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Effect of COVID-19 Closures and Distance-Learning on Biology Research Projects of High School Students in Israel

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Abstract: The COVID-19 pandemic has created a situation, the "anthropopause", of lockdowns and distancing among individuals to reduce the spread of the disease. One of the major problems to surface is the inequality of the educational process in schools. We present a study of high school students who conduct a year-long research project with an academic. We hypothesized that the projects would not be impacted because of the individual manner of study involved. We analyzed the number of research proposals submitted in the years 2015–2021. We compared the data of the pre-epidemic period with the two pandemic years, 2020 and 2021. Our data show that in the years of the pandemic, significantly less research proposals were submitted, and the number of research proposals rejected was lower, but the total number of research proposals approved, or the number of theses submitted, was not significantly different. The research areas in which Israeli high school students conducted research were mostly in the laboratory (63.2%) and agriculture (27.5%), while ecology was relatively insignificant—whether in captivity (3.1%) or the field (5.1%). A new field that is fast becoming of interest is bioinformatics. Research in agriculture was significantly lower during the pandemic period, while there were no differences in the other subjects between the two periods. We conclude that the fewer research proposals submitted suggest that those that did not take the subject seriously enough did not begin the process. This resulted in a lower number of rejections and is substantiated by the fact that an equal number of students that submitted their final theses did not differ from the years before the pandemic. We are optimistic that the truly motivated students will continue to make the effort to be involved in biology science projects over and above their regular school curriculum and in spite of the COVID-19 restrictions and limitations.

Keywords: biology; science projects; high school; COVID-19; motivation

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1. Introduction

Coronavirus disease 2019 (COVID-19, or 2019-nCoV), coupled with the Delta variant recognized as the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) since May 2021, has in the past two years created a situation where humans have had to readjust their lifestyles and minimize exposure to conspecifics [1,2]. Because it was found that the disease spread following close contact between individuals, one of the containment measures recommended, which was adopted by most countries, was to resort to voluntary/mandatory distancing and isolation, resulting in mass quarantines [3].

This distancing between individuals, now termed the "anthropopause" [4,5], has resulted in the disruption of almost all daily practices of individuals, their family units, and the communal life as known before the onset of the pandemic. This distancing and country-wide lockdowns have not only influenced humans but also other spheres dominated or influenced by humans (such as wildlife; [6]). However, the novel situation has forced organizations where humans congregate (places of worship, schools, and academic institutions) to practice distancing to try and reduce the spread of the infectious disease [7].

COVID-19 is the greatest challenge to an already challenged system that the national educational systems have had to face to date [8]. In schools and academic institutions, the strategy of distant learning was almost instantaneously adopted worldwide in most countries [9]. However, this was limited to only those countries that have the technological capabilities where the teaching staff and all the students could log on simultaneously from their solitary/familial confinement in residences via the internet [7,10]. However, in countries where electronic hardware and technology are not readily available to the poor or because of geographic barriers, education was either truncated for extended periods or continued despite the dangers [9,11–13].

It was suggested that de-schooling of the obligatory system was required to produce mentally healthier children who retain their inborn curiosity [14]. From a situation wherein e-learning and correspondence courses are a part of the enrichment curriculum and the syllabus of informal education, it has now been forcefully become the norm in all walks of life, especially in education [15]. The instantaneous mandatory school closures have forced teachers, even if they felt incompatible with modern technology and did not have the skills, to be forced to adapt and to learn the hardware at their disposal instantly and to master new platforms to be able to teach online [10]. The younger generation switched over naturally because of their compatibility with modern technology. This switch over from regulated schooling in a central facility has become one of a dispersed nature where the attendance does not require the individual to even be in the neighborhood or the city.

Despite the suggestions to revamp our schooling systems, the reality is that it will take much more of the same to force the authorities to rethink and overcome existing paradigms [9,14]. One of the major problems to surface is the inequality in the working conditions of all involved and the inequity of the educational process for the audience, whether they are school pupils or university students.

A wide range of responses of the audience has been reported to date. It was discovered that, in high schools in Greece, the high-performing students abstained more than the lower-performing students, allowing themselves more time off from school, and that pupils from poor neighborhoods were less likely to observe distancing guidelines [16]. This is of cardinal importance because if the better students are unable to progress because of the lack of restraints to which they are used to in school, they will probably reduce personal investment and their output will become mediocre. Additionally, it is well known that, in many countries, the income inequality is growing [17] and the percentage of children affected ranges from ca. 5% in the Nordic countries to more than 20% in the USA and Israel [10,18]. This is especially critical because [19] showed that little of a pupil's achievement in school is associated with the school (teachers, principal, and curriculum) and that most can be explained by influencing factors outside the school gates. The attempt by public schools to create a situation of equality, normality, and equity is not successful in most cases [10].

One of the countries with a large number of scientific publications about the effects of the COVID-19 pandemic on all levels of education is Israel. A random search of Google Scholar (keywords: Pandemic, Impact, Education) showed that out of 905,000 hits globally, 41,000 (4.5%) related to a wide range of subjects about education in Israel. These included the advantages and disadvantages of virtual teaching during the pandemic of subjects such as mathematics [20,21] and chemistry [22], including how to pay special attention to vulnerable populations [23]. However, it was also pointed out that online learning in Israel, especially in the universities, is not performing as expected because of the lack of awareness, applicable policies, preparation, and planning [24], and was also found to be true in the Philippine context [25].

Researchers contended that the most successful education systems are those that combine equity and excellence in their educational policies and practices [10]. Here we present a study wherein most of these external influences are nullified by the fact that children of parents from all walks of life are allowed to participate in an educational program that does not require conventional schooling—that of conducting a research project with an academic, with a minimum of a master's degree, and that works at an academic institution or research facility. In the Israeli schooling system, children in the 10th and 11th standard (ages 15 and 16 years) can volunteer to work for almost a whole school year with an academic who is ready to mentor high school children in scientific thought and methods (instructions in Hebrew at https://pop.education.gov.il/tchumey_daat/biologya/chativa-elyona/biology-pedagogy/thesis/, accessed 26 September 2021). The process requires the high school student with his/her mentor to write a research proposal, which is then submitted online to the Ministry of Education and checked for soundness and viability by an experienced teacher–researcher. Once permission is granted, the student can proceed with the experiment under the supervision of the academic. Subsequently, the academic mentor then helps the student analyze the data, write up the thesis, and submit it to the department of science projects for evaluation and grading. The last is done by an independent researcher who is chosen from the specific field of expertise in which the project was undertaken. The evaluator is required to read the theses and conduct an interview with the high school student. Based on the theses and the interview, the student is then awarded the final grade, which is included in the school-leaving certificate (bagrut) and is considered to be the equivalent of having studied a science course in the same field as the research subject, i.e., in our case, to have specialized in biology for the high school certificate, and is accorded five points for the course.

The fact that the high school students do not study or work on the project in the framework of the conventional school and are exposed to the academic world, scientific thought, and procedures that are strange to them can create situations wherein they acquire vocational skills and awareness over and above that taught in a regular school. Hence, we hypothesized that because the COVID-19 pandemic has dictated distant learning, the research projects would not necessarily be impacted because of the individual manner of study involved, which did not require groupings with other schoolmates or staff. Additionally, the fact that some of the projects are conducted outside laboratories would allow for the projects not to be curtailed. We also wished to elucidate the projects in which the students are involved and how that may have influenced their participation. We evaluated the science projects undertaken in biology, of which the authors are in charge in the Israel Ministry of Education.

2. Material and Methods

2.1. Study Period

We collated all data for the years 2015–2021 (N = 7 years) for the number of research proposals submitted. However, because the 2021 cycle is at present ongoing and the final submissions have not started, we considered only up to 2020, i.e., 6 years. This allowed us to compare the data of the pre-COVID-19 epidemic period and the two years, 2020 and 2021, during which the global and national shutdown forced the education system to resort to distance learning. We considered the years 2015–2019 (N = 5) as the pre-pandemic years and 2020 and 2021 as the pandemic period (N = 2).

2.2. Data

All data were derived from the website of the biology section for science projects of the Israel Ministry of Education. All research projects were submitted by high school students in the 10th or 11th standard (ages 15 and 16 years).

We separated the study into two sections—research proposals and the final submission of the thesis. We divided the section of the research proposals into three parts—initial submissions, those that are rejected, and those approved to initiate their research programs. We compared those that received final approval of their research proposals to the total number of students who finished their research and successfully submitted their written theses.

Further, to elucidate the interests of the Israeli high school students, we analyzed the research proposals of the projects into four major categories: (1) agriculture (animal husbandry, crop cultivation, pest mitigation, etc.), (2) in the laboratory (universities, research institutes, hospitals, etc.), (3) enclosure ecology (Biblical Zoo in Jerusalem, Underwater Observatory in Eilat, etc.), (4) field ecology (reefs, nature reserves, wildlife biology, etc.), and (5) bioinformatics (collation of data from the web, existing datasets, etc.).

Owing to our being at present in the cycle of submissions for the 2021–2022 school year, we have evaluated only the research proposals submitted and are as yet unable to present the data of the projects completed. We consider this important because the year 2020 demonstrates the impact of the initial stages of the pandemic while the 2021 data will also display the added effects of the Delta SARS-CoV-2 variant on the population. This is especially important in light of the fact that the Delta variant has proved to be especially virulent and geographically widespread [26].

2.3. Statistical Analysis

To test differences between years with and without pandemic, we used Pearson's Chi-squared test [27]. We also conducted correlation analyses (such as the Spearman rho correlation coefficient) to compare the numbers of research proposals that were approved to the total number of projects submitted at the final stage. Calculations were performed with R statistical software [28].

3. Results

In the seven years, a total of 3209 research proposals were submitted (average 458 proposals/year), of which 1946 projects completed the full cycle (324 projects/year). A total of 415 (12.9%) research proposals were rejected, and, of the 2416 proposals submitted in the six years, 1946 (80.5%) successfully completed their research projects and submitted their final theses. In the five pre-pandemic years, a total of 2345 research proposals were submitted, of which 2060 (87.9%) were approved, of which 1585 (76.9% of approved) also submitted their final theses. In comparison, during the two years of the pandemic, a total of 864 research proposals were submitted, of which 734 (85.0%) were approved. In 2020, 361 (65.4%) students submitted their theses.

Our data showed that in the two years of COVID-19 (2020, 2021), the number of research proposals submitted was significantly lower than in the years before the pandemic (average 432 ± 76. SD vs. 4469 ± 78.3; Pearson's χ^2 test = 5.98, df = 4, p =0.01; Table 1). Similarly, we found that the number of research proposals rejected was lower during the pre-pandemic years (57 ± 28.3 vs. 65 ± 31.1; Pearson's χ^2 test = 6.08, df = 4, p =0.01) but the total number of research proposals approved was not significantly different (412 ± 52.5 vs. 367 ± 42.3; Pearson's χ^2 test = 2.46, df = 4, p = 0.116).

Table 1. The number of research proposals submitted and approved and subsequent theses submitted by Israeli high school students in biology during the years 2015–2021 (N = 7 years). The shaded years are during the SARS-CoV-2 years.

Year	Research Proposals				Final Project	
	Submitted	**Failed**	**Approved**	**%**	**Submitted**	**%**
2015	344	22	322	93.6	281	87.3
2016	472	47	425	90.1	266	62.6
2017	459	44	415	90.4	316	76.2
2018	541	89	452	83.6	341	75.4
2019	529	83	446	84.3	381	67.5
Avg. ± SD	469 ± 78.3	57 ± 28.3	412 ± 52.5	87.9	317 ± 46.3	74 ± 9.4
COVID-19						
2020	486	87	399	82.1	361	65.4
2021	378	43	335	88.6		
Avg. ± SD	432 ± 76.4	65 ± 31.1	367 ± 45.3	87.1		
OVERALL:						
Avg. ± SD	458.4 ± 67.9	59.29 ± 24.7	399.1 ± 47.8	87.1	324.3 ± 41.2	72.4 ± 8.3

Of all the proposals approved, we observed that during the pandemic year, a lower percent of high school students succeeded in completing their research projects and submitting the written thesis projects (65 vs. 75%), but there was no relationship between the two (rho = 0.49, p = 0.32; Table 1).

Overall, the research areas of interest of Israeli high school students can be ranked as those that are conducted in the laboratory (63.2%, Table 2), agriculture (27.5%), and ecology are relatively insignificant—whether in captivity (2.8%) or the field (4.8%) (χ^2 test = 9.211, df = 3, p = 0.012). Bioinformatics is fast becoming a field of research that has essentially overtaken studies in captive and field ecology within a short span of the last three years.

Table 2. The major topics of science projects in biology of Israeli high school students in which they submitted research proposals. Encl. Ecol. denotes enclosure ecology and F. Ecol = field ecology. The shaded years are during the SARS-CoV-2 years.

Year	Research Areas				
	Agriculture	Laboratory	Encl. Ecology	F. Ecology	Bioinformatics
2015	84	210	12	16	
2016	123	279	8	15	
2017	115	271	11	18	
2018	134	281	12	25	
2019	137	276	11	22	4
Avg. ± SD	118.6 ± 21.2	263.4 ± 30.1	10.8 ± 1.6	19.2 ± 4.2	
N (%)	593 (28.7)	1317 (63.8)	54 (2.6)	96 (4.7)	4 (0.2)
COVID-19					
2020	112	243	8	19	17
2021	64	207	15	18	31
Avg. ± SD	88.0 ± 33.9	225 ± 25.5	11.5 ± 5.0	18.5 ± 0.7	24.0 ± 9.9
N (%)	176 (23.9)	450 (61.3)	23 (3.1)	37 (5.1)	6.5
OVERALL:					
Avg. ± SD	109.9 ± 24.8	252.4 ± 30.2	11 ± 2.3	19 ± 3.2	17.3 ± 11.0
N (%)	769 (27.5)	1767 (63.2)	77 (2.8)	133 (4.8)	52 (1.9)

Research areas of interest in which the high school students undertook their projects was significantly lower during the pandemic period in agriculture (118.6 ± 21.2 vs. 88.0 ± 33.9; Pearson's χ^2 test = 8.118, df = 4, p = 0.004), while there were no differences of the number of research projects conducted in the laboratory (263.4 ± 30.1 vs. 225.0 ± 25.5; Pearson's χ^2 test = 1.1194, df = 4, p = 0.29), enclosure ecology (10.8 ± 1.6 vs. 11.5 ± 5.0; Pearson's χ^2 test = 0.79615, df = 4, p-value = 0.37), or field ecology (19.2 + 4.2 vs. 18.5 + 0.7; Pearson's χ^2 test = 0.25, df = 4, p = 0.93).

4. Discussion

Our data showed that fewer high school students opted for individual study science projects in biology during the pandemic, and this is evident in the decrease in the number of research proposals submitted in the years 2020 and 2021. However, this resulted in fewer proposals being rejected, suggesting that only the sincere students applied and committed to the rigorous process. This is further substantiated by the fact that, despite the decrease in the number of research proposals submitted for evaluation, the number of proposals approved was not significantly different between the two periods, and further, the number of students who submitted their final thesis was not significantly affected.

We found that the majority of the projects are conducted in the laboratory (63.2%), followed by projects related to agriculture (including animal husbandry; 27.5%), and ecological projects, whether in enclosures/captivity or the wild, comprised only 7.6%. However, we feel that this distribution does not necessarily display student preferences and that in Israel the numbers of academics that agree to mentor high school students are much greater in hospitals, university or research laboratories, etc., as compared to field biologists. This raises the subject of the dearth of academics that agree to mentor students, which is acute and a limiting factor, and academia needs to reconsider their priorities on what subsets of the society they are ready to invest time and effort in. We feel that high school students are the future of the nation and must be primed at an early age to become responsible citizens and future decision-makers.

As is evident from the data, the field that evolved just before the onset of the pandemic was bioinformatics. We consider the pandemic to have been especially conducive to the subject and to have encouraged more students to choose to study in the field of bioinformatics, not only because of its growing popularity in the biosciences but also to overcome the problems of lockdowns and the restrictions of access to closed areas, such as laboratories and university campuses. We believe that we will see more of the students that chose to work in laboratories opting for bioinformatics also because of the fast-evolving hi-tech market in Israel. The increase in these two fields of research can also be expected because of the interest that the student body has in the present pandemic, which can be readily studied in the laboratory or via analyses of regional or global datasets [29].

Tamim et al. [30] found that a meta-analysis review of a 40-year study showed that the impact of technology on learning was significantly better than more traditional, technology-free, instruction. Accordingly, ref. [31] provided a bottom-up approach for using online technologies in chemistry teaching. This is also true for the scientific projects wherein the students are exposed to technology in academic laboratories or in the field that are not readily available in schools. This exposure to modern research techniques with appropriate instruments is an important enticement for students to volunteer to participate in the science projects program [32]. This may also further explain the increasing trend of the students that choose to conduct research in bioinformatics. This trend suggests that, in the near future, we can expect to see a reduction in the number of projects undertaken in laboratories and to be balanced by those that choose to study bioinformatics.

Heyd-Metzuyanim et al. [21] demonstrated the importance of mathematical literacy in the public, especially in situations of a pandemic, where one has to try and make sense of the large numbers and data presented by the public media. The authors found a strong relationship between the levels of mathematics acquired by the individual at the high school level and his/her mathematical literacy as a citizen. This is also true for public understanding of the science behind the pandemic and the steps taken to remedy the situation, especially when students are exposed to masses of fake news and conspiracy theories [33,34]. This is also appropriate for students that are involved in science projects. In our interaction with our students, we find that the fact that they are involved in analyzing data that they have collected gives them a perspective of looking critically at all other pseudo-scientific reports that are circulated, especially by the public and social media.

No less important is the personal interaction between the mentor and the student, another reason for students not completing their theses. Owing to the lack of academic experience on the part of the high school student, the mentor has to display much more patience towards them than to a university graduate. Hence, the importance of the meetings and inculcation of scientific thought into a young mind is very painstaking and requires patience. This is especially a bonus for the student because many times the theoretical material learned in schools becomes reality for the student. Similarly, ref. [35] found that physical education teachers recognize the importance of face-to-face lessons to avoid losing the meaning of their subject, leading to disenchantment. This was also stressed for institutions of higher education (Peking University) [36]. Hence, we believe that the mentoring of high school students in science projects is of the utmost importance for the academic society and may even be amongst the few studies that the student will cherish in the future from all of their school years.

Researchers thought that reassuring students and parents is a vital element of institutional response and considered asynchronous teaching to be optimal in digital formats [8]. He also stressed the point that different students have different needs and the inequity of attention by the teacher can result in withdrawals and other negative symptoms such as loneliness [37]. These studies essentially support our claims that participation in science projects is asynchronous education wherein the student does not have to suffer the rigors of regular schools. The personal achievement motivation and drive of the student are what ensure the success of the project [7]. Hence, the personal interaction and personal responsibility in an asynchronous atmosphere can lead to students achieving more than if they were only restricted to the regular, distant classes. Motivated students can reach great achievements when allowed to learn from their own mistakes, experiences, and successes. This is evident in the high-quality projects that students undertook and that culminated in scientific publications [32,38,39].

The pandemic has stressed the subject of the lack of cooperation upon the part of some of the students, whether because they are the better students who take the chance to abscond [16] or those that are lonely and frustrated [37]. The option of involving a greater number of students in individual science projects of their choice may be a viable alternative to enhance and strengthen those that feel neglected or those that take negative advantage of their capabilities. The one-on-one interaction that is so needed by those who are emotionally distressed [40] could be resolved by creating a new curriculum wherein individual research becomes an important part of the grading system. In any case, we recommend teachers to resort to teaching through research to keep their students curious and mentally active during periods of distant teaching, including those from vulnerable and disadvantaged minorities [23]. This also needs to be included in the syllabus of teachers' colleges for those in training at present so that they are equipped with the proper tools required [41]. This can also be achieved by conducting workshops that target environment issues and how the daily practices of every individual can influence community-level effects and influences.

Following our findings, the environment-related community of academics needs to recognize that it is not enough to study the wide range of issues concerning climate change, or the conservation of biodiversity, etc., without including motivated high school students in their research programs. If we can encourage a higher percentage of students to take an interest in the environment that exists outside the walls of the laboratories or in online data bases, we will recruit greater numbers of knowledgeable adults and decision-makers in the future into our communities. Ref. [42] used an adage that is most appropriate to this situation—"By failing to prepare, you are preparing to fail!". They suggested that, from the policy and practice perspectives, schools should be encouraged to engage in more geographical and environmental education in the post-pandemic future. By joining the effort, one can try and take advantage of this unique situation that the pandemic has forced on us and try and make education more equitable [10]. However, the trend towards laboratory confined projects or digital studies need to be balanced with more environment awareness and advocacy projects.

In conclusion, in these trying times of the COVID-19 pandemic, the fact that fewer research proposals were submitted appears to have weeded out those that did not take the subject and the responsibility seriously enough. Consequently, this resulted in a lower number of rejections of the highly motivated students. This is substantiated by the fact that an equal number of students that submitted their final theses did not differ between the periods [42]. We assume that this trend will continue as long as the pandemic continues and distant learning and quarantines remain the norm at schools. However, we are optimistic that the truly motivated students will continue to make the effort to be involved in biology and other science projects, such as physics or chemistry, over and above their regular school curriculum and the handicaps of the COVID-19 restrictions. We highly recommend the authorities of the Israeli Ministry of Education to consider education-through-research as a viable option for equitable teaching in the post-pandemic period.

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