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Perspective

‘Sleep Blindness’ in Science Education: How Sleep Health Literacy Can Serve as a Link between Health Education and Education for Sustainable Development

Anna Beniermann [1,*], Martin Glos [2], Heike Schumacher [3], Ingo Fietze [2], Stephan Völker [3] and Annette Upmeier zu Belzen [1]

[1] Humboldt-Universität zu Berlin, Department of Biology, 10099 Berlin, Germany; annette.upmeier@biologie.hu-berlin.de
[2] Interdisciplinary Center of Sleep Medicine, Charité-Universitätsmedizin Berlin, Charitéplatz 1, 10117 Berlin, Germany; martin.glos@charite.de (M.G.); ingo.fietze@charite.de (I.F.)
[3] Department Lighting Engineering, Technical University of Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany; heike.schumacher@tu-berlin.de (H.S.); stephan.voelker@tu-berlin.de (S.V.)
* Correspondence: anna.beniermann@hu-berlin.de

Abstract: Sleep disorders are risk factors for diseases such as dementia or diabetes, and cause enormous costs. Despite the crucial impacts of sleep on human health, there is little to no research on sleep and health in the field of science education. Although health education is an overarching goal of science education in school, the topic of sleep is rarely addressed. In the related field of medical education, empirical studies shed light on the impact of school projects concerning sleep health but are yet unrecognized by science education research. Systematic reviews demonstrate the effectiveness of school-based sleep education programs for increasing sleep knowledge but show contradicting findings regarding the impact on sleep behaviors. Lacking knowledge about healthy sleep is related to unhealthy sleep behavior. In this perspective article, we prepare the topic of sleep for the field of science education by presenting the state of research concerning sleep education. Using the connection between light pollution and sleep disruption, we present a concept of *sleep health literacy* in science education, argue for the implementation of sleep health literacy in science education curricula, and describe how the topics of sleep and light can serve as a link between health education and Education for Sustainable Development.

Keywords: sleep; sleep health literacy; science education; SDG3; health education; education for sustainable development; engineering; ESD; light pollution

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1. Introduction

Restorative sleep is essential for mental and physical recreation and keeping proper health conditions along with other metrics such as stress reduction, work–life balance, well-balanced diet, physical activity, body weight, abstaining from nicotine, and avoidance of alcohol abuse as well as other substances. The night-time use of electric lighting, TV, and mobile devices can lead to a shortening of bedtime and worsening sleep quality [1,2], while healthy sleep patterns are known as a crucial process for memory consolidation and restructuring [3]. Sleep disorders are a known risk factor for other diseases such as dementia, obesity, cardiovascular disease, depression, diabetes, inflammation, and cancer [4–6] and additionally cause enormous costs for healthcare systems, the economy, and society as a whole [7–9].

The achievement of health literacy [10] is a growing challenge, even beyond the context of sleep [11]. While people have access to a great amount of health-related information, they are not sufficiently prepared and supported to make health-related lifestyle choices. The WHO [11] calls this the ‘health decision-making paradox’, in which education systems

do not succeed in providing students with skills to access and understand, use, and assess health-related information adequately. This 'health literacy crisis' [11] is crucial, as the effects of poor health literacy on people's actual health are well known, e.g., through unhealthy choices and riskier behavior [11]. Health literacy was implemented by the WHO as a key dimension of the European health policy framework Health 2020 [11]. It is also an emerging topic in health education [12,13] and is expected to become a central theme for students globally [11,14–16].

However, even though sleep is a crucial factor for human health, and although health education [17,18] is one of the overarching goals of science education (science education in this article refers to school science and the related research field of science education with its professional journals) in schools, sleep is neither part of science curricula (e.g., Canada: [19]; Germany: [15,20]; United States: [21]), nor is it addressed in common health literacy definitions [11]. It becomes apparent that sleep is a 'non-issue' in discussions and recommendations about health literacy and health education. This 'sleep blindness' expands over the whole research and practice field of science education and points to the need for considerations about sustainable sleep education approaches in schools and a conception of *sleep health literacy*.

While there is little to no empirical research on sleep education in the field of science education, several empirical studies shed light on the impact of school projects concerning sleep quality and sleep health that originate from the field of medical education (medical education in this article refers to the research field of medical education with its professional journals) (e.g., [22,23]). Systematic reviews of these school-based sleep education programs demonstrate their effectiveness for increasing sleep knowledge but show contradicting findings regarding the impact on sleep hygiene (e.g., [24,25]). The potential of sleep education is large, not only because of its high relevance for human health but also because children and adolescents are very interested in sleep-related questions [26]. Such interest is often provoked by personally relevant questions in the context of the environment and health [13,27]. Both fields are increasingly structurally thought of as linked together, e.g., in the *Education for Sustainable Development* (ESD; [28]) framework. However, health is an important but often underrated aspect in the context of ESD [29,30].

Light pollution in particular is a specific phenomenon that connects the environment and health in ESD. Light pollution has negative effects on energy efficiency and ecosystem functioning [31,32] as well as on human health, e.g., through the suppression of the hormone melatonin and circadian disruption [33,34].

In this perspective article, we prepare the topic of sleep for the field of science education by presenting the state of research from the fields of science and medical education concerning sleep education. We describe the relevance of sleep for ESD, present the first comprehensive concept of sleep health literacy in a science education context, and argue for the implementation of sleep health literacy as an outcome of sleep education in science education curricula. We furthermore describe how the topic of sleep and light pollution can serve as a link between health education and Education for Sustainable Development.

2. Theoretical Background

2.1. Health Literacy in Science Education

2.1.1. The Concept of Health Literacy

Health literacy is fundamental to achieving health and well-being in modern society [11]. It is relevant to all areas of health (e.g., promotion, prevention) and illness (acute and chronic illness, palliative care settings [35]). The term health literacy has been defined in diverse ways since the concept was first introduced. Nutbeam [36–38] conceptualized health literacy into (a) functional health literacy, (b) communicative/interactive health literacy, and (c) critical health literacy.

Functional health literacy is the *'ability to read and understand basic health-related information and the management of chronic diseases'* [11] and hence is related to the application of literacy to health-related materials such as medicine labels and prescriptions [36]. When

assessing health literacy, applied instruments often focus on functional health literacy [39]. The application of social skills to understand different forms of health-related communication is summarized under the term communicative/interactive health literacy, while critical health literacy involves the appraisal of health information and acting upon health information [36]. Other scholars furthermore include media health literacy [40,41] or electronic health literacy [42] as aspects of health literacy.

Malloy-Weir et al. [43] analyzed definitions of health literacy. They concluded that the commonly used definitions are open to multiple interpretations and often based on assumptions that are not always justified. Based on their analysis, Ratzan and Parker's [44] definition was by far the most commonly used: *'the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions'* [44] (p. vi) followed by the WHO's [45] definition: *'the cognitive and social skills which determine the motivation and ability of individuals to gain access to, understand and use information in ways which promote and maintain good health'* [45] (p. 10). All often-used definitions of health literacy treat a person's abilities as central to health literacy [43]. However, the specific skills vary between the definitions and so do the actions associated with these skills, e.g., *'to make appropriate health decisions'* [44], to *'promote and maintain good health'* [45], *'to function in the health care environment'* [46], and *'to make informed choices, reduce health risks and increase quality of life'* [47].

Malloy-Weir et al. [43] pointed out that even the often-used definitions have some weaknesses. The often-assumed relation between health information and maintenance of health or reduction of health risks (e.g., [45,47]) is not always justified, e.g., for individuals suffering from a terminal condition [43]. Moreover, the assumption that understanding and processing health information is related to adequate health decisions [44,48] is not true for all cases. Health-related decision-making is affected by diverse factors, e.g., individual values and beliefs and social and cultural backgrounds [43].

Several reviews about health literacy definitions concluded that there is no single commonly accepted and used definition [10,43,49,50]. A broad and inclusive definition of health literacy was developed in 2012 by the European Health Literacy Consortium [11]:

> *'Health literacy is linked to literacy and entails people's knowledge, motivation and competences to access, understand, appraise and apply health information in order to make judgements and take decisions in everyday life concerning health care, disease prevention and health promotion to maintain or improve quality of life during the life course.'*

The related conceptual model identifies 12 subdimensions of health literacy [10,11]. These comprise a person's competencies of accessing, understanding, using, and assessing health-related information within health care, disease prevention, and health promotion situations.

This reflects a trend of redefinition of the term health literacy. The growing research and practice field of health literacy focuses on the abilities of individuals and society to navigate complex health issues across the lifespan [37]. Vamos et al. [12] described how health literacy in terms of research, practice, and policy shifted towards a much broader conceptualization beyond health care including application at workplaces, in school, or at home. This shift reflects the aim to increase health and well-being across the lifespan for individuals and communities. Nutbeam [37] pointed out that health literacy is also *'seen as a means to enabling individuals to exert greater control over their health and the range of personal, social and environmental determinants of health'* [37] (p. 20174). This highlights the importance of an enabling environment to facilitate health literacy. To follow this aim, education for health literacy (i.e., health education) is crucial not only concerning individual actions but also in supporting adequate social and political actions [12].

2.1.2. Addressing Health Literacy in Science Education

Nutbeam [38] describes health literacy as *'an observable set of skills that can be developed and improved through effective communication and education'* (p. 708). Education is a key factor

to tackle poor health literacy worldwide [12] and to achieve an enabling environment for people to make health-related decisions for their lives [37]. In particular, formal science education in schools is predestined to enhance health literacy. In schools around the world, all school-aged children are reached over a long period [51]. Hence, health literacy is a concept with increasing attendance [12]. The WHO Health Promoting School framework (www.who.int/health-topics/health-promoting-schools, accessed on 25 April 2023) as an established concept based on the WHO's Global School Health Initiative. The aim is to improve the health of students and their families, staff members, and other members of the community through schools. Hence, the WHO defines a health-promoting school as one that *'constantly strengthens its capacity as a healthy setting for living, learning and working'*. This underlines the idea of building an enabling environment for health-promoting behavior.

Nowadays, it is increasingly acknowledged that health education should start at a very early age in school [52] and that besides the level of health literacy of parents [53], teachers play a key role in promoting health literacy [54,55]. There is some evidence that higher levels of health literacy are related to healthier behaviors in adolescents [39] and increased health outcomes in school students [56,57].

2.1.3. Sleep as a 'Non-Issue' in Health Literacy and Health Education in Schools

However, what are healthier behaviors, and how are they defined? Descriptions of health literacy remain vague about a description of healthy behavior. Oftentimes, as in the WHO [11] report, a healthy diet and physical exercise are explicitly mentioned. Intervention studies reported increased healthy behaviors in nutrition and physical exercise through knowledge transfer in school-based programs [58,59]. However, even though sleep is one crucial factor for human health [60], sleep is not addressed in common descriptions of health education and behavior or in health literacy intervention studies. In the WHO [11] report, sleep is not addressed at all. In their position statement, the American Academy of Sleep Medicine criticizes the lack of sleep health education [61]. It becomes apparent that sleep is a 'non-issue' in discussions and recommendations about health literacy and health education in schools.

Mindell et al. [62] surveyed 106 medical schools in 11 countries and demonstrated that the coverage of the topic of sleep even in medical school education is very limited. The average amount of time for sleep education was about 2.5 h, while 27% of medical schools reported that they do not cover sleep education [62]. Only a few scholars in the field of science and health education embedded sleep in the psychological category within the categories for maintaining or promoting health, but do not assign it to the category of physical factors to maintain health [63].

While the general health literacy definitions often remain vague concerning the health-related contents, several health-related literacies for specific areas of health education were described, including food literacy [64,65], nutrition literacy [66], mental health literacy [67], and health-promoting media literacy [68]. Truman et al. [69] identified three skill categories (information acquisition, information analysis, and application of information) within definitions of these specific health-related literacies. Furthermore, they discovered knowledge, attitudes, and behaviors as the three categories of desired outcomes that are often addressed in these definitions [69].

2.2. Education for Sustainable Development (ESD)

Humanity faces global challenges such as wars, inequality, climate change, and biodiversity loss in the Anthropocene. These cause dramatic changes within ecosystems, which also lead to new challenges related to human health [70]. The Agenda 2030 of the United Nations was introduced in 2015 to tackle such global challenges [30]. As part of the Agenda 2030, 17 Sustainable Development Goals (SDGs) were introduced that entail environmental, economic, and social goals. The concept of sustainability refers to economic and natural resources on the one hand and to a balance between the needs of the present and the future on the other hand [29]: *'Humanity has the ability to make development sustainable to ensure that*

it meets the needs of the present without compromising the ability of future generations to meet their own needs' [71] (section 3.27).

Questions concerning environment and health are both increasingly important contexts for science education because they lead to personally relevant questions [13,27]. Both fields are connected through the approaches science | environment | health [72], One Health [73], Planetary Health [74,75], or Education for Sustainable Development (ESD [28]). In these frameworks, health not only refers to human health but also the health of ecosystems [29].

ESD is the key driver to fulfilling the SDGs [28,76]. ESD is a transformative action-oriented educational approach to enable citizens to effectively contribute to sustainable societies by empowering them to make responsible decisions [13,77,78]. The ESD concept *'aims to encourage students to address sustainability issues at the intersection of science and society, to reflect on these issues, and to learn to undertake sustainable actions'* [29] (p. 3–4). Kioupi and Voulvoulis [79] described competencies in the context of ESD, which comprise, among others, systems thinking, collaboration, critical thinking, and integrated problem-solving.

Health is an important but often underrated aspect in the context of ESD [29,30]. Several SGDs point to health, and one SDG is directly focused on human health (SDG 3: *'Ensure healthy lives and promote well-being for all at all ages'*; [80]). Kjærgård et al. [30] emphasized a mutual relationship between health and sustainability in a way in which both are conditioned by each other.

Light Pollution as a Context for ESD

Engineers have defined light pollution as the sum total of all adverse effects of artificial light [81]. Astronomers use the term light pollution to represent the deterioration of human views of the night sky (astronomical light pollution [82]). Astronomical light pollution concerns all inhabited areas on Earth [83]. At the beginning of the century, only 40% of people in the United States lived in places where it becomes sufficiently dark at night for the human eye to view the stars in the sky [83]. Artificial light at night (ALAN) exponentially increases worldwide, accelerated through new and more efficient light sources [34]. Looking not only at the light source but at the complete lighting system, it becomes clear that modern LED lighting systems are unfortunately not more efficient because they do not bring the light exclusively to where it is ultimately needed.

Longcore and Rich [82] defined artificial light that modifies natural patterns of light and dark in ecosystems as ecological light pollution that includes *"chronic or periodically increased illumination, unexpected changes in illumination, and direct glare"* [82] (p. 191). Ecological light pollution can stem from road lights, lighted buildings, lights on vehicles, fishing boats, cruise ships, or security lights among others. This has substantial effects on ecology, e.g., the deaths of migratory birds around tall enlightened structures, of young sea turtles disoriented by lights on their beaches [82], sleep disruption in free-living animals [84], or the decline of insects [85]. Hence, ecological light pollution is a threat to biodiversity [32]. There is reliable evidence for serious harmful consequences of increased ALAN not only for the environment but also for human health, e.g., through suppression of the hormone melatonin and circadian disruption [33,34]. Moreover, light pollution causes enormous costs and wastes energy [86].

The topic of light connects questions of human health and well-being, mitigation of climate change, energy efficiency, ecosystem functioning, as well as socioeconomic consequences [31]. Furthermore, public awareness of harmful ALAN is rising, as visible through the growing success of the campaign Earth Hour since 2007, which was celebrated in 188 countries in 2018 [87]. Since the 1990s, the number of legal cases related to light pollution has increased globally, which points to a higher awareness of its harmful consequences [88]. Therefore, ALAN and ecological light pollution are suitable contexts for ESD, since they connect several SDGs and include personally relevant questions [13].

3. Sleep as a Central Aspect of Human Health

Sleep is more and more recognized as essential to overall health [89,90]. Along with well-balanced nutrition and the practice of physical exercise, a sufficient amount, as well as the quality of sleep, is essential for mental and physical health [91]. Therefore, sleep was identified as a key behavioral factor to promote as implemented for instance in the United States on an information platform by the Centers for Disease Control and Prevention (CDC; www.cdc.gov/healthyschools, accessed on 25 April 2023) where information on sleep and sleep disorders are provided (www.cdc.gov/sleep, accessed on 25 April 2023). Similar resources are available in some other countries, e.g., in Scandinavia by the Norwegian Institute of Public Health (NIPH; www.fhi.no/en/mp/sleep-and-sleep-disorders, accessed on 25 April 2023). However, up to date, the European Centre for Disease Prevention and Control (ECDC; www.ecdc.europa.eu, accessed on 25 April 2023), an agency of the European Union (EU), did not put focus on sleep and sleep disorders in general. In Germany, sleep has only been included recently in the Guidelines for the Prevention of Disturbances to Health set out by the GKV (public health insurance) [92].

Several sleep disorders are well-known to be a health risk and a public health issue [93]: sleep deprivation and insufficient sleep quality lead to dementia, obesity, cardiovascular disease, depression, diabetes, inflammation, and cancer [4–6] and cause enormous costs [7–9]. Sleep disorders are associated with migraines [94], and in recent years, the COVID-19 pandemic has affected sleep health [95,96]. Lopes et al. [95] assumed that the COVID-19 pandemic increased unhealthy sleep behavior in students and concluded that further studies are required to understand the impact of the pandemic on students' sleep health.

Inadequate and non-restorative sleep, i.e., reduced sleep duration and poor sleep quality [25,97] are induced by genetic, physiologic, and sociocultural factors such as shift work, jetlag, delays in circadian rhythms, increased use of electronic devices, use of drugs, or increased autonomy in bedtime [98–102]. Only one-fifth of adolescents in the United States get what is often described as the necessary amount of 9 h of sleep on school nights [103]. Several researchers assume that adolescents' decreases in sleep time and increases in delayed bedtimes suggest an emerging sleep restriction as a worldwide and intercultural problem [104–106].

A large number of young people across the world are affected by inadequate sleep and chronic sleep loss [19,107]. Unhealthy sleep patterns in children and adolescents are known to not only predict physical [108,109] but also mental health problems in adults [110,111]. Hence, fostering healthy sleep behaviors may be a potentially effective preventive health model for physical as well as mental health [112]. Unhealthy sleep has negative impacts not only on mental and physical health but also on students' academic performance [3,113–115]. Hence, one could assume that the negative effects of disturbed and inadequate sleep should raise the awareness of education politicians and ministries. It is all the more surprising that the potential of improved sleep for learning and preventing diseases has remained largely unexploited [3].

Sleep hygiene habits are practices that reduce harmful sleep behavior and improve sleeping conditions [95]. These include environmental factors, e.g., light and temperature, as well as behavioral aspects such as physical activity, consistent bedtimes, and no use of electronic devices before going to sleep [116].

Health behaviors are associated with health beliefs that can be defined as health myths if an evidence base is lacking [97]. It has been demonstrated that health myths can have negative effects on public health, e.g., concerning smoking [117]. Robbins et al. [97] compiled a collection of sleep myths, i.e., false beliefs about sleep that lack sufficient evidence. These were rated concerning their falseness and their significance for public health by experts from the fields of sleep medicine and sleep research. The resulting 20 sleep myths can be categorized into the domains of sleep duration, sleep timing, behaviors during sleep, daytime behaviors related to sleep, pre-sleep behaviors, as well as brain function and sleep.

Among the myths, several were rated as very false, including "During sleep, the brain is not active", "Lying in bed with your eyes closed is almost as good as sleeping", "If you have difficulty falling asleep, it is best to stay in bed and try to fall back to sleep", "In terms of your health, it does not matter what time of day you sleep", "Being able to fall asleep 'anytime, anywhere' is a sign of a healthy sleep system", "Many adults need only 5 or less h of sleep for general health", "Your brain and body can learn to function just as well with less sleep". Especially the three last mentioned as well as "Although annoying for bed partners, loud snoring is mostly harmless" and "Alcohol before bed will improve your sleep" were rated as very significant for public health.

Based on the identified sleep myths [97], Pantesco and Kan [118] surveyed adults in the United States to identify their endorsement of sleep myths and their relation to sleep health behavior. They demonstrated that the belief in sleep myths was fairly common, as about 50% of the sample endorsed about 50% of sleep myths. Sleep myths with the highest agreement among the respondents were "If you can get it, more sleep is always better", "Boredom can make you sleepy even if you got adequate sleep before", "If you are having difficulties sleeping, taking a nap in the afternoon is a good way to get adequate sleep", "A sound sleeper rarely moves at night", "If you have difficulty falling asleep, it is best to stay in bed and try to fall back to sleep".

The belief in sleep myths was related to unhealthy sleep behavior, e.g., inconsistency in bedtimes, more in-bed activities, and perceiving fewer consequences of insufficient sleep [118]. The authors conclude that targeting sleep myths in interventions may be a potentially beneficial approach.

In general, there 'appears to be a significant lack of awareness among children, adolescents, young adults, and adults of the extent of sleep loss during the middle and high school-aged youngsters as well as society in general' [91] (p. 595). As recently as 25 years ago, Carskadon et al. [103] recommended decreasing nightly homework hours and including sleep education programs in the curricula.

4. Research about Sleep Education

4.1. Outcomes of Sleep Education Programs

In general, research on school health programs suggests that these programs can improve health outcomes [119]. However, while this research is taking place in schools and directly interferes with the domain of science education in schools, most sleep education programs and accompanying research are located in the field of medical education. There is almost no empirical research in the field of science education about sleep education or sleep health and behavior. This implies a certain 'sleep blindness' in science education and builds upon sleep as a 'non-issue' in health education in general.

School-based programs in general aim to provide interventions that improve sleep behaviors and/or increase sleeping times through the gain of knowledge about sleep and sleep hygiene [25]. Few studies have demonstrated that sleep education approaches can lead to healthier sleep habits including increased sleep duration [120]. However, Gruber et al. [19] summarized that school education programs for healthier sleep did not show convincing results concerning effects on everyday life as the impact on sleep knowledge and behavior was mixed. Often, school education programs lead to increased sleep knowledge, but lack evidence for improved sleep behavior [112].

Blunden et al. [112] reviewed the empirical literature concerning sleep education programs targeting children and adolescents up to the age of 19 from 1990 to 2011. By including only peer-reviewed studies with pre-post measurement they identified only eight studies and four pilot studies in abstract form. This indicates a generally small number of sleep education studies. All of the reviewed studies were published in journals from the field of medicine, sleep research, and cognitive science; none of them was published in a science education journal.

The reviewed studies included sleep education programs with overlapping contents [112]. The programs comprised information about what sleep is, sleep physiol-

ogy, why we sleep and, how much sleep is necessary at which age, reasons for sleep disruption, and consequences of poor sleep [121–129]. Other aspects of sleep such as sleep debt [126,129], sleep hygiene [121,123,124,127–130], methods to control sleep patterns [122–125,128,129], or the effect of caffeine, alcohol, or other substances on sleep [123,124,126,128,130] were covered by some of the programs. The programs had different durations and used different methods, e.g., oral presentations, web-based activities, or group discussions [112].

To assess the effectiveness of the sleep education programs, the studies used different standardized and non-standardized measures to assess a diversity of outcome measures. The main outcome variable in several studies was knowledge about sleep [121–126,128,129]. Besides sleep knowledge, additional outcome variables were sleep hygiene [128,130], sleep habits [121,130], sleep patterns [125,129], daytime sleepiness [125,127,129], and sleep quality [127,130].

One finding of the comparative review was that knowledge about sleep significantly improved through most of the programs in which it was measured [122–126,129]. As mentioned above, behavioral outcome variables such as sleep hygiene and sleeping patterns showed almost no change through the program in most studies [112].

By use of a controlled trial, Rigney et al. [23] surveyed Australian students with a mean age of 12 years. Students were provided with four classroom lessons and a group project on sleep. The program did not lead to any changes in sleep knowledge or sleep hygiene. The only effect was an increased bedtime by 10 min on average [23].

Another review focused on studies that aimed to change sleep behavior [131]. The authors emphasized the importance of self-efficacy and motivation to change children's and adolescents' sleep behaviors. They recommend individualizing and digitalizing programs [131].

In another systematic review, Dietrich et al. [132] searched for empirical studies about the effectiveness of sleep education programs for college students 18 years and older. They found only four studies that fit their exclusion criteria and concluded that there is insufficient evidence to determine the effectiveness of sleep education programs on knowledge about sleep hygiene, sleep hygiene behavior, or sleep quality for college students [132]. However, in a randomized and controlled intervention study, Hershner and O'Brien [133] demonstrated how a brief online sleep education intervention can improve sleep behavior and sleep quality—but not sleep knowledge—in college students. In this 20 min intervention, a sleep personality profile was built based on two questionnaires and two educational videos introducing aspects of healthy sleep hygiene and the effects of sleep deprivation. Quan et al. [134] used a web-based learning module of the Harvard Medical School (www.understandingsleep.org, accessed on 25 April 2023) about sleep physiology and hygiene for psychology students. They conclude that the use of such a module has the potential to increase sleep literacy, as knowledge about sleep was improved after the module. The authors furthermore assume that the integration of such a module can change sleep behavior among psychology students [134].

A systematic review of approaches to improve children's (2–9 years) sleep hygiene in pediatric settings revealed that existing methods and techniques to improve the sleep hygiene of children are easy to apply and effective [135]. Gruber et al. [22] developed a school-based sleep education program for elementary schools. Participation in this program was associated with significant improvements in students' sleep and academic performance compared to a control group.

The most recent review of school-based sleep education programs was provided by Rigney et al. [25]. While Blunden et al. [112] identified eight studies on school-based sleep education programs, a decade later, Rigney et al. [25] included 32 studies in their systematic review (exclusion criteria: e.g., age 5–18 years of students), of which Australian researchers conducted one quarter. The authors emphasized that there is an increasing number of studies on school-based sleep education as about half of the articles have been published between 2015 and 2020. These more recent studies were more often randomized

controlled trials and included more digital and more innovative content, such as video-based training [136], setting of goals and self-monitoring of sleep behavior, and inclusion of families, i.e., providing them with helpful information about the program [25]. Contents were similar to those shown in earlier reviews, covering knowledge about sleep (What is sleep? Why do we sleep?), sleep physiology, healthy sleep duration, factors that disturb sleep, and consequences of poor sleep as well as strategies for sleep hygiene [25]. The review results show that sleep education programs increase sleep knowledge, as there was only one study that showed a different result [23]. In addition, measures of sleep knowledge are mostly designed for individual programs and are unstandardized [25]. In contrast, changes in sleep behavior, as well as variables such as mental health or sleep hygiene practices, were not clearly visible [25].

4.2. Methodology of Sleep Education Programs

Most studies measured sleep variables such as sleep duration, weekday and weekend sleep patterns, and others. Studies that utilized actigraphy as an objective measurement of sleep almost all reported beneficial changes in sleep variables directly post-intervention. One study reported long-term sleep improvement with objective measurement [137]. Applying a subjective measure of sleep behavior by use of self-reporting or sleep diaries led to varying pre-post results for most variables but sleep hygiene [138,139] and daytime sleepiness [138,140].

Moreover, in more recent studies, validated instruments for background variables were increasingly used, but inconsistent between studies [25]. Even if some studies point to improvements in motivation and mental health [141], in general, the effects of school-based sleep education programs on such secondary variables have been inconsistent so far [25].

4.3. Integration of Sleep Education in School Curricula

As sleep problems in adolescents are very common, Blunden and Rigney [24] suggest including at least basic aspects of sleep education as part of general health education. Sleep education aims to improve awareness of poor sleeping habits and the importance of adequate sleep. Sleep education programs can increase knowledge about sleep. Fostering sleep knowledge is the first and major goal of sleep education following Blunden and Rigney [24]. They summarized that sleep education programs are feasible and well accepted and extracted a list of 'Dos' and 'Don'ts' in sleep education and the associated research that may be helpful for the adoption of future sleep education programs in schools [24].

The crucial importance of sleep for a healthy life is to date largely missing from modern curricula. Several scholars from different countries, e.g., Gruber et al. [19] for the Canadian school system, describe the lack of sleep education in school curricula. The German biology curricula in all federal states and for all school forms are missing aspects of sleep education [20]. The American Academy of Sleep Medicine offers courses for teachers to educate their students about sleep (e.g., www.school.sleepeducation.com/, accessed on 25 April 2023). However, the Next Generation Science Standards (NGSS), which are the current science education standards for K–12 education across a large number of states in the United States, do not mention the topic of sleep at all [21].

Gruber et al. [19] described the need for and the potential benefits of integrating sleep education into schools:

> *'Successful school-based sleep health promotion programs hold the promise of having a long-lasting positive impact on students' physical and mental health, academic performance and daytime functioning.'* [19] (p. 9)

The investigated programs in the most recent review [25] took between four and six weeks. In an earlier review of school-based sleep education programs, Gruber [142] described that none of the studies included in her systematic review continued to implement the program after the study period ended. The author emphasized the need to work towards sustainable sleep education by identifying barriers to long-term implementation and working closely together with other stakeholders such as schools and teachers [142].

While in past studies the facilitator of the sleep education program often was one of the researchers involved in the study, it is now common to train teachers via training manuals [137] or in-person training [23,112,128,143] so they can teach the sleep education program. This new strategy is an important step onwards sustainable school-based sleep education programs.

Furthermore, Rigney et al. [25] summarized that the more recent programs often were incorporated into broader health teaching to avoid overloading the curricula. An already overcrowded curriculum seems to be one of the main barriers to implementing sleep education in school. Hence, integrating sleep education into general health education is a way for sustainable sleep education [25].

5. The Concept of Sleep Health Literacy

As described before (see Section 2.1.2), health education is a key factor in tackling poor health literacy worldwide [12]. Healthy sleep is crucial for human health and academic performance. Schools are an ideal setting to promote health literacy as they reach the whole youth population of a country over a long period [51,144]. Nevertheless, curricula are lacking sleep education (see Section 4.3) and the research on sleep education programs in schools is located in the medical fields, but not in science education research. Rigney et al. [25] pointed out that the majority of studies did not report the theoretical foundation of the education program applied, which is necessary to ensure an evidence-based program.

Moreover, several potential barriers exist to integrating sleep education in schools. In most cases, science teachers have not been trained in sleep education [19] and have presumably low knowledge and awareness about healthy sleep hygiene, and effective interventions or even believe in sleep myths [118]. One possible solution is the use of workshops for teachers to improve their awareness [19]. However, so far, as sleep is not part of science teacher training, it could be beneficial to implement sleep education in health education for biology pre-service teachers.

In sum, sleep education so far is neither part of science curricula (e.g., Canada: [19]; Germany: [15,20]; United States: [21]) nor integrated into health literacy concepts (e.g., [11]). This 'sleep blindness' in science education points to the need for considerations about sustainable sleep education approaches and a conception of *sleep health literacy*.

Quan et al. [134] used the term *sleep literacy* and referred to increased knowledge about sleep after the use of a web-based educational module. However, they did not define the term sleep literacy in their study and rather implicitly linked it to knowledge about sleep. Richardson et al. [145] surveyed the sleep knowledge, practices, and attitudes concerning pediatric sleep of Australian health professionals. They also used the term sleep literacy as '*paediatric sleep literacy*' and defined it as '*knowledge, understanding and skills to identify*[,] *manage and prevent paediatric sleep disorders*' [145] (p. 332).

As with the term sleep literacy, the term sleep health literacy has seldom been used so far. Bonuck et al. [146] proposed its use to describe '*the knowledge, motivation, and competencies to promote healthy sleep and to recognize the signs of a sleep problem*' [146] (p. 23). The authors utilized the review of Sørensen et al. [10] to base their definition on the core elements of health literacy definitions. However, even if the terms sleep literacy and sleep health literacy were used before, they have not been defined in detail and are not prevalently used. Furthermore, their usage is limited to studies from the field of medicine and their survey groups were college psychology students [134], health professionals [145], parents, and staff in head start schools [146].

In the following, we describe a detailed definition of *sleep health literacy* for the context of science education based on the concepts of health literacy [11], the former sleep health literacy description [146], and the structure of health literacy descriptions [69]. Based on this, we define sleep health literacy as follows:

Sleep health literacy entails knowledge, motivation, and the ability to access, appraise, and apply sleep health information in order to make judgments and decisions in everyday

life concerning sleep hygiene, prevention of sleep disorders, and sleep health promotion to maintain or improve quality of life during the life course.

As Arnold [147] described in her integrated model of decision-making in health contexts, knowledge can be seen as a critical factor for motivation, and in consequence also for decisions in favor of preventive health behavior. Following Zeyer [35], health literacy can be seen as knowledge-based competency in health-related decision-making. Three types of abilities are entailed in the sleep health literacy definition that stems from the WHO's [11] definition, the review by Sørensen et al. [10], as well as from the analysis of Truman et al. [69]:

Access: seek, find, and obtain health information;

Appraise: interpret, filter, analyze, judge, and evaluate the accessed health information;

Apply: communicate and use the information to make a decision in order to maintain and improve health.

As knowledge is the foundation for motivation and subsequently health-related decisions, we focus on the knowledge dimension of sleep health literacy. Drawing from the literature and expert discussion with sleep researchers from sleep medicine, we compiled a framework of sleep health knowledge comprising content knowledge about sleep health necessary for sleep health literacy (Table 1). We differentiate between three forms of knowledge described in the context of decision-making in health contexts [147], which are also pointing to the three different abilities introduced above:

Table 1. Structure of sleep health knowledge as an aspect of sleep health literacy. Each cell represents examples of the five themes of sleep health knowledge in combination with the three forms of knowledge.

	Forms of Knowledge		
Themes	**System Knowledge** **Knowledge about…**	**Action-Related Knowledge** **Knowledge about…**	**Effectiveness Knowledge** **Knowledge about…**
sleep basics	• what sleep is, sleep structure • functions of sleep and importance for daily life • brain and body function and sleep • …	• guidelines/recommendations about the duration and quality of sleep • actions to get to know the wake–sleep structure • …	• how many hours and what quality of sleep are healthy • which factors have to be changed to improve sleep health • …
chronorhythms	• individual chronotypes • interaction of circadian rhythm and sleep timing • influence of shift work and jet lag on chronorhythm • …	• guidelines/recommendations about sleep for different chronotypes • actions to get to know the chronotype • …	• how to align sleep behavior and chronotype • which factors change sleep behavior according to chronotype • …
sleep hygiene	• influence of daytime activity and behavioral habits on sleep (food and drink intake) • healthy sleep duration • influence of environmental factors on sleep (e.g., light, temperature) • …	• (non)-beneficial suggestions for food and drink intake before sleep • sleep hygiene recommendations for a restorative sleep • …	• how to substitute non-beneficial food and drink choices before sleep • how to optimize environmental factors for sleep effectively • …
prevention of sleep disorders	• what the symptom is, what the disease is • most common sleep disorders with an overview of diagnosis and treatment options • mechanism of sleeping pills • …	• recommendations about recognizing and treatment of sleep disorders • the use of sleeping pills • …	• for which symptoms a doctor should be consulted • how to act when a sleep disorder is recognized • …

Table 1. *Cont.*

	Forms of Knowledge		
Themes	**System Knowledge** **Knowledge about...**	**Action-Related Knowledge** **Knowledge about...**	**Effectiveness Knowledge** **Knowledge about...**
sleep health promotion	• negative effects of stress and mental overload on sleep • influence of daytime behaviors related to sleep (e.g., physical exercise) • influence of in-bed activities on sleep • ...	• approaches for work–life balance management • exercise practices to relax physically and switch off mentally • ...	• how to apply effective strategies to reduce stress • how to reduce in-bed activities before sleeping • ...

System knowledge: (*access*) knowledge about the system of the body, its functioning, and (possible) malfunctioning in order to understand causal relationships;

Action-related knowledge: (*access*) knowledge about guidelines, recommendations, and behavioral options, i.e., how to *appraise* and *apply* system knowledge about health and illness in order to prevent diseases and promote health;

Effectiveness knowledge: (*access*) knowledge about the effects and relative potentials of different actions in order to prevent diseases and promote health. This allows for *appraising* different actions as a foundation for a decision to *apply* them.

The theme 'sleep basics' comprises content knowledge about what sleep is in physical terms, how much sleep humans need, and which body functions are central elements of sleep. 'Chronorhythms' aggregates content knowledge regarding different chronotypes and e.g., how they interact with sleep timing. Crowley et al. [98] describe how the need for about nine hours of sleep per night on average demonstrates a challenge for lots of adolescents. In their 'Perfect Storm Model', it is explained how the combination of circadian phase delay in adolescents combined with a rise in bedtime autonomy, screen time, and social interactions on the one hand and early school start times, on the other hand, shorten sleep time. As described earlier, insufficient sleep can cause physical [108,109] and mental health problems [110,111] as well as academic problems [3,114]. Furthermore, the phenomenon of 'social jetlag' adds to this problem. Social jetlag describes the phenomenon that sleep timing differs between work and free days, resulting in 'sleep debt' on work days. This especially affects late chronotypes [148].

The theme 'sleep hygiene' describes content knowledge concerning sleep hygiene habits which are practices that reduce harmful sleep behavior and improve sleeping conditions [95]. These include the optimization of environmental factors, e.g., light and temperature, as well as behavioral aspects such as physical activity, consistent bedtimes, no use of electronic devices closely before going to sleep, and fewer in-bed activities in general [116,118]. Appropriate lighting conditions at home can positively affect sleep quality as well as circadian timing, e.g., through reduced evening light and increased morning light [98].

The themes 'prevention of sleep disorders' and 'sleep health promotion' include content knowledge concerning healthy sleep behaviors. Regarding healthy sleep and sleep disorders, there are a large number of mobile apps for sleep tracking and management available, but they are currently lacking common standards [149,150].

This sleep health literacy definition and framework is built to be integrated or used in the boundaries of science education curricula. Potential connecting points in the NGSS of the United States are the core ideas 'Human impacts on Earth systems' (ESS3.C; [21]) and 'Influence of engineering, technology, and science on society and the natural world' (ETS2.B; [21]). The first focuses on how humans change the planet and how these causes can have damaging effects on the ecosystem and human health. The second core idea relates to the question, of how science, engineering, and the resulting technologies affect

how people live and the natural world. This includes all short- and long-term human activity that has consequences for the ecosystem and human health.

In the state curricula of the German states of Berlin and Brandenburg, there are also several potential links to integrate sleep education based on the concept of sleep health literacy. In the basic concept 'development/evolution' (German: 'Entwicklung'), a learning goal is to recognize relationships between environmental influences and their consequences on the health of organisms [20]. Another learning goal within the basic concept 'structure and function' (German: 'Struktur und Funktion') focuses on measures to maintain the health of one's own body and their justification [20]. Moreover, two subject areas, i.e., 'health–disease' (German: 'Gesundheit–Krankheit') and 'structure and function of the nervous system' (German: 'Bau und Funktion des Nervensystems') are predestined to integrate the function of sleep and its role in health promotion and disease prevention.

Besides linking the health literacy framework to the national curricula, it is necessary to follow a multidisciplinary approach when integrating sleep education in schools. Based on the WHO Health Promoting Schools framework (www.who.int/health-topics/health-promoting-schools, accessed on 25 April 2023), the whole school setting should address a health-promoting environment, e.g., through health-promotion programs or the implementation of policies. This particularly addresses the effectiveness knowledge and hence the foundation to make health-promoting decisions and apply health-promoting behavior.

6. Sleep Health Literacy and Light Pollution as Link between Health Education and Education for Sustainable Development

Environment and health are two important contexts in science education and are more and more structurally thought together. Zeyer and Dillon [13] point out how health and environmental education can mutually inform and benefit each other and how they lead to personally relevant questions for students.

We suggest that the topic of sleep is a topic that builds a bridge between health education and ESD. The sharply rising numbers of people with sleep disorders are undesired side effects of a modern lifestyle, such as night-time use of electric lighting and mobile devices [1,2] as well as environmental factors such as street noise, urban lighting, and rising temperatures [111]. In the following, we demonstrate how sleep health literacy can be addressed when combining health education and ESD as a transformative action-oriented educational approach. We utilize the relation between light pollution as a topic of ESD and sleep health as a topic of health education.

A 24 h lifestyle has led to high levels of urban lighting and a loss of darkness [151]. During the last decades, light pollution has been increasing every year [152]. More than 99% of the population of the United States and the European Union live in areas where the night sky is more than 10% brighter than it would be naturally [83]. One reason for this trend is the rising illuminance level over the years [153] with lower cost for luminaires. ALAN on the streets is increasingly recognized as a form of environmental pollution [2]. Excessive light exposure at night, whether through indoor or outdoor sources, is associated with harmful effects on human health [2], especially for more than one-third of the population with disturbed sleep [154–156]. The night-time use of electric lighting has led to a shortening of bedtime and a worsening sleep quality of humans [1] as well as animals [84].

These 'dark sides of light' [31] are extensive and relate to the concept of sustainability as they affect economic and natural resources on the one hand and the needs of the present and the future on the other hand [29]. This already makes sleep and light pollution a suitable topic for teaching in the context of ESD. However, there are also bright sides to urban lighting.

Large parts of the population have positive associations with 'light' and tend to see 'darkness' as a threat to safety. Especially street lightning is a strong predictor of perceived safety [157]. In Germany, road lighting is the biggest emitter of light with 32% [158], but was explicitly exempted from the state emission protection law [159]. Good lighting technology today should generate only as much light as is needed and direct it to where it is needed.

Studies have shown that a precise lighting distribution can save 50% of produced light and energy [160].

Hence, the 'dark' and 'bright' sides of urban lighting connect questions of human health and well-being, mitigation of climate change, energy efficiency, ecosystem functioning, as well as social and socioeconomic consequences [31]. There are a large number of links and potential questions that can be stated in class based on this phenomenon in ESD-oriented teaching. Lots of these questions affect the personal lives of students, their families, and the society they live in, which makes them personally relevant questions [13].

ESD on sleep and light pollution has to enable students to make responsible decisions concerning their sleep hygiene as well as private, and, if applicable, public use of lighting. This allows them to make evidence-based health-related decisions [147], take care of their health and well-being, and effectively contribute to sustainable societies [13,77,78]. Furthermore, ESD approaches to sleep and light pollution have to emphasize a mutual relationship between health and sustainability [30]. This requires fostering competencies that are crucial for teaching and learning in ESD contexts such as systems thinking, collaboration, critical thinking, and integrated problem-solving [79].

One way to foster these competencies is to address different forms of knowledge (see 5). Moreover, it is advisable to discuss the contradiction between the positive and negative aspects in the context of sleep and light pollution, e.g., through perspective-taking [161] and argumentation [162] in the classroom. As ESD is the key driver to fulfilling the SDGs [28,76], these have to be addressed when teaching in the context of ESD. Several of the 17 SDGs which entail environmental, economic, and social goals [80] can be addressed when teaching about sleep, illumination, and light pollution (Table 2).

Table 2. Recommendations for teaching with Sustainable Development Goals (SDGs) about sleep and light pollution in an Education for Sustainable Development (ESD) setting.

Sustainable Development Goals	Links to Teaching about Sleep and Light Pollution
SDG 3: *'Ensure healthy lives and promote well-being for all at all ages'*	• sleep is essential for human health and well-being [89,90] • sleep disorders are well-known to be a health risk and a public health issue [93] • ALAN is a threat to human sleep, e.g., through suppression of the hormone melatonin and circadian disruption [33,34] • sleep deprivation and insufficient sleep quality lead to dementia, obesity, cardiovascular disease, depression, diabetes, inflammation, and cancer [4–6]
SDG 4: *'Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all'*	• a large number of young people across the world are affected by inadequate sleep and chronic sleep loss [19,107] • adolescents' decreases in sleep time and increases in delayed bedtimes suggest an emerging sleep restriction as a worldwide and intercultural problem [104–106] • fostering healthy sleep behaviors may be a potentially effective preventive health model for physical as well as mental health [112] • unhealthy sleep has negative impacts on students' academic performance [3,113–115] • belief in sleep myths is related to unhealthy sleep behavior [118] • there is a lack of awareness among children, adolescents, and adults of the extent of sleep loss [91] • one of the most effective approaches to preventing sleep problems is the education of new parents on how to encourage healthy sleep for their children [111] • sleep education for sleep health literacy in schools is necessary to ensure the health of children, adolescents, and adults globally
SDG 5: *'Achieve gender equality and empower all women and girls'*	• women tend to have a different experience of sleep than men and they respond differently to disordered sleep, as well as to sleep deprivation and sleep deficit, and express individual health outcomes as a result of poor sleep [163] • safety aspects of road lighting are presumably more relevant to girls and women, as they are more often victims of crime [164]
SDG 9: *'Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation'*	• technical innovations may help to reduce light pollution, e.g., the use of shielding on road lights to prevent direct upward light, avoid over lighting, constraining illumination to the area where it is needed and the time it will be used [33] • increased awareness of lighting solutions that avoid light pollution will lead to innovative and sustainable developments in urban lighting and the lighting industry [160]

Table 2. *Cont.*

Sustainable Development Goals	Links to Teaching about Sleep and Light Pollution
SDG 11: *'Make cities and human settlements inclusive, safe, resilient and sustainable'*	• ALAN exponentially increases worldwide, accelerated through new and more efficient lighting technologies [34] • light pollution causes enormous costs for societies [86] • most cities don't become sufficiently dark at night for the human eye [83] • sleep deprivation and insufficient sleep quality cause enormous costs for societies [7–9] • noise exposure in cities leads to sleep disturbances [165] • street lighting is a strong predictor of perceived safety in cities [157]
SDG 13: *'Take urgent action to combat climate change and its impacts'*	• energy-related CO_2 emissions need to be reduced to mitigate climate change [160] • light pollution originates in inefficient lighting solutions [33] that waste energy [86] • the thermal environment affects human sleep quality [166,167]
SDG 14: *'Conserve and sustainably use the oceans, seas and marine resources for sustainable development'*	• ecological light pollution modifies natural patterns of light and dark in ecosystems [82] • ecological light pollution of the oceans, seas, and coasts can stem from lighted buildings, fishing boats, cruise ships, flares on offshore oil platforms, or lights on undersea research vessels [82] • ecological light pollution has substantial effects on ecology, e.g., the deaths of young sea turtles disoriented by lights on beaches [82] • ecological light pollution is a threat to biodiversity [32]
SDG 15: *'Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss'*	• ecological light pollution modifies natural patterns of light and dark in ecosystems [82] • ecological light pollution of terrestrial ecosystems can stem from streetlights, lighted buildings, security lights, or lights on vehicles [82] • strong evidence of the adverse effects of ALAN on animals and on human health [31] • ecological light pollution affects the structure and functioning of ecosystems [31] • ecological light pollution has substantial effects on the ecology, e.g., the deaths of migratory birds around tall enlightened structures [82], sleep disruption in free-living animals [84], or the decline of insects [85]

7. Conclusions and Outlook

Several school-based programs about sleep were conducted in the field of medical education. They aimed to provide interventions that improve sleep behaviors and/or increase sleeping times through the gain of knowledge about sleep and sleep hygiene [25]. We recommend that researchers and practitioners learn from these diverse studies and develop and conduct school-based programs and intervention studies for healthy sleep based on them.

The literature regarding research on school sleep health programs suggests that these programs can improve health outcomes. However, the programs' impacts on sleep knowledge and behavior were ambiguous [25]. Often, sleep education programs in school lead to increased sleep knowledge, but lack evidence for improved sleep behavior [19,112]. These inconsistencies also point to methodological issues. The studies vary concerning the assessed variables and instruments. Although more recent studies increasingly used validated instruments, they are most often not comparable between studies [25]. Hence, methodological consistency and the use of validated instruments are crucial for science education research.

Furthermore, Blunden and Rigney [24] described how sleep knowledge is the first and major goal of sleep education. This is consistent with the integrated model of decision-making in health contexts in the field of science education, in which knowledge is a critical factor for motivation, and for health-related decisions [147]. In Table 1, we present sleep health knowledge as an aspect of sleep health literacy. This first concept of sleep health literacy may help researchers and practitioners to integrate aspects of sleep health literacy in their research, teaching, and subsequently into health-related curricula. For a sustainable sleep education, it is advisable to incorporate teaching towards sleep health literacy into general health education or ESD in the curricula as an overcrowded curriculum seems to be a main barrier to implementing sleep education in school [19,25]. Moreover, teachers need adequate training concerning sleep health literacy. Gruber et al. [19] recommended incorporating sleep-related knowledge and skills in pre-service teacher training and professional development courses for teachers.

The connection between light pollution and sleep quality seems to be a promising topic to address in science teaching, as it addresses several SDGs (see Table 2). Other

examples to address sleep in the context of ESD are noise levels or rising temperatures. These connections between sleep health literacy and ESD are suitable contexts for science education, as they lead to personally relevant questions [13] and require health-related decision-making [147].

In this article, we identified a 'sleep blindness' in science education which builds upon sleep as a 'non-issue' in health education and school curricula. We presented the topic of sleep as highly relevant to the field of science education. By presenting a first comprehensive concept of sleep health literacy in a science education context, we argue for the implementation of sleep health literacy in science education curricula. This integration could be realized in the context of health education as well as in the context of ESD.

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References

1. Blume, C.; Garbazza, C.; Spitschan, M. Effects of light on human circadian rhythms, sleep and mood. *Somnologie* **2019**, *23*, 147. [CrossRef] [PubMed]
2. Min, J.Y.; Min, K.B. Outdoor artificial nighttime light and use of hypnotic medications in older adults: A population-based cohort study. *J. Clin. Sleep Med.* **2018**, *14*, 1903–1910. [CrossRef] [PubMed]
3. Ribeiro, S.; Stickgold, R. Sleep and school education. *Trends Neurosci. Educ.* **2014**, *3*, 18–23. [CrossRef]
4. Parthasarathy, S.; Vasquez, M.M.; Halonen, M.; Bootzin, R.; Quan, S.F.; Martinez, F.D.; Guerra, S. Persistent insomnia is associated with mortality risk. *Am. J. Med.* **2015**, *128*, 268–275. [CrossRef]
5. Park, Y.M.M.; White, A.J.; Jackson, C.L.; Weinberg, C.R.; Sandler, D.P. Association of exposure to artificial light at night while sleeping with risk of obesity in women. *JAMA Intern. Med.* **2019**, *179*, 1061–1071. [CrossRef]
6. Von Ruesten, A.; Weikert, C.; Fietze, I.; Boeing, H. Association of sleep duration with chronic diseases in the European Prospective Investigation into Cancer and Nutrition (EPIC)-Potsdam study. *PLoS ONE* **2012**, *7*, e30972. [CrossRef]
7. Hafner, M.; Stepanek, M.; Taylor, J.; Troxel, W.M.; Van Stolk, C. Why sleep matters—The economic costs of insufficient sleep: A cross-country comparative analysis. *Rand Health Q.* **2017**, *6*, 11.
8. Jasani, F.; Seixas, A.A.; Madondo, K.; Li, Y.; Jean-Louis, G.; Pagán, J.A. Sleep duration and health care expenditures in the United States. *Med. Care* **2020**, *58*, 770. [CrossRef]
9. Wickwire, E.M.; Tom, S.E.; Scharf, S.M.; Vadlamani, A.; Bulatao, I.G.; Albrecht, J.S. Untreated insomnia increases all-cause health care utilization and costs among Medicare beneficiaries. *Sleep* **2019**, *42*, zsz007. [CrossRef]
10. Sørensen, K.; Van den Broucke, S.; Fullam, J.; Doyle, G.; Pelikan, J.; Slonska, Z.; Brand, H. Health literacy and public health: A systematic review and integration of definitions and models. *BMC Public Health* **2012**, *12*, 80. [CrossRef]
11. World Health Organization (WHO). Health Literacy: The Solid Facts. 2013. Available online: https://apps.who.int/iris/bitstream/handle/10665/128703/e96854.pdf (accessed on 23 April 2023).
12. Vamos, S.; Okan, O.; Sentell, T.; Rootman, I. Making a case for "Education for health literacy": An international perspective. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1436. [CrossRef]
13. Zeyer, A.; Dillon, J. Science | Environment | Health—Towards a reconceptualization of three critical and inter-linked areas of education. *Int. J. Sci. Educ.* **2014**, *36*, 1409–1411. [CrossRef]
14. Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland (KMK). Empfehlung zur Gesundheitsförderung und Prävention in der Schule [Recommendation on Health Promotion and Prevention at School]. 2012. Available online: https://www.kmk.org/fileadmin/veroeffentlichungen_beschluesse/2012/2012_11_15-Gesundheitsempfehlung.pdf (accessed on 18 April 2023).

15. Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland (KMK). Bildungsstandards im Fach Biologie für die Allgemeine Hochschulreife [Educational Standards in the Subject Biology for the General Higher Education Entrance Qualification]. 2020. Available online: https://www.kmk.org/fileadmin/veroeffentlichungen_beschluesse/2020/2020_06_18-BildungsstandardsAHR_Biologie.pdf (accessed on 18 April 2023).
16. OECD. OECD Future of Education and Skills 2030. OECD Learning Compass 2030. A Series of Concept Notes. 2019. Available online: http://www.oecd.org/education/2030-project/contact/OECD_Learning_Compass_2030_Concept_Note_Series.pdf (accessed on 18 April 2023).
17. Laschke, L.; Flottmann, M.; Schlüter, K. Let's Ask the Teachers: A Qualitative Analysis of Health Education in Schools and Its Effectiveness. *Sustainability* **2023**, *15*, 4887. [CrossRef]
18. Schaal, S.; Dannemann, S.; Arnold, J.; Kahl, L.; Spörhase, U.; Simon, U.; Schaal, S. Was ist schulische Gesundheitsförderung? Eine Begriffsklärung [What is school health promotion? A clarification of terms]. *SCHÜLER Wissen Für Lehr.* **2020**, 70–71.
19. Gruber, R.; Somerville, G.; Finn, C. School-based sleep health education in Canada. *Sleep Med.* **2019**, *56*, 9–15. [CrossRef]
20. Landesinstitut für Schule und Medien Berlin-Brandenburg (LISUM). Rahmenlehrplan Biologie für die Jahrgangsstufen 7–10 der Länder Berlin und Brandenburg [Framework Curriculum Biology for Grades 7–10 of the Länder Berlin and Brandenburg]. 2015. Available online: https://bildungsserver.berlin-brandenburg.de/fileadmin/bbb/unterricht/rahmenlehrplaene/Rahmenlehrplanprojekt/amtliche_Fassung/Teil_C_Biologie_2015_11_10_WEB.pdf (accessed on 18 April 2023).
21. NGSS Lead States. Next Generation Science Standards: For States, By States. 2013. Available online: https://nap.nationalacademies.org/catalog/18290/next-generation-science-standards-for-states-by-states (accessed on 28 June 2023).
22. Gruber, R.; Somerville, G.; Bergmame, L.; Fontil, L.; Paquin, S. School-based sleep education program improves sleep and academic performance of school-age children. *Sleep Med.* **2016**, *21*, 93–100. [CrossRef]
23. Rigney, G.; Blunden, S.; Maher, C.; Dollman, J.; Parvazian, S.; Matricciani, L.; Olds, T. Can a school-based sleep education programme improve sleep knowledge, hygiene and behaviours using a randomised controlled trial. *Sleep Med.* **2015**, *16*, 736–745. [CrossRef]
24. Blunden, S.; Rigney, G. Lessons learned from sleep education in schools: A review of dos and don'ts. *J. Clin. Sleep Med.* **2015**, *11*, 671–680. [CrossRef]
25. Rigney, G.; Watson, A.; Gazmararian, J.; Blunden, S. Update on school-based sleep education programs: How far have we come and what has Australia contributed to the field? *Sleep Med.* **2021**, *80*, 134–157. [CrossRef]
26. Swirski, H.; Baram-Tsabari, A.; Yarden, A. Does interest have an expiration date? An analysis of students' questions as resources for context-based learning. *Int. J. Sci. Educ.* **2018**, *40*, 1136–1153. [CrossRef]
27. Zeyer, A.; Kyburz-Graber, R. (Eds.) *Science | Environment | Health: Towards a Renewed Pedagogy for Science Education*, 2nd ed.; Springer: Dordrecht, Netherlands, 2012.
28. Laurie, R.; Nonoyama-Tarumi, Y.; Mckeown, R.; Hopkins, C. Contributions of education for sustainable development (ESD) to quality education: A synthesis of research. *J. Educ. Sustain. Dev.* **2016**, *10*, 226–242. [CrossRef]
29. Heuckmann, B.; Zeyer, A. Science | Environment | Health, One Health, Planetary Health, Sustainability, and Education for Sustainable Development: How Do They Connect in Health Teaching? *Sustainability* **2022**, *14*, 12447. [CrossRef]
30. Kjærgård, B.; Land, B.; Bransholm Pedersen, K. Health and sustainability. *Health Promot. Int.* **2014**, *29*, 558–568. [CrossRef] [PubMed]
31. Hölker, F.; Moss, T.; Griefahn, B.; Kloas, W.; Voigt, C.C.; Henckel, D.; Tockner, K. The dark side of light: A transdisciplinary research agenda for light pollution policy. *Ecol. Soc.* **2010**, *15*, 13. [CrossRef]
32. Hölker, F.; Wolter, C.; Perkin, E.K.; Tockner, K. Light pollution as a biodiversity threat. *Trends Ecol. Evol.* **2010**, *25*, 681–682. [CrossRef]
33. Falchi, F.; Cinzano, P.; Elvidge, C.D.; Keith, D.M.; Haim, A. Limiting the impact of light pollution on human health, environment and stellar visibility. *J. Environ. Manag.* **2011**, *92*, 2714–2722. [CrossRef]
34. Grubisic, M.; Haim, A.; Bhusal, P.; Dominoni, D.M.; Gabriel, K.M.; Jechow, A.; Hölker, F. Light pollution, circadian photoreception, and melatonin in vertebrates. *Sustainability* **2019**, *11*, 6400. [CrossRef]
35. Zeyer, A. A Win-Win Situation for Health and Science Education: Seeing Through the Lens of a New Framework Model of Health Literacy. In *Science | Environment | Health: Towards a Renewed Pedagogy for Science Education*, 2nd ed.; Zeyer, A., Kyburz-Graber, R., Eds.; Springer: Dordrecht, Netherlands, 2012; pp. 147–173.
36. Nutbeam, D. Health literacy as a public health goal: A challenge for contemporary health education and communication strategies into the 21st century. *Health Promot. Int.* **2000**, *15*, 259–267. [CrossRef]
37. Nutbeam, D. The evolving concept of health literacy. *Soc. Sci. Med.* **2008**, *67*, 2072–2078. [CrossRef]
38. Nutbeam, D. Health education and health promotion revisited. *Health Educ. J.* **2019**, *78*, 705–709. [CrossRef]
39. Fleary, S.A.; Joseph, P.; Pappagianopoulos, J.E. Adolescent health literacy and health behaviors: A systematic review. *J. Adolesc.* **2018**, *62*, 116–127. [CrossRef]
40. Levin-Zamir, D.; Lemish, D.; Gofin, R. Media Health Literacy (MHL): Development and measurement of the concept among adolescents. *Health Educ. Res.* **2011**, *26*, 323–335. [CrossRef]
41. Manganello, J.A. Health literacy and adolescents: A framework and agenda for future research. *Health Educ. Res.* **2008**, *23*, 840–847. [CrossRef]

42. Norman, C.D.; Skinner, H.A. eHealth literacy: Essential skills for consumer health in a networked world. *J. Med. Internet Res.* **2006**, *8*, e506. [CrossRef]
43. Malloy-Weir, L.J.; Charles, C.; Gafni, A.; Entwistle, V. A review of health literacy: Definitions, interpretations, and implications for policy initiatives. *J. Public Health Policy* **2016**, *37*, 334–352. [CrossRef]
44. Ratzan, S.C.; Parker, R.M. Introduction. In *Current Bibliographies in Medicine: Health Literacy*; Selden, C.R., Zorn, M., Ratzan, R.M., Parker, R.M., Eds.; National Institutes of Health, U.S. Department of Health and Human Services: Rockville Pike, MA, USA, 2000; pp. v–vi.
45. World Health Organization (WHO). Health Promotion Glossary. 1998. Available online: https://www.who.int/publications/i/item/WHO-HPR-HEP-98.1 (accessed on 18 April 2023).
46. Ad Hoc Committee on health literacy for the Council on Academic Affairs, American Medical Association. Health literacy: Report of the council on academic affairs. *JAMA* **1999**, *281*, 552–557. [CrossRef]
47. Zarcadoolas, C.; Pleasant, A.; Greer, D.S. Understanding health literacy: An expanded model. *Health Promot. Int.* **2005**, *20*, 195–203. [CrossRef]
48. Kickbusch, I.; Wait, S.; Maag, D. *Navigating Health: The Role of Health Literacy*; Alliance for Health and the Future, International Longevity Centre-UK: London, UK, 2005.
49. Baker, D.W. The meaning and the measure of health literacy. *J. Gen. Intern. Med.* **2006**, *21*, 878. [CrossRef]
50. Liu, C.; Wang, D.; Liu, C.; Jiang, J.; Wang, X.; Chen, H.; Zhang, X. What is the meaning of health literacy? A systematic review and qualitative synthesis. *Fam. Med. Community Health* **2020**, *8*, e000351. [CrossRef]
51. Paakkari, L.; Okan, O. Health literacy—Talking the language of (school) education. *HLRP Health Lit. Res. Pract.* **2019**, *3*, e161–e164. [CrossRef]
52. Paakkari, L.; Inchley, J.; Schulz, A.; Weber, M.W.; Okan, O. Addressing health literacy in schools in the WHO European Region. *Public Health Panor.* **2019**, *5*, 186–189.
53. Velardo, S.; Drummond, M. Understanding parental health literacy and food related parenting practices. *Health Sociol. Rev.* **2013**, *22*, 137–150. [CrossRef]
54. Dadaczynski, K.; Rathmann, K.; Hering, T.; Okan, O. The role of school leaders' health literacy for the implementation of health promoting schools. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1855. [CrossRef] [PubMed]
55. Peterson, F.L.; Cooper, R.J.; Laird, J.A. Enhancing teacher health literacy in school health promotion a vision for the new millennium. *J. Sch. Health* **2001**, *71*, 138–144. [CrossRef] [PubMed]
56. Paakkari, O.; Torppa, M.; Villberg, J.; Kannas, L.; Paakkari, L. Subjective health literacy among school-aged children. *Health Educ.* **2018**, *118*, 182–195. [CrossRef]
57. Shih, S.F.; Liu, C.H.; Liao, L.L.; Osborne, R.H. Health literacy and the determinants of obesity: A population-based survey of sixth grade school children in Taiwan. *BMC Public Health* **2016**, *16*, 280. [CrossRef]
58. Harris, K.C.; Kuramoto, L.K.; Schulzer, M.; Retallack, J.E. Effect of school-based physical activity interventions on body mass index in children: A meta-analysis. *Cmaj* **2009**, *180*, 719–726. [CrossRef]
59. Hatzis, C.M.; Papandreou, C.; Kafatos, A.G. School health education programs in Crete: Evaluation of behavioural and health indices a decade after initiation. *Prev. Med.* **2010**, *51*, 262–267. [CrossRef]
60. Grandner, M.A.; Fernandez, F.X. The translational neuroscience of sleep: A contextual framework. *Science* **2021**, *374*, 568–573. [CrossRef]
61. Ramar, K.; Malhotra, R.K.; Carden, K.A.; Martin, J.L.; Abbasi-Feinberg, F.; Aurora, R.N.; Trotti, L.M. Sleep is essential to health: An American Academy of Sleep Medicine position statement. *J. Clin. Sleep Med.* **2021**, *17*, 2115–2119. [CrossRef]
62. Mindell, J.A.; Bartle, A.; Abd Wahab, N.; Ahn, Y.; Ramamurthy, M.B.; Huong, H.T.D.; Goh, D.Y. Sleep education in medical school curriculum: A glimpse across countries. *Sleep Med.* **2011**, *12*, 928–931. [CrossRef]
63. Mahajan, B.S.; Chunawala, S. Indian secondary students' understanding of different aspects of health. *Int. J. Sci. Educ.* **1999**, *21*, 1155–1168. [CrossRef]
64. Truman, E.; Lane, D.; Elliott, C. Defining food literacy: A scoping review. *Appetite* **2017**, *116*, 365–371. [CrossRef]
65. Vidgen, H.A.; Gallegos, D. Defining food literacy and its components. *Appetite* **2014**, *76*, 50–59. [CrossRef]
66. Silk, K.J.; Sherry, J.; Winn, B.; Keesecker, N.; Horodynski, M.A.; Sayir, A. Increasing nutrition literacy: Testing the effectiveness of print, web site, and game modalities. *J. Nutr. Educ. Behav.* **2008**, *40*, 3–10. [CrossRef]
67. O'Connor, M.; Casey, L.; Clough, B. Measuring mental health literacy–a review of scale-based measures. *J. Ment. Health* **2014**, *23*, 197–204. [CrossRef]
68. Bergsma, L.J.; Carney, M.E. Effectiveness of health-promoting media literacy education: A systematic review. *Health Educ. Res.* **2008**, *23*, 522–542. [CrossRef]
69. Truman, E.; Bischoff, M.; Elliott, C. Which literacy for health promotion: Health, food, nutrition or media? *Health Promot. Int.* **2020**, *35*, 432–444. [CrossRef]
70. Butler, C.D. Sounding the alarm: Health in the Anthropocene. *Int. J. Environ. Res. Public Health* **2016**, *13*, 665. [CrossRef]
71. World Commission on Environment and Development. Report of the World Commission on Environment and Development: Our Common Future. 1987. Available online: https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf (accessed on 18 April 2023).

72. Dillon, J. Science, environment and health education: Towards a reconceptualization of their mutual interdependences. In *Science | Environment | Health: Towards a Renewed Pedagogy for Science Education*, 2nd ed.; Zeyer, A., Kyburz-Graber, R., Eds.; Springer: Dordrecht, The Netherlands, 2012; pp. 87–101.
73. Lerner, H.; Berg, C. The concept of health in One Health and some practical implications for research and education: What is One Health? *Infect. Ecol. Epidemiol.* **2015**, *5*, 25300. [CrossRef]
74. Seltenrich, N. Down to earth: The emerging field of planetary health. *Environ. Health Perspect.* **2018**, *126*, 072001. [CrossRef] [PubMed]
75. Whitmee, S.; Haines, A.; Beyrer, C.; Boltz, F.; Capon, A.G.; de Souza Dias, B.F.; Yach, D. Safeguarding human health in the Anthropocene epoch: Report of The Rockefeller Foundation–Lancet Commission on planetary health. *Lancet* **2015**, *386*, 1973–2028. [CrossRef] [PubMed]
76. Boeve-de Pauw, J.; Gericke, N.; Olsson, D.; Berglund, T. The effectiveness of education for sustainable development. *Sustainability* **2015**, *7*, 15693–15717. [CrossRef]
77. Fröberg, A.; Lundvall, S. Sustainable development perspectives in physical education teacher education course syllabi: An analysis of learning outcomes. *Sustainability* **2022**, *14*, 5955. [CrossRef]
78. Rieckmann, M. Learning to transform the world: Key competencies in Education for Sustainable Development. *Issues Trends Educ. Sustain. Dev.* **2018**, *39*, 39–59.
79. Kioupi, V.; Voulvoulis, N. Education for sustainable development: A systemic framework for connecting the SDGs to educational outcomes. *Sustainability* **2019**, *11*, 6104. [CrossRef]
80. United Nations. Transforming Our World: The 2030 Agenda for Sustainable Development. 2015. Available online: https://sustainabledevelopment.un.org/post2015/transformingourworld/publication (accessed on 18 April 2023).
81. *CIE S 017/E:2011 ILV*; International Lighting Vocabulary. International Commission on Illumination: Vianna, Austria, 2011. Available online: https://cie.co.at/eilvterm/17-29-177 (accessed on 25 April 2023).
82. Longcore, T.; Rich, C. Ecological light pollution. *Front. Ecol. Environ.* **2004**, *2*, 191–198. [CrossRef]
83. Cinzano, P.; Falchi, F.; Elvidge, C.D. The first world atlas of the artificial night sky brightness. *Mon. Not. R. Astron. Soc.* **2001**, *328*, 689–707. [CrossRef]
84. Raap, T.; Pinxten, R.; Eens, M. Light pollution disrupts sleep in free-living animals. *Sci. Rep.* **2015**, *5*, 13557. [CrossRef]
85. Owens, A.C.; Cochard, P.; Durrant, J.; Farnworth, B.; Perkin, E.K.; Seymoure, B. Light pollution is a driver of insect declines. *Biol. Conserv.* **2020**, *241*, 108259. [CrossRef]
86. Gallaway, T.; Olsen, R.N.; Mitchell, D.M. The economics of global light pollution. *Ecol. Econ.* **2010**, *69*, 658–665. [CrossRef]
87. Jechow, A. Observing the impact of WWF earth hour on urban light pollution: A case study in Berlin 2018 using differential photometry. *Sustainability* **2019**, *11*, 750. [CrossRef]
88. Zielińska-Dabkowska, K.M.; Xavia, K.; Bobkowska, K. Assessment of citizens' actions against light pollution with guidelines for future initiatives. *Sustainability* **2020**, *12*, 4997. [CrossRef]
89. Hirshkowitz, M.; Whiton, K.; Albert, S.M.; Alessi, C.; Bruni, O.; DonCarlos, L.; Hillard, P.J.A. National Sleep Foundation's sleep time duration recommendations: Methodology and results summary. *Sleep Health* **2015**, *1*, 40–43. [CrossRef]
90. Watson, N.F.; Badr, M.S.; Belenky, G.; Bliwise, D.L.; Buxton, O.M.; Tasali, E. Recommended amount of sleep for a healthy adult: A joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society. *J. Clin. Sleep Med.* **2015**, *11*, 591–592. [CrossRef]
91. Sheldon, S.H. Sleep education in schools: Where do we stand? *J. Clin. Sleep Med.* **2015**, *11*, 595–596. [CrossRef]
92. Hupfeld, J.; Wanek, V. *Leitfaden Prävention [Prevention Guide]*; GKV-Spitzenverband: Berlin, Germany, 2023. Available online: https://www.gkv-spitzenverband.de/media/dokumente/krankenversicherung_1/praevention__selbsthilfe__beratung/praevention/praevention_leitfaden/Leitfaden_Pravention_Akt_03-2023_barrierefrei.pdf (accessed on 28 April 2023).
93. Buysse, D.J. Sleep health: Can we define it? Does it matter? *Sleep* **2014**, *37*, 9–17. [CrossRef]
94. Waliszewska-Prosół, M.; Nowakowska-Kotas, M.; Chojdak-Łukasiewicz, J.; Budrewicz, S. Migraine and sleep—An unexplained association? *Int. J. Mol. Sci.* **2021**, *22*, 5539. [CrossRef]
95. Lopes, M.C.; Gutierres, G.P.; Pavoni, M.B.; Mendes, A.B.S.M.M.; Campos, M.B.; Bastos, I.B.; Spruyt, K. Social media for students' sleep health promotion–a health intervention report during COVID-19. *Sleep Epidemiol.* **2021**, *1*, 100018. [CrossRef]
96. Ramar, K. The COVID-19 pandemic: Reflections for the field of sleep medicine. *J. Clin. Sleep Med.* **2020**, *16*, 993–996. [CrossRef]
97. Robbins, R.; Grandner, M.A.; Buxton, O.M.; Hale, L.; Buysse, D.J.; Knutson, K.L.; Jean-Louis, G. Sleep myths: An expert-led study to identify false beliefs about sleep that impinge upon population sleep health practices. *Sleep Health* **2019**, *5*, 409–417. [CrossRef]
98. Crowley, S.J.; Wolfson, A.R.; Tarokh, L.; Carskadon, M.A. An update on adolescent sleep: New evidence informing the perfect storm model. *J. Adolesc.* **2018**, *67*, 55–65. [CrossRef] [PubMed]
99. DeSantis, A.S.; Diez Roux, A.V.; Moore, K.; Baron, K.G.; Mujahid, M.S.; Nieto, F.J. Associations of neighborhood characteristics with sleep timing and quality: The Multi-Ethnic Study of Atherosclerosis. *Sleep* **2013**, *36*, 1543–1551. [CrossRef] [PubMed]
100. Dudley, K.A.; Patel, S.R. Disparities and genetic risk factors in obstructive sleep apnea. *Sleep Med.* **2016**, *18*, 96–102. [CrossRef]
101. Perrault, A.A.; Bayer, L.; Peuvrier, M.; Afyouni, A.; Ghisletta, P.; Brockmann, C.; Sterpenich, V. Reducing the use of screen electronic devices in the evening is associated with improved sleep and daytime vigilance in adolescents. *Sleep* **2019**, *42*, zsz125. [CrossRef]

102. Tashjian, S.M.; Mullins, J.L.; Galván, A. Bedtime autonomy and cellphone use influence sleep duration in adolescents. *J. Adolesc. Health* **2019**, *64*, 124–130. [CrossRef]
103. Carskadon, M.A.; Wolfson, A.R.; Acebo, C.; Tzischinsky, O.; Seifer, R. Adolescent sleep patterns, circadian timing, and sleepiness at a transition to early school days. *Sleep* **1998**, *21*, 871–881. [CrossRef]
104. Dollman, J.; Ridley, K.; Olds, T.; Lowe, E. Trends in the duration of school-day sleep among 10-to 15-year-old South Australians between 1985 and 2004. *Acta Paediatr.* **2007**, *96*, 1011–1014. [CrossRef]
105. Olds, T.; Maher, C.; Blunden, S.; Matricciani, L. Normative data on the sleep habits of Australian children and adolescents. *Sleep* **2010**, *33*, 1381–1388. [CrossRef]
106. Tynjälä, J.; Kannas, L.; Välimaa, R. How young Europeans sleep. *Health Educ. Res.* **1993**, *8*, 69–80. [CrossRef]
107. Matricciani, L.; Olds, T.; Petkov, J. In search of lost sleep: Secular trends in the sleep time of school-aged children and adolescents. *Sleep Med. Rev.* **2012**, *16*, 203–211. [CrossRef]
108. Chaput, J.P.; Gray, C.E.; Poitras, V.J.; Carson, V.; Gruber, R.; Olds, T.; Tremblay, M.S. Systematic review of the relationships between sleep duration and health indicators in school-aged children and youth. *Appl. Physiol. Nutr. Metab.* **2016**, *41*, S266–S282. [CrossRef]
109. Paiva, T.; Gaspar, T.; Matos, M.G. Sleep deprivation in adolescents: Correlations with health complaints and health-related quality of life. *Sleep Med.* **2015**, *16*, 521–527. [CrossRef]
110. Gregory, A.M.; Caspi, A.; Eley, T.C.; Moffitt, T.E.; O'Connor, T.G.; Poulton, R. Prospective longitudinal associations between persistent sleep problems in childhood and anxiety and depression disorders in adulthood. *J. Abnorm. Child Psychol.* **2005**, *33*, 157–163. [CrossRef]
111. Gruber, R.; Carrey, N.; Weiss, S.K.; Frappier, J.Y.; Rourke, L.; Brouillette, R.T.; Wise, M.S. Position statement on pediatric sleep for psychiatrists. *J. Can. Acad. Child Adolesc. Psychiatry* **2014**, *23*, 174.
112. Blunden, S.L.; Chapman, J.; Rigney, G.A. Are sleep education programs successful? The case for improved and consistent research efforts. *Sleep Med. Rev.* **2012**, *16*, 355–370. [CrossRef]
113. Curcio, G.; Ferrara, M.; De Gennaro, L. Sleep loss, learning capacity and academic performance. *Sleep Med. Rev.* **2006**, *10*, 323–337. [CrossRef]
114. Dewald, J.F.; Meijer, A.M.; Oort, F.J.; Kerkhof, G.A.; Bögels, S.M. The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: A meta-analytic review. *Sleep Med. Rev.* **2010**, *14*, 179–189. [CrossRef]
115. Sadeh, A.; Gruber, R.; Raviv, A. The effects of sleep restriction and extension on school-age children: What a difference an hour makes. *Child Dev.* **2003**, *74*, 444–455. [CrossRef]
116. Meijer, A.M. Chronic sleep reduction, functioning at school and school achievement in preadolescents. *J. Sleep Res.* **2008**, *17*, 395–405. [CrossRef]
117. Leventhal, H.; Glynn, K.; Fleming, R. Is the smoking decision an 'informed choice'? Effect of smoking risk factors on smoking beliefs. *JAMA* **1987**, *257*, 3373–3376. [CrossRef]
118. Pantesco, E.J.; Kan, I.P. False beliefs about sleep and their associations with sleep-related behavior. *Sleep Health* **2020**, *8*, 216–224. [CrossRef] [PubMed]
119. Kolbe, L.J. School health as a strategy to improve both public health and education. *Annu. Rev. Public Health* **2019**, *40*, 443–463. [CrossRef] [PubMed]
120. De Bruin, E.J.; van Run, C.; Staaks, J.; Meijer, A.M. Effects of sleep manipulation on cognitive functioning of adolescents: A systematic review. *Sleep Med. Rev.* **2017**, *32*, 45–57. [CrossRef]
121. Azevedo, C.V.; Sousa, I.; Paul, K.; MacLeish, M.Y.; Mondéjar, M.T.; Sarabia, J.A.; Madrid, J.A. Teaching chronobiology and sleep habits in school and university. *Mind Brain Educ.* **2008**, *2*, 34–47. [CrossRef]
122. Bakotić, M.; Radošević-Vidaček, B.; Košćec, A. Educating adolescents about healthy sleep: Experimental study of effectiveness of educational leaflet. *Croat. Med. J.* **2009**, *50*, 174–181. [CrossRef]
123. Blunden, S. The implementation of a sleep education program in adolescents. *Sleep Biol. Rhythm.* **2007**, *5*, A31.
124. Blunden, S. The implementation of a sleep education program in primary school children. *Sleep Biol. Rhythm.* **2007**, *5* (Suppl. S1), A32.
125. Cain, N.; Gradisar, M.; Moseley, L. A motivational school-based intervention for adolescent sleep problems. *Sleep Med.* **2011**, *12*, 246–251. [CrossRef]
126. Cortesi, F.; Giannotti, F.; Sebastiani, T.; Bruni, O.; Ottaviano, S. Knowledge of sleep in Italian high school students: Pilot-test of a school-based sleep educational program. *J. Adolesc. Health* **2004**, *34*, 344–351. [CrossRef]
127. De Sousa, I.C.; Araújo, J.F.; De Azevedo, C.V.M. The effect of a sleep hygiene education program on the sleep-wake cycle of Brazilian adolescent students. *Sleep Biol. Rhythm.* **2007**, *5*, 251–258. [CrossRef]
128. Kira, G.; Maddison, R.; Hull, M.; Blunden, S.; Olds, T. Sleep education improves the sleep duration of adolescents: A randomized controlled pilot study. *J. Clin. Sleep Med.* **2014**, *10*, 787–792. [CrossRef]
129. Moseley, L.; Gradisar, M. Evaluation of a school-based intervention for adolescent sleep problems. *Sleep* **2009**, *32*, 334–341. [CrossRef]
130. Brown, F.C.; Buboltz, W.C., Jr.; Soper, B. Development and evaluation of the Sleep Treatment and Education Program for Students (STEPS). *J. Am. Coll. Health* **2006**, *54*, 231–237. [CrossRef]

131. Cassoff, J.; Knäuper, B.; Michaelsen, S.; Gruber, R. School-based sleep promotion programs: Effectiveness, feasibility and insights for future research. *Sleep Med. Rev.* **2013**, *17*, 207–214. [CrossRef]
132. Dietrich, S.K.; Francis-Jimenez, C.M.; Knibbs, M.D.; Umali, I.L.; Truglio-Londrigan, M. Effectiveness of sleep education programs to improve sleep hygiene and/or sleep quality in college students: A systematic review. *JBI Evid. Synth.* **2016**, *14*, 108–134. [CrossRef]
133. Hershner, S.; O'Brien, L.M. The impact of a randomized sleep education intervention for college students. *J. Clin. Sleep Med.* **2018**, *14*, 337–347. [CrossRef]
134. Quan, S.F.; Anderson, J.L.; Hodge, G.K. Use of a supplementary internet based education program improves sleep literacy in college psychology students. *J. Clin. Sleep Med.* **2013**, *9*, 155–160. [CrossRef]
135. Halal, C.S.; Nunes, M.L. Education in children's sleep hygiene: Which approaches are effective? A systematic review. *J. Pediatr.* **2014**, *90*, 449–456. [CrossRef]
136. John, B.; Bellipady, S.S.; Bhat, S.U. Sleep promotion program for improving sleep behaviors among adolescents in selected schools: A randomized controlled trial. *Int. J. Ment. Health Promot.* **2017**, *19*, 51–68. [CrossRef]
137. Rey, A.E.; Guignard-Perret, A.; Imler-Weber, F.; Garcia-Larrea, L.; Mazza, S. Improving sleep, cognitive functioning and academic performance with sleep education at school in children. *Learn. Instr.* **2020**, *65*, 101270. [CrossRef]
138. Lin, C.Y.; Strong, C.; Scott, A.J.; Broström, A.; Pakpour, A.H.; Webb, T.L. A cluster randomized controlled trial of a theory-based sleep hygiene intervention for adolescents. *Sleep* **2018**, *41*, zsy170. [CrossRef]
139. Wolfson, A.R.; Harkins, E.; Johnson, M.; Marco, C. Effects of the Young Adolescent Sleep Smart Program on sleep hygiene practices, sleep health efficacy, and behavioral well-being. *Sleep Health* **2015**, *1*, 197–204. [CrossRef] [PubMed]
140. Tamura, N.; Tanaka, H. Effects of a sleep education program with self-help treatment on sleeping patterns and daytime sleepiness in Japanese adolescents: A cluster randomized trial. *Chronobiol. Int.* **2016**, *33*, 1073–1085. [CrossRef] [PubMed]
141. Bonnar, D.; Gradisar, M.; Moseley, L.; Coughlin, A.M.; Cain, N.; Short, M.A. Evaluation of novel school-based interventions for adolescent sleep problems: Does parental involvement and bright light improve outcomes? *Sleep Health* **2015**, *1*, 66–74. [CrossRef]
142. Gruber, R. School-based sleep education programs: A knowledge-to-action perspective regarding barriers, proposed solutions, and future directions. *Sleep Med. Rev.* **2017**, *36*, 13–28. [CrossRef]
143. van Rijn, E.; Koh, S.Y.; Ng, A.S.; Vinogradova, K.; Chee, N.I.; Lee, S.M.; Chee, M.W. Evaluation of an interactive school-based sleep education program: A cluster-randomized controlled trial. *Sleep Health* **2020**, *6*, 137–144. [CrossRef]
144. World Health Organization (WHO). Health-Promoting Schools: A Healthy Setting for Living, Learning and Working. 1998. Available online: https://apps.who.int/iris/handle/10665/63868 (accessed on 18 April 2023).
145. Richardson, C.; Ree, M.; Bucks, R.S.; Gradisar, M. Paediatric sleep literacy in Australian health professionals. *Sleep Med.* **2021**, *81*, 327–335. [CrossRef]
146. Bonuck, K.A.; Schwartz, B.; Schechter, C. Sleep health literacy in head start families and staff: Exploratory study of knowledge, motivation, and competencies to promote healthy sleep. *Sleep Health* **2016**, *2*, 19–24. [CrossRef]
147. Arnold, J.C. An integrated model of decision-making in health contexts: The role of science education in health education. *Int. J. Sci. Educ.* **2018**, *40*, 519–537. [CrossRef]
148. Wittmann, M.; Dinich, J.; Merrow, M.; Roenneberg, T. Social jetlag: Misalignment of biological and social time. *Chronobiol. Int.* **2006**, *23*, 497–509. [CrossRef]
149. Al Mahmud, A.; Wu, J.; Mubin, O. A scoping review of mobile apps for sleep management: User needs and design considerations. *Front. Psychiatry* **2022**, *13*, 1037927. [CrossRef]
150. Nuo, M.; Fang, H.; Wang, T.; Liang, J.; He, Y.; Han, H.; Lei, J. Understanding the research on tracking, diagnosing, and intervening in sleep disorders using mHealth apps: Bibliometric analysis and systematic reviews. *Digit. Health* **2023**, *9*, 20552076231165967. [CrossRef]
151. Czeisler, C.A. Perspective: Casting light on sleep deficiency. *Nature* **2013**, *497*, S13. [CrossRef]
152. Kyba, C.C.; Kuester, T.; Sánchez de Miguel, A.; Baugh, K.; Jechow, A.; Hölker, F.; Guanter, L. Artificially lit surface of Earth at night increasing in radiance and extent. *Sci. Adv.* **2017**, *3*, e1701528. [CrossRef]
153. Fotios, S.; Gibbons, R. Road lighting research for drivers and pedestrians: The basis of luminance and illuminance recommendations. *Light. Res. Technol.* **2018**, *50*, 154–186. [CrossRef]
154. American Association of Sleep Medicine (AASM). Insomnia. 2008. Available online: https://aasm.org/resources/factsheets/insomnia.pdf (accessed on 18 April 2023).
155. Baglioni, C.; Altena, E.; Bjorvatn, B.; Blom, K.; Bothelius, K.; Devoto, A.; Riemann, D. The European Academy for Cognitive Behavioural Therapy for Insomnia: An initiative of the European Insomnia Network to promote implementation and dissemination of treatment. *J. Sleep Res.* **2020**, *29*, e12967. [CrossRef]
156. Morin, C.M.; Jarrin, D.C.; Ivers, H.; Mérette, C.; LeBlanc, M.; Savard, J. Incidence, persistence, and remission rates of insomnia over 5 years. *JAMA Netw. Open* **2020**, *3*, e2018782. [CrossRef]
157. Painter, K. The influence of street lighting improvements on crime, fear and pedestrian street use, after dark. *Landsc. Urban Plan.* **1996**, *35*, 193–201. [CrossRef]
158. Kuechly, H.U.; Kyba, C.C.; Ruhtz, T.; Lindemann, C.; Wolter, C.; Fischer, J.; Hölker, F. Aerial survey and spatial analysis of sources of light pollution in Berlin, Germany. *Remote Sens. Environ.* **2012**, *126*, 39–50. [CrossRef]

159. Deutscher Bundestag. Lichtverschmutzung: Rechtliche Regelungen zur Beschränkung von Beleuchtung in Deutschland und Ausgewählten Europäischen Staaten [Light Pollution: Legal Regulations to Restrict Lighting in Germany and Selected European Countries]. 2019. Available online: https://www.bundestag.de/resource/blob/632966/7ba7c4cdlcfef87380d58376flc2f165/WD-7-009-19-pdf-data.pdf (accessed on 18 April 2023).
160. Voelker, S. New Ways to achieve climate aim in roadway lighting. In Proceedings of the 29th Quadrennial Session of the CIE; International Commission on Illumination (CIE 2019), Washington, DC, USA, 14–22 June 2019. [CrossRef]
161. Kahn, S.; Zeidler, D.L. A conceptual analysis of perspective taking in support of socioscientific reasoning. *Sci. Educ.* **2019**, *28*, 605–638. [CrossRef]
162. Erduran, S.; Jiménez-Aleixandre, M.P. *Argumentation in Science Education. Perspectives from Classroom-Based Research*; Springer: Dordrecht, The Netherlands, 2007.
163. Pengo, M.F.; Won, C.H.; Bourjeily, G. Sleep in women across the life span. *Chest* **2018**, *154*, 196–206. [CrossRef] [PubMed]
164. Haans, A.; De Kort, Y.A. Light distribution in dynamic street lighting: Two experimental studies on its effects on perceived safety, prospect, concealment, and escape. *J. Environ. Psychol.* **2012**, *32*, 342–352. [CrossRef]
165. Mucci, N.; Traversini, V.; Lulli, L.G.; Vimercati, L.; Rapisarda, V.; Galea, R.P.; Arcangeli, G. Neurobehavioral alterations in occupational noise exposure: A systematic review. *Sustainability* **2021**, *13*, 12224. [CrossRef]
166. Lan, L.; Tsuzuki, K.; Liu, Y.F.; Lian, Z.W. Thermal environment and sleep quality: A review. *Energy Build.* **2017**, *149*, 101–113. [CrossRef]
167. Okamoto-Mizuno, K.; Mizuno, K. Effects of thermal environment on sleep and circadian rhythm. *J. Physiol. Anthropol.* **2012**, *31*, 14. [CrossRef]