A Thematic Review of the Present Photonic Education

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Abstract: In the presented study, we discussed the thematic review of 68 recent conference studies focused on elementary and secondary school levels to enlighten the future needs of Optics and Photonics Education.

1. Introduction, Purpose, and Significance

Photonics and photonics technologies have been getting greater attention and importance in our life day by day. As photonics technologies use photons instead of electrons in electronics, they have substantial potential applications from consumers to technology developers [1]. The fiber-optic internet network surrounding the world today is an excellent example that photons rapidly take electrons' duty places. Moreover, we will use more quantum-based photonics technologies, the second quantum revolution, in computers, sensors, and information in the near future [2,3]. These inclusions evoke two essential needs in society: (1) workforce for the photonics industry, (2) scientific literacy on photonics named as photonics literacy in this study. Firstly, there is an increasing demand for engineers and technicians to deploy and convey these technologies to everyday living areas and scientists who study to develop these technologies [4]. As the photonics industry progress, the need for qualified labor forces who promote this field will increase [5]. Secondly, although society and students everyday use photonics technologies, face photonics-related issues, or encounter problems that can be solved with the aid of photonic technologies [6], their awareness and understandings of photonics are open to discussion [7]. Well-prepared photonics education curricula, collaborative systems, and institutions may be the key components to meet these needs [8,9]. There is a necessity for photonics education at every level starting from the younger ages [10]. If photonics education starts at lower levels, it is believed that the number of photonics-literate citizens can increase [11]. As a result, qualified photonics labors will be trained for future needs in a short time [12]. Therefore, we believe that it is crucially important to examine the current studies conducted about photonics education for young students. The aim of this research is to analyze the current trends in photonics education with a thematic review of Education and Training in Optics and Photonics (ETOP) and Optics Education and Outreach Conferences' Proceedings that studied at elementary and secondary level, published in the last five years (from 2015 to 2019) and discuss current conditions and future applications of these studies from the eyes of two Science Educators and one professional photonic researcher.

2. Method

In this research, a thematic review of 68 photonics education studies has been conducted using a matrix that consisted of general features (year, demographic properties), content features (rationales, aims, research methods, samples, data collections, results, and suggestions), and photonics features (level, relevancy, photonics concept, application/training/teaching method) [13]. On optics and photonics education, 324 proceeding abstracts of the ETOP and Optics Education and Outreach Conferences have been read, and 68 of these proceedings on which elementary and secondary levels, or public and teacher education have been selected and analyzed.

3. Findings

In general, we conclude three major findings from the thematic review. Firstly, secondary school levels (47, 75%) are considered more appropriate for photonics education than elementary level (33, 31%) in the studies analyzed. In addition, public understanding (15,14%) and teacher training (10,10%) in photonics education are also considered important. Secondly, photonics education is generally introduced with outreach activities (31) aiming awareness and career introducing in Optics and Photonics and adopting STEM (Science-Technology-Engineering-Mathematics) education (6), hands-on activities (3), and low-cost designs (3), as seen in Table 1 (The major results are listed because of limited space, the extended version of finding tables will be given in the full text.). Furthermore, attention on festivals/exhibition/science events (4) and experiments or lesson designs (15) have been discovered apart from outreach activities. Thirdly, the research methods and the results of studies are not clearly stated in the many reviewed studies, in general. The results of studies focus on student gains in implementations (activities, lessons, outreaches, etc.) in qualitative ways such as acquiring knowledge, awareness or enjoyment in optics and photonics contents, awareness of career options, the discovery of STEM careers, or developing science

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processes skills at most (Table 2). (Note that, the preliminary data are presented in the table, as the new findings added, the sub-themes and the frequencies probably will increase.) Although they give information about the developed and/or implemented activities, most of the reviewed studies need to be fulfilled with their outcomes or influences on the students in many dimensions.

Table 1: Applications of the studies

Themes	Sub-themes	Codes	f
Outreach activity	Science Activities		24
		STEM / STEAM	*6*
		Low-cost materials	*3*
	Experiment Kit		4
	Grant/Collaborative Projects		3
	Trainer training/Workshop		4
		Awareness	*3*
	International Year of Light		7
		Summer Schools	*1*
Activity development	Trainer training/workshop	…	2
	Festivals/Exhibit/Fairs		4
Material development	Curriculum Development	…	2
	Experiment / Lesson Design		15

Table 2: Results of the studies

Themes	Sub-themes	Codes	f
Student Gains	Cognitive Domain	*Knowledge*	3
		Awareness	1
	Affective Domain	*Enjoyment*	2
		Active involvement …	1
	Psychomotor Domain	*Science process skills*	2
		21st century skills …	1
	Career Development	*Discovery of STEM careers*	2
		Awareness of career options	2
Teacher Gains	Pedagogical content knowledge	*Inquiry-based activity planning*	1
		Implementation skills	1
Public Gains	Awareness	*Appreciation in everyday life*	2
	…		
Course/ Lesson/ Experiment Delivery	Outcomes	*Positive feedbacks*	2
	Design	*Reachable/ Affordable for all socioeconomic levels*	2
…			

4. Discussion and Conclusion

We interpret that the conference topics guide the literature in Photonics Education. These reflections can be seen in the extensiveness of Outreach Programs which is a topic of conferences. The results of the thematic review reveal that there is a great effort to expand photonics awareness to students, teachers, and the public in general. These actions are mainly taken by Scientists from Science and Engineering departments, Staff of Science Centers, or Organizations actively studying in Optics and Photonics fields. On the other hand, more substantial and permanent studies, like curriculum development and policy-making steps in the early stages, are required for the widespread impact on this area. The educators should also be more aware of this necessity and actively involved in improvements and studies to expand epistemological and pedagogical dimensions of Photonics Education. This thematic review could pave the way for the evaluation of existing studies or deficiencies by teachers and program developers in this field.

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