approaches were consistent between the observations and interviews, there were others that were not. Despite this inconsistency, the overall results generated from the interviews, lesson plans, and classroom observations show that plastic waste as an SSI is implemented inadequately among teachers at various levels for engaging students on multidisciplinary structures.

By implementing the engineering design cycle, Mary effectively incorporated the plastic waste issue into the political, social, ethical, and economic structures. As students designed prototypes to tackle the problem of plastic waste, they were exposed to the multidisciplinary structures of the issue. Students designed creative, optimized

solutions that were practical, affordable and feasible. They were engaged in problem-solving processes, such as determining objectives and constraints, researching, prototyping, testing and evaluating.

According to Chow et al. (2017), there are no standard pedagogies created precisely for teaching about plastic waste management in schools. Nevertheless, traditional lectures were found to be less effective to affect behaviors in environmental-related topics due to minimal interactive learning and thinking experiences provided to students (Duerden & Witt, 2010). Meanwhile, experiential learning is more effective in empowering and engaging students to participate in environmental learning and actions (Sipos et al., 2008).

The teaching strategies reflected certain aspects of SSI, such as integrating disciplines, making connections to real-world problems, questioning, using student-centered approaches, and involving students in discussions. Nevertheless, project-based learning, engineering design, technological literacy, scientific inquiry, debates, scaffolding, higher order practices (argumentation, reasoning, reflection), and problem-based learning were rarely implemented. Particularly, the teachers exhibited limited implementation of incorporating the political, social, ethical, and economic aspects of plastic waste into their science instruction on plastic waste.

Furthermore, findings from this study revealed that the integration of NOS themes was only implemented with Mary. Similarly, one study finds that science teachers rarely integrate features of NOS or make it explicit to students in science learning (Mellado et al. 2007). Other studies from the literature reveal that science teachers hold inadequate conceptions of NOS (Haidar 1999; Lederman 1992).

Nevertheless, science teacher's integration of NOS leads SL in the classroom (Sadler, 2002; Nuangchalerm, 2009). In other words, a developed PCK for NOS is essential for developing SSI teaching strategies to lead SL. In this study, science teachers that possessed more advanced understandings of related science concepts and conceptual scientific understanding of plastic waste, had more effectively implemented SSI teaching strategies about plastic waste. Hence, the researcher hypothesizes that developing a science teacher's understanding of NOS helps promote teaching strategies that reflect aspects for teaching about SSI.

5.3. Limitations of the Study

The researcher studied a particular phenomenon in-depth and presented a rich, holistic and descriptive analysis of each science teacher. The researcher was able to interview the ten participants, obtain lesson plans from them, and conduct classroom observations with only seven science teachers. The number of observed sessions was limited as the researcher was not able to observe sessions with Sophia, Victoria and Nina. Also, even though the researcher observed sessions with the other seven science teachers, the number of sessions observed was small (one session with each). The main reason was that the science teachers did not allocate additional sessions for their teaching on plastic waste.

5.4. Conclusions

This study was the first attempt to explore the pedagogical content knowledge of science teachers in Lebanon on teaching about plastic waste and plastic waste as a socio-scientific issue. The findings of this study revealed that despite the science teachers

acknowledged including plastic waste in the curriculum, their PCK on the topic was identical to the one used on traditional content knowledge. Nevertheless, effective science teaching on SSI engages students in making sense of plastic waste and its disposal, the scientific ideas behind it, along with the multidisciplinary structures that comprise the issue. The findings of this study revealed that science teachers were incompetent on focusing on the social dimensions of plastic waste.

The review of literature revealed the importance of SL as one of the fundamental goals of science education in developing scientifically literate citizens. More specifically, SSI is a crucial context for SL in order to prepare scientifically literate individuals who can undergo informed decisions. In order to develop SL and understand scientific practices, students must primarily engage in scientific investigations, analyze and explain outcomes, use evidence to support claims, and participate in discourse about plastic waste as an SSI. SSI provide ideal contexts for teachers to authentically integrate these processes in their classroom (Presley et al., 2013). Through teaching about plastic waste as an SSI, students can be involved in leading the way to reduce plastic pollution, evaluating strong actions to protect biodiversity, and building an unpolluted future.

Findings showed that the teaching strategies used by the science teachers reflected certain aspects of SSI, such as integrating disciplines, making connections to real-world problems, questioning, and involving students in discussions. Nevertheless, higher order thinking, scientific argumentation, inquiry-based learning, and understanding NOS were rarely implemented. Science teacher must use teaching strategies that help students confront the different dimensions of plastic waste. In other words, science teachers must develop specific PCK for teaching about plastic waste as an SSI. Science teachers who

teach SSI must occupy appropriate knowledge on the subject matter, be effective in linking the issue to the curriculum, have skills for dealing with argumentation in the classroom, and possess knowledge of assessing students' skills in reasoning.

5.5. Implications and Recommendations for Further Practice

The findings of this research open up new possibilities for researchers. Given that research on teaching about plastic waste is still limited, several recommendations can be made for future studies.

a. Science teacher's understanding of NOS must be developed;
b. Despite its benefits, teachers might not address SSIs in classroom (McGinnis & Simmons, 1999). Teachers must undergo training to develop their capabilities of utilizing complex SSIs in science education. In other words, teachers must be provided with professional development on different teaching strategies and approaches that would reflect teaching about SSI aspects;
c. Curriculum designers must incorporate social issues with science content to enrich the Lebanese science curriculum;
d. Professional developers and administrators must assist teachers in implementing SSI-based instruction;
e. Stakeholders must facilitate the implementation of plastic waste instruction as an SSI in the classroom to tackle the plastic problem on all levels of the global education community;
f. University degrees offering courses on education should incorporate instructional strategies to teach about SSI;

g. Cross-cultural comparative studies must be conducted to study the Lebanese contexts with respect to other contexts;
h. Teachers and school personnel must develop strategies for discussing concerns on SSI-based instruction with parents and the community to justify to them why students must learn the issue.
i. Teacher education programs must integrate various emergent scientific technologies in the teacher training related to STEM education in the context of SSI.
j. Teacher education programs must incorporate contentious educational scenarios that, based on active learning methodologies, SSI and developing scientific technologies, permit the development of the PCK of teachers to promote education on environmental sustainability.
k. Teacher education programs need to employ unique practices that help promote students' ability to apply science learning to SSI about which they must be able to undergo informed decisions.
l. Qualified personnel of professional development and administrators of teacher training programs must ensure that teachers are provided with ample opportunities to practice successful instruction on SSI.

5.6. Perspectives for Future Research

The science teachers from the study work in schools that were all located in Beirut, Lebanon. Future research could include more participants from schools outside the Beirut area. Moreover, researchers must also consider diversifying the research methods to include a quantitative approach. A greater sample sizes may be considered to

develop a more macroscopic view on teachers' perceptions and beliefs on their understanding about plastic waste as an SSI, in order to generalize results in Lebanon. Furthermore, future research must explore the strategies and approaches for which science teachers in different contexts (other than Lebanon) are using to teach about plastic waste. Also, future research must explore science teachers' practices on teaching about plastic waste at the college level. Besides plastic waste, further studies must investigate how science teachers can use different topics, such as waste management, as contexts to teach SSI.

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Appendices

Appendix A

Interview Questions

I. Teacher's Background Information:

1. What is your educational background (degree and area of specialty)?
2. What is (are) the subject(s) that you teach?
3. What grade level(s) do you teach?
4. Which curriculum do you use to teach in your science classroom?
5. How many years of teaching experience do you have?
6. What do you see as your strength with respect to science area and specific content topics?
7. What area(s) do you feel could use strengthening with respect to science area or specific content topics?
8. How would you characterize effective science teaching?
9. What do you think is the relation between science and society?
10. Do you think that controversial and debatable issues in science are necessary for students to know or important for teachers to spend time on?
    10.1. Why?
11. How many times have you taught about plastic waste before?
12. How many sessions do you spend teaching about plastic waste?
13. What is the most challenging about teaching plastic waste?

Definition of socio-scientific issues (SSI): Socio-scientific issues are controversial, socially relevant, real-world problems that are informed by science and often include an ethical component (Sadler et al, 2006). Example: cloning, abortion, climate change, etc.

Teachers' Understandings/ Beliefs about Plastic Waste

1. Please give an example of a socio-scientific issue.
2. Do you consider plastic waste as a socio-scientific issue? Why?
3. Should socio-scientific issues be a part of the science curriculum?
   3.1. If yes, why? If no, why not?
4. Do you believe it is important to spend instructional time in your science classroom to teach students about SSI?

4.1. If yes, why?

4.2. If you think it is important what do you think is the best way to integrate SSI into your science instruction? Please give an example.

4.3. If no, why not?

5. Do you spend time teaching SSI in your classroom?
   5.1. If yes, please give one or more examples.
   5.2. If your response is no, why not?

II. Teachers' PCK for Plastic Waste as an SSI

Subject Matter Related Questions

1. What is plastic waste?
2. How confident do you feel about your understanding and knowledge related to plastic waste and its disposal?
3. If you had more information about plastic waste, would it change your response to the previous questions? Why or Why not?
4. What is the relationship between plastic waste and climate change?
5. What are the effects of plastic waste?

Student Related Questions

1. If you taught plastic waste what were your students' weakness and difficulties?
   1.1.If not, what difficulties would you anticipate?
2. What might be some of your students' misconceptions about plastic waste and topics related to this?

Curriculum Related Questions

1. In what units could plastic waste be included?
2. What science concept(s) would be stressed on using plastic waste within the curriculum?
3. Is plastic waste and/or related topics important to include in the curriculum? (If Yes, why? If No, why?)
4. What learning objectives in the curriculum are related to plastic waste?

Pedagogy Related Questions

1. What teaching strategies would you use to teach about plastic waste in the classroom?
2. How would you assess students' understanding of plastic waste?
3. How do you address students' misunderstandings of plastic waste? Please give an example.
4. What kind of teaching approaches would you use to avoid creating misconceptions on plastic waste?

School Related Questions

1. Is SSI instruction contextually related to the school and community environment? (If yes, why? If no, why).
2. Do you feel free to express your opinion or belief about plastic waste in your school? (If yes, why? If no, why).

Appendix B

Classroom Observation Protocol for Instruction on Plastic Waste

This protocol aims to describe and characterize plastic waste teaching practices in science classrooms.

Direction: Fill this out as you are observing classes.

Part I: Background Information

Observer _____ Teacher _____

Grade/Level _____ Topic or topics _____ _____

Observation date Time Start End

Part II: Lesson Implementation

Direction: Please make in the category that you observed and provide description/ examples about item. (0= not observed, 1= observed once time, 2= observed two or more times)

	Observation Categories	Scale			Observation Journal
	1. Teacher promoted conceptual scientific understanding	0	1	2	

Focus of Instruction	2. Teacher related science content to the real world	0	1	2	
	3. Teacher considered NOS themes associated with plastic waste	0	1	2	
	4. Teacher focused on risks and benefits of plastic waste	0	1	2	
	5. Teacher focused on social dimensions of plastic waste	0	1	2	
	6. Teacher focused on higher order practices (e.g. argumentation, reasoning, and scientific modeling	0	1	2	
Teaching Moves	1. Teacher provided scaffolding for higher order practices	0	1	2	
	2. Teacher provided opportunities for students' reflections about their learning	0	1	2	

	3. Teacher related what students learn to prior knowledge	0	1	2	
	4. Teacher presented plastic waste first and continues focusing on plastic waste	0	1	2	
	5. Teacher used current media to connect content to plastic waste	0	1	2	
	6. Teacher assessed students' conceptual scientific understanding (Summative or Formative)	0	1	2	
	7. Teacher assessed students' higher order practices (Summative or Formative)	0	1	2	
Role of Teacher	1. Teacher acted as learning facilitator instead of authority	0	1	2	
	2. Teacher knows the science content related to plastic waste	0	1	2	
Role of Students	1. Students engaged in higher order practices	0	1	2	

	2. Students negotiated social dimensions of plastic waste	0	1	2	
	3. Students assessed risks and benefits of plastic waste	0	1	2	
	4. Students collected and/or analyzed scientific data related to plastic waste	0	1	2	
	5. Students confronted the ethical dimension of plastic waste	0	1	2	
Classroom Environment	1. The classroom environment is collaborative and interactive	0	1	2	
	2. Students and teachers show respect to each other	0	1	2	
Total					

Appendix C

Rubric for PCK-Plastic Waste

PCK	Questions	Inadequate (0)	Eclectic (1)	Reform-based (2)
Teacher's understanding about Plastic Waste	Please give an example of a socio-scientific issue.	Fails to recognize and define socio-scientific issues.	Fails to recognize and define socio-scientific issues. But explain SSI as societal issue and emphasize importance of teaching SSI in the classroom.	Having a basis in science, involve forming opinions, making choices at personal or societal level, are frequently media reported, address local, national and global dimensions, involve some cost-benefit analysis, involve values and

				ethical reasoning. SSI has incomplete information because of conflicting/ incomplete scientific evidence, and inevitably incomplete reporting.
	Do you consider plastic waste as a socio-scientific issue?	Fails to recognize and define plastic waste as a socio-scientific issue.	Fails to recognize and define plastic waste as a socio-scientific issue. But explains plastic waste as a societal issue and emphasizes the importance of teaching about	Having a basis in science involves forming opinions, making choices at personal or societal level, are frequently media reported, address local,

			plastic waste in the classroom.	national and global dimensions, involves some cost-benefit analysis, values and ethical reasoning. Plastic waste has incomplete information because of conflicting/ incomplete scientific evidence, and inevitably incomplete reporting.
	Should plastic waste be a part of the science curriculum?	Offers a very simplistic or illogical	Making connection between functional	Making connection between functional

		explanation without considering scientific literacy.	scientific literacy and plastic waste. But explains plastic waste as societal issue and emphasizes importance of teaching about plastic waste for science education.	scientific literacy and plastic waste. Explaining the connection in detail such as improve understanding of content knowledge and NOS, inquiry existing knowledge and enable students engage in discussion based on scientific evidence and enable.

	Do you believe it is important to spend instructional time in your science classroom to teach students about plastic waste? (If yes, why? And if no, why not?)	Offers a very simplistic or illogical explanation without considering scientific literacy and humanistic face of scientific decision	Fails to make relationship between plastic waste and scientific literacy. But, explains plastic waste as a societal issue.	Explains plastic waste as a societal issue and emphasizes importance of teaching about plastic waste for science education.
	If you think it is important, what do you think is the best way to integrate plastic waste into your science instruction? Please give an example.	Fails to describe strategies for integrating plastic waste into science instruction.	Describe some of teaching strategies (discussion, questioning etc.) but not to explain the reasons.	Giving details about discussion or dialogic teaching as an opportunity for students to express their understanding and ideas to other students in a supportive and

				evaluative environment.
	Do you spend time teaching about plastic waste in your classroom? If yes, please give one or more examples. If your response is no, why not?	Not to spend any time for teaching about plastic waste in his/her classroom.	Not to spend much time teaching about plastic waste. But, interested in integrating plastic waste into the classroom.	Spending much time teaching about plastic waste in the classroom and explain the reasons why teaching about plastic waste is preferred.
Curriculum	In what units could plastic waste be included?	Unsuccessful to recognize the unit.	Mentions the title of the unit but not exactly.	Successful to recognize the unit.
	What science concept(s) would be stressed using plastic waste within the curriculum?	Unsuccessful to recognize the concepts.	Few concepts.	Mentions all concepts related to plastic waste (e.g. Recycling).

	Is plastic waste and/or related topics important to include in the curriculum? (If Yes, why? If No, why?)	Illogical explanation without considering scientific literacy.	Explains SSI as a societal issue and emphasizes the importance of teaching SSI in the classroom, but, fails to make a relationship between SSI and scientific literacy	Explains the relationship between SSI and scientific literacy.
	What learning objectives in the curriculum are related to plastic waste?	Fails to recognize the learning objectives related to plastic waste in the curriculum.	Recognizes the objectives, but, not adequately.	Recognizes all the objectives related to plastic waste in the curriculum.
Pedagogy	How would you use the topic plastic waste instructionally in the classroom?	Unsuccessful to describe strategies.	Describes some of teaching strategies (discussion, questioning etc.) but, does not	Adequately details teaching strategies, (inquiry-based and

			explain the reasons.	argumentation) and explains the reasons.
	What is the advantage of using these strategies?	Inadequate explanation of the connection between the strategies and students' learning process.	Weak rationales for the connection between instructional strategies and students' learning.	Strong rationales for the connection between the instructional strategies and student learning Explains advantages and disadvantages of the strategies.
	How would you assess students' understanding of plastic waste?	Describes only summative assessment strategies. Focuses on learning product	Describes some assessment strategies, but does not to associate the strategies with SSI learning process.	Assesses students' decision-making skills, such as, use of evidence, argument, and counterargument . Focuses on the

		rather than the learning process.		process and product. Assesses students using authentic evaluation strategies.
	How do you address students' misunderstandings of plastic waste? Please give an example.	Does not refers to the importance of organizing lesson in connection with student prior understanding?	Refers to the importance of students' prior knowledge but no link between organizing lesson and addressing students' misunderstandings.	Determines students' difficulties for the lesson and organizes the lesson based on the difficulties.
	What kind of teaching approaches would you use to avoid creating misconceptions?	Inadequate explanation of the connection between the instructional strategies and	Describes some of teaching strategies, but does not associate with misconceptions	Provides details about teaching strategies (inquiry-based strategies, argumentation)

		students' misconceptions related to plastic waste.	related to plastic waste.	Explains the relationship. between the strategies and misconceptions about plastic waste.
	What kind of teaching approaches would you use to help alleviate students' misconceptions?	Inadequate explanation of the connection between the instructional strategies and students' misunderstanding related to plastic waste.	Describes some of the teaching strategies, but, does not associate them with misconceptions related to plastic waste.	Mentions details about teaching strategies (inquiry-based strategies, argumentation) and explains the relationship between the strategies and misconceptions about plastic waste.
Content	How confident do you feel about your	Low self-efficacy	Medium self-efficacy	High self-efficacy

	understanding and knowledge related to plastic waste and its disposal?			
	If you had more information about plastic waste, would it change your response to the previous questions? Why or Why not?	Low awareness level	Weak rationales	High awareness level on the importance of content knowledge and explains the reasons how content knowledge affect the quality of plastic waste teaching
	What is plastic waste?	Fails to define the plastic waste.	Lacks subject matter knowledge	Describes the meaning of plastic waste in detail in connection with environmental,

				social, economic, and political aspects.
	What is the relationship between plastic waste and climate change?	Inadequate explanation	Lacks subject matter knowledge	Mentions how the plastic waste influences climate change in detail
	What are the effects of plastic waste?	Inadequate explanation	States few effects of plastic waste.	Confidently states the effects of plastic waste
Student	If you taught plastic waste, what were your students' weakness and difficulties? If not, what difficulties would you anticipate?	Fails to recognize the students' weakness and difficulties about plastic waste.	Offers a very simplistic or illogical weakness and difficulties about plastic waste. Offers a very simplistic or illogical misconceptions	Giving details about students' difficulties of understanding the plastic waste, including examples. Describe some students' misconception.

			about plastic waste.	
School	Is plastic waste instruction contextually related to the school and community environment? (If yes, why? If no, why).	Unsupported	Mid-supported	Strong supported
	Do you feel free to express your opinion or belief about plastic waste in your school? (If yes, why? If no, why).	Uneasiness	Occasionally	Supportive school