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**Research Article**

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# Use of logic for improving the higher-order thinking skills of student teachers

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**ABSTRACT**

This paper is a report on the results of the intervention program designed for improving the higher-order thinking skills (HOTS) of Israeli Arab student teachers. The intervention program represents a series of webinars on the foundations of the Aristotelian logic, propositional logic, and some of the contemporary models of informal argumentation. Zoom application was used for the implementation of the webinars. This research project was designed as a pre-/post-test quantitative study with a qualitative component. A mixed-item questionnaire with two open-ended items was used to measure participants' understanding of logical reasoning and argumentation. The results of the pilot showed good internal reliability of the scale ($\alpha$<0.81). Tests of argumentation were performed to examine participants' actual argumentation skills. The pre-intervention results indicated that many of the participants from both control and intervention groups had a vague understanding of logical reasoning and argumentation and weak argumentation competence. The post-intervention data suggested positive changes in the intervention group participants' understanding of logical thinking and argumentation and an improvement in their actual argumentation skills. This study was planned as the first one in a series of studies aimed at using informal and formal logic to foster students' HOTS.

**Keywords:** Israeli Arab student teachers, higher-order thinking skills, reasoning and argumentation skills, Aristotelian logic, formal and informal argumentation

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## INTRODUCTION

Since ancient times, an idea has been promoted that logic can be a powerful tool for increasing the thinking skills of students, both in the framework of compulsory education and non-formal contexts of lifelong learning. Courses in formal and informal logic are offered at a tertiary level, but in the system of secondary education, logic is rarely taught as a standalone subject. In primary and secondary schools, an enhancement of students' reasoning and argumentation skills is usually part of broader strategies of developing students' higher-order thinking skills (HOTS) in the context of a specific subject matter (infusion approach) (Seif, 2017). In Israeli high schools, foundations of formal logic are studied by those who specialize in mathematics and computer sciences in the framework of vocational education. Basics of informal argumentation are taught within the instruction of various subject matters as part of the strategies for developing students' HOTS (Eizenberg & Zelivansky, 2018; Seif, 2017; Yoad, 2009). In Israeli system of teacher education, students are periodically engaged in various activities to develop logical reasoning and argumentation skills. Yet, there is a lack of comprehensive courses in logic for student teachers, such as an introductory course in logic offered to students of humanities and social sciences in framework of Open University of Israel (n. d.).

The research reports issued over the last decades indicate that quite often secondary and tertiary students have problems in logical reasoning and argumentation (Larson et al., 2009; Peloghitis, 2017). Researchers (Cerbin, 1988; Hyytinen et al., 2016; Schwarz & Baker, 2016) point out to faulty reasoning and argumentation that involves logical errors or inappropriate inferences, few reasons to back up claims, underdeveloped arguments, and little or no attention to counterarguments or conflicting evidence. In the Israeli education system, the above problems particularly concern a large number of Arab students. It was revealed that in comparison to their Jewish counterparts, Arab students required more assistance from instructors in learning contexts involving critical reflection, reasoning and argumentation (Abed & Dori, 2013; Pieterse et al., 2018; Seif, 2019). A study by Seif (2020), which involved novice students from four Israeli Arab teacher colleges, showed that more than 40% of the participants produced arguments that could be defined as "underdeveloped mental models of argument structure" (Cerbin, 1988, p. 4). Research results suggest that many of the Israeli Arab school teachers do not possess necessary abilities to teach about correct ways of thinking (Abu-Hussain & Abu-Hussain, 2018; Abu-Hussein, 2015).

Israeli educational research on logic is largely dedicated to developing student thinking skills by means of formal symbolic logic.

In regulatory literature, the development of logical reasoning and argumentation is often associated with fostering students' mathematical thinking (Ministry of Education of Israel, 2013). Israeli researchers (particularly in the domain of informal argumentation) distinguish between "arguing to learn", which is used as a means to improve domain specific content learning, and "learning to argue" that refers to activities and programs created to improve students' argumentation competencies (Asterhan & Schwarz, 2016, p. 5). Researchers throughout the world hold that failures in the evaluation and construction of arguments result from the lack of explicit instruction and practice in argumentation skills (Hyytinen et al., 2016; Marchis, 2013). A standpoint prevails that logical reasoning and argumentation skills should be fostered in the context of a specific subject matter (Schwarz & Baker, 2016). Less voices are heard in support of teaching logic as a separate subject in addition to the content-based (infusion) approach (Duman, 2019). To date, no studies have been reported on developing Israeli students' thinking skills through implementing a separate course in formal and informal logic.

The factors listed above have necessitated the current investigation, which represents the first attempt to explore the use of the study of logic for improving HOTS of Israeli Arab student teachers. As part of author's research activities dedicated to fostering HOTS of Israeli Arab students and teachers (Seif, 2017, 2019, 2020; Seif & Tilchin, 2013), an intervention program was designed in the form of webinars on logic. It was expected that the knowledge instilled through this course would help students become more confident in logical thinking and argumentation. The current paper presents the results of the intervention program organized for novice students from two Israeli Arab teacher colleges. The key research question investigated whether the program had an effect on participants' declarative and procedural knowledge of logic. The following sub-questions were posed to examine the impact of the program on participants' awareness of the significance of logical thinking and argumentation in different life contexts and on their actual skills in argumentation.

1. Did the program have an impact on participants' understanding of the meaning of logical thinking and argumentation?
2. What were participants' viewpoints on the transfer of the reasoning and argumentation skills learnt in class to everyday thinking practices?
3. Did the program have an impact on participants' comprehension of the importance of argumentation skills for addressing socio-political issues?
4. Were there changes in participants' perceptions of the role of collaborative work in developing logical thinking, as a consequence of the intervention?
5. Was there an increase in participants' self-esteem and motivation as a result of studying logic?
6. Did the program have an impact on participants' actual skills in argument construction?

The current research project was designed as an experimental study that involved a small number of participants (n=32). They were intended to learn fundamentals of formal and informal reasoning and argumentation through the acquaintance with Aristotle's logic, propositional logic, and some of the contemporary models of informal argumentation as well. The webinars also included a brief overview of the role of the study of logic in Islamic world. In the current research, the focus is on students' abilities to construct single arguments, namely, to make an assertion or set of assertions that represent the reasons to justify a conclusion. Participants' understanding of the role of logical thinking and argumentation in different contexts was examined from some of the aspects of the cognitive and dispositional domains of HOTS. Their actual skills in argument construction were assessed by using the methods of evaluation of single arguments.

The idea of studying logic through webinars emerged at the time when educational institutions were closed due to the COVID-19 pandemic, which caused an unprecedented crisis in many areas and created new challenges for education. Students stayed long hours at home, spending much time on the internet to study syllabus and communicate through online social networks. The implementation of the program was expected to encourage the youth to spend their time on the internet more effectively and rewardingly, but there was also an additional purpose. Since the time of the Abbasid Caliphate (750 CE-1258), the instrumental role of logic was acknowledged by the Islamic theology and philosophy for religious and secular reasoning. Logic as a discipline was studied and applied as a reasoning tool in the Palestinian schools of Islamic theology and philosophy in the medieval time and later (Akrami, 2017; Totah, 1932). Over the last three centuries, the Aristotelian logic has been also taught in some of the Christian schools in Palestine. Today, Israeli university students can learn about the legacy of reputed Arab logicians and the influence of the Aristotelian logic on certain Islamic sciences, but in Arab public schools and system of teacher education such opportunities do not exist. For a variety of reasons, the ideas of great Arab philosophers and logicians have had gradually lost their significance in the education of Palestinian Arab youth and they need a revival in the present time.

## THEORETICAL BACKGROUND

From the ontological point of view, the theoretical background of this study relies on the doctrine of realism according to which there is an objective reality studied through the use of senses and reason. Educationally, this standpoint implies the need to rely on a well-established empirical knowledge in order to teach students reasoning skills developed on the basis of objective facts and values (Tan, 2006). Logic can serve as a tool to elaborate, classify and evaluate correct and incorrect forms of reasoning in each domain of knowledge (Chelpanov, 2010; Dowden, 2017). In the Israeli education system, the practice of instilling effective argumentation skills in students is based on the developments in cognitive psychology and critical constructivist pedagogy (Yoad, 2009; Zohar, 2004, 2008). Program's design is inspired by some of the reputed textbooks on logic and supports the idea of the partnership of formal and informal argumentation in increasing the level of student HOTS (Jing, 2021).

## LITERATURE REVIEW

### Introduction

This section of the paper considers a number of topics that are of importance to the content of the current intervention program. The sources consulted for this review include articles published in peer-reviewed journals, conference papers, and monographs, including a large number of introductory courses in logic. The review reveals that

a considerable part of introduction to logic are dedicated exclusively to formal logic since their authors believe that only a study of this kind of logic enables students to distinguish correct argumentation from the incorrect one (DeLancey, 2017; Goldshtein, 2010; Hardegree, 1999). This section highlights the textbooks that provide a viewpoint that correct thinking should be acquired through studying both formal and informal types of logic, including the Aristotelian logic as a general theory of reasoning. In what follows, there is a brief description of the way in which the logic of Aristotle was presented in the textbooks written over the last three centuries. Some of the contemporary literature on the typology of arguments and evaluation thereof is highlighted, as is the role of argumentation in learning practices.

### Ways of Teaching About the Aristotelian Logic

For centuries, the logic of Aristotle had been taught, following a certain order determined by the medieval concept of different operations of the intellect: simple apprehension (characteristics of notions/terms as perceptions of real world objects; judgement (judgement as a relation between two notion/terms when compared in the mind and then expressed verbally in a proposition); and discursive reasoning (syllogism, argumentation and sophistic reasoning/fallacies). This order manifests itself with slight variations in the majority of the textbooks written over the 18$^{th}$-early 20$^{th}$ centuries (Baumeister, 1989; Chelpanov, 2010; Coppens, 1891; Munro, 1850; Stock, 1888). The description of the properties ascribed to individual objects of a real world (the primary substances) is followed by the explanation of the specific properties attributed to the secondary substances (categories) to which individual things belong. These topics create the basis for the matters of a universal and particular predication, term distribution in a proposition, and syllogistic reasoning. The key principle is that in the Aristotelian logic, a reflection of the real world objects in language constructions is essential to argumentation.

The idea that students would better comprehend formal reasoning after having learned about the role of language and meaning in the characteristics of a term has seemingly influenced the design of some of the contemporary textbooks (Baronett, 2018; Copi et al., 2014, 2018; Hurley, 2014; Hurley & Watson, 2018). The aforementioned authors, except for Baronett (2018), placed the topics of sophistic reasoning after those highlighting the issues of the term definition. The latter and informal fallacious arguments constitute the content of the chapters dedicated to informal logic for which a main concern is the way our mind represents reality and the matter or content of argument. These chapters are followed by those that deal with formal reasoning. This order of topics does go in line with the concept that Aristotle's doctrine of reason explicates the illative mechanism through an understanding of natures (Groarke, 2021). By contrast, some of the scholars (Mosley & Baltazar, 2019) do not focus on the metaphysical nature of the Aristotelian logic. By stating that "Aristotelian logic is a formal language" (Mosley & Baltazar, 2019, p. 68), they refer to the universal and particular predication and categorical syllogism, which they regard as the key parts of the Aristotelian logic. The issue of term connotation is included in order to emphasize that both subject and predicate terms must be unambiguous and precise.

### Importance of Teaching About Definition & Division of Terms

Since the times of Plato, definition and division have been interconnected processes and both have been considered important to the clarity of the expression of thoughts. The contemporary typology of the term definition distinguishes between the definitions by function (e.g., stipulative, lexical, précising) and those made by using techniques depending on the processes of extension and intension of terms (e. g., ostensive, operational, and definitions by genus and difference) (Copi et al., 2014). The definition by genus and difference seems to be most commonly relied on in the definition of terms that denote classes of objects (Baronett, 2018; Copi et al., 2018). For the description of the essential and accidental characteristics of terms, most of the textbooks written until the early 20$^{th}$ century provide the five-fold definition of general terms (five heads of predicable) developed by Porphyry (234?-305? CE) in addition to Aristotle's concept of predicable.

In the contemporary courses of logic (Indira Gandhi National Open University [IGNOU], n. d.), the essential attributes are those that represent the connotation of a term (by proximate genus and the differentia) and those, which follow from the connotation (properties). The attributes that do not follow from the connotation are accidental ones (accidents). Noticeably, the topic of the term division does not appear in some of the contemporary textbooks of logic, whereas the logical division of terms is key in the knowledge organization systems (Frické, 2012) and in the information retrieval systems with which students deal on a daily basis.

### Concepts of Argument in Natural Discourse

A large variety of argumentation models have been developed since ancient times. By drawing on the techniques and targets of persuasion used in ancient Greece, Aristotle established the fundamental concepts of classical rhetoric by standardizing persuasion strategies and argument structure (Rubinelly, 2009). The time-honored persuasion strategies include ethos (by proving one's own credibility on a topic or using credible sources), logos (logical and clear reasoning based on sound evidence), pathos (an appeal to audience's emotions), and Kairos (proper timing in terms of the importance of discussing the topic in a certain moment and call to immediate action in order to cease an opportunity to do something). Both rhetoric strategies and components of argument (introduction or hook, background of the topic, claims backed by relevant evidence, taking account of opposing standpoints, conclusion, and call to action) represent a classic form of writing a rhetorical essay and manifest themselves in one way or another in argumentation models developed over time.

During the 20$^{th}$ century, the number of argumentation styles have significantly enlarged. Walton (2013), for example, determines the structure of argument in a dialogue by the kind of goal to be achieved, e.g., inquiry, persuasion dialogue (critical discussion), negotiation, forensic debate, and so on. The Rogerian argument model is claimed to work well in order to establish the basis of mutual interest with contradictory viewpoints (Brian, 2003).

It is characterized by a negotiation strategy aimed at ending disputes peacefully. Toulmin's (2003) framework has been one of the most frequently cited method of the argumentation, particularly in the field of education. It is held that this type of argument represents a good model for constructing both verbal and written arguments in a variety of contexts (Cerbin, 1988; Lansford, 2002), including online environments (Erdugan, 2018). Many of the researchers (Noroozi et al., 2018; Stegmann et al., 2012) believe that an application of Toulmin's (2003) model is more effective in analyzing completed declarative arguments than in capturing and recognizing them in the dynamic process of collaborative discourse.

### Evaluation of Formal and Informal Arguments

A fundamental principle of evaluating a formal argument is that the conclusion should necessarily follow from the premise(s). The conclusion is true if the form of an argument is valid, and premises are true. As to sound formal arguments, both form and content should be considered. In order to test the accuracy of a premise, one must verify whether it is based on a well-established knowledge and whether all relevant factors have been considered (Nickerson, 2020). An application of the term definition and division principles is of importance to the verification of the correspondence of propositions in a syllogism with the facts of objective reality. For Aristotle, procuring true propositions through correct definitions leads to the objective outcome of dialectical reasoning (Rubinelly, 2009).

There exist a number of approaches to evaluating the arguments that occur in natural language. These include the fallacies approach suggested by Aristotle and developed by contemporary scholars (Blair & Johnson, 1987), natural language deductivism (Groarke, 2020), logical analogies approach established by Burbidge (1990), ARS (acceptability, relevance and sufficiency) criteria (Blair, 2019), and through various argument schemes like those developed by Toulmin (2003) and Walton (2013). A detailed description and comparison of the listed above methods is beyond the scope of this paper. It needs to be said that different schemes can be interrelated to be suitable to their purposes and different circumstances (Walton, 2013) and underlie the methods of determining students' argumentation competence (Rapanta et al., 2013).

### Argumentation Competence

It has been acknowledged (Asterhan, 2015; Asterhan & Schwarz, 2016) that both "arguing to learn" and "learning to argue" are important since individuals learn and practice how to argue about a certain subject and by doing so improve their knowledge on that subject. A viewpoint exists that so far there has been no consensus among researchers as to a homogenous definition of argumentation competence and therefore there is no standardized instrument to analyze and evaluate the argumentation competence components (Haro et al., 2020). So far, argumentation competence has been usually determined by assessing the skills students manifest during argumentative discourse activities, through the use of strategies or achievement of specific argumentation goals, and by tests of argumentation skills prior to and after discussion activities (Noroozi et al., 2018).

Some of the studies (Haro et al., 2020; Stegmann et al., 2012) showed that students demonstrated knowledge of constructing single arguments but failed to use this knowledge in collaborative discourse activities. Therefore, it was suggested that a reliable measurement of argumentation competence could be based on both the argumentation knowledge of students and their behavior during actual discourse. Walton's (2013) types of argumentation dialogues were used to generate effective classroom discourse within secondary education classroom settings (Rapanta & Christodoulou, 2019). For an evaluation of single arguments in the process of assessing student argumentation competence, a number of researchers (Haro et al., 2020; Stegmann et al., 2012) elaborated the definitions, such as "simple claims", "qualified claims", and "grounded claims" based on Toulmin's argument model (2003).

The development of reasoning and argumentation competence is a gradual process. Initially, students should internalize a model of argument by learning the basic components of arguments and the processes of reasoning. When students able to identify and explain the components of arguments, they possess a mental model of well-organized reasoning process that they need to extensively perform in different situations (Cerbin, 1988). These "know-what" skills are related to the metacognitive aspects of knowing that are needed to construct valid informal arguments (Rapanta et al., 2013, p. 491). A necessary condition for performing correct reasoning and argumentation is the possession of the topic knowledge as the base for the evidence to support argumentation process (Haro et al., 2020). Constructive and frequent feedback to students (particularly to novice ones) is of great importance until they could perform an effective assessment and construction of arguments (Cerbin, 1988; Noroozi et al., 2018).

## METHODOLOGY

### Research Design, Population, and Setting

This research project was conducted in the form of a pretest-posttest quantitative study with a qualitative component. The study participants (participants) were novice students from the two Arab teacher colleges. These students were approached electronically to identify those who had an interest in studying logic as a separate subject with the purpose of personal enrichment. It was explained that this would be an experimental program that sought the ways to help students learn in a more efficient way with the help of logic. In the letters sent to students, the purpose and conditions of this study were explained in detail. To obtain a random sample, the lottery method was used. As a result, 32 students at the age ranging from 17 to 19 years old formed the intervention (n=16) and control (n=16) groups. Female participants represented 75% of the whole research population (among Israeli Arabs, mostly female school graduates choose teaching profession). As it was mentioned earlier in this paper, the course took place in an online setting. Following the recommendations of Ministry of Education with regard to remote learning, the Zoom application was chosen to complete questionnaires and carry out webinars. The intervention group was divided into two groups of eight people each, so that more time could be dedicated to every participant, and they could get more out of the program. The course consisted of 12 modules each of which included a number of topics (68 webinars including current tests). These were performed over the period of an academic year (usually two meetings a week, about one hour and a quarter per meeting).

### Independent Variable

In the current study, an intervention program served as an independent variable. Webinar topics are listed in **Table 1** and followed by a brief characteristic of the course content.

Conceptually, the program is inspired by the manuals of logic that include the foundations of the Aristotelian logic and pay attention to the aspects of language and meaning in reasoning. The course is structured so that earlier topics provide a foundation for the later ones, with some of them being revisited at a new level. For example, participants get a general understanding of the concept of proposition at the beginning of the course. They then enhance the comprehension thereof when learning about the words that can be used as subject or predicate of a proposition. Further, they learn in detail about categorical propositions and syllogisms. Due to the limit of time, some topics (e. g.,

**Table 1.** Webinar topics

| No | Webinar topics |
|---|---|
| 1 | **Introduction to basic concepts of logic:** Logic as part of philosophy. Logic & rhetoric. An analysis of different types of sentences to explicate concepts of "inference", "premise", "proposition", & "argument". Reasoning & argumentation. Distinction between deductive (formal) & inductive (informal) inferencing. Formal & material truth. |
| 2 | **Notion, word, name, & term:** Characteristics of notion in logic. Notion as product of human perception of real world objects & phenomena. Notion as a product of abstract thinking. Notions from fairytales as allegories of real world. Words as means to convey meaning behind notions. Different types of notions (singular, general, & collective; positive, negative, & privative, etc.). Names as words that can be used as terms to construct a proposition. Relating two terms in a proposition. General term as a name of a class. Aristotelian logic as logic of classes/categories. |
| 3 | **Definition:** Kinds of definitions on their function & structure. Connotation (intension) & denotation (extension) of a term. Definition by genus & difference. Limitations of definitions by genus & difference. Essential vs. accidental properties. Rules to avoid fallacies in definition.<br>**Division:** Types of division. Meaning of logical division. Division by dichotomy. Rules to avoid fallacies in logical division. Logical division in knowledge organization systems & information retrieval. |
| 4 | **Propositions:** Different types of propositions. Categorical logic. General categorical propositions. Diagramming categorical propositions Aristotle's fundamental principles of thought. Structure & significance of four types of categorical propositions (affirmative-negative; universal-particular). Conversion, obversion, & contraposition. Distributed & undistributed terms in propositions. Aristotle's square of opposition. |
| 5 | **Categorical syllogism:** Standard form of categorical syllogism, figures, & moods. Diagramming categorical syllogisms. Form ves. content (valid & sound syllogisms). Rules & fallacies for categorical syllogisms. Venn diagrams for categorical syllogisms. |
| 6 | **Propositional logic**<br>**Hypothetical syllogism:** Wholly hypothetical syllogisms. Mixed hypothetical syllogisms: Modus ponens & modus tollens. Fallacies of hypothetical syllogism.<br>**Disjunctive syllogism:** Exclusive/inclusive disjunction. Fallacies of disjunctive syllogism. |
| 7 | **Formal & informal arguments revisited**: Deductive vs. abductive & inductive reasoning. Valid, sound, & strong arguments. Criteria for judging quality of arguments. Evaluating truth of a premise. |
| 8 | **Standardization of arguments:** Identifying an argument in context & putting it into standard form. Syllogisms in ordinary discourse. Implicit premises (enthymemes) & conclusions. |
| 9 | **Argument typology:** Aristotelian or classical argument. Argument models created in 20th century (Toulmin's, Rogerian's, & Walton's argument schemes). |
| 10 | **Formal & informal fallacies revisited:** Sophistic reasoning.<br>**Fallacies of relevance:** Appeal to emotions. Appeal to force. Appeal to pity. Red herring. Straw man. Argument against the person. Is/ought fallacy.<br>**Fallacies of weak induction:** Appeal to ignorance**.** Appeal to inappropriate authority. False cause. Unwarranted generalization. Weak analogy. Slippery slope.<br>**Fallacies of illicit presumption:** Composition/division fallacies. Accident**.** Begging question. Complex question. False dichotomy.<br>**Fallacies of linguistic emphasis:** Accent. Manipulative framing. Quoting out of context. |
| 11 | **Multimodal arguments:** Visuals in combination with verbal arguments. |
| 12 | **Logic in Islamic world:** A brief overview of the heritage of… |

sorites, dilemmas) were not included. It is noteworthy to mention that participants began to study the topics of sophistic reasoning (module 10) towards the end of the course. Such an order follows the concept that students should be taught about reasoning fallacies after having acquired the knowledge of the term connotation and denotation and types of formal and informal arguments. The knowledge of the theory of terms, propositions and syllogisms was also helpful when participants were acquainted with the development of logic in the Islamic world.

The instruction and learning processes involved an active teacher-student interaction during the presentation of the new material and consolidation of the material covered (**Appendix A**). Intensive scaffolding techniques were employed to help participants understand and remember the topic content: abundant visual aids and clear-cut explanations and examples of using the rules. The material from the high school curriculum was used for the examples of using rules and exercises. Participants were advised to use reliable sources of knowledge and information, such as encyclopedias, dictionaries, regulatory documents, and reliable electronic and printed sources that presented empirically proven results of scientific studies. The presentation of text and schemes was done with the help of the Google Doc application. To store the summaries of topics, visual materials and exercises performed during the webinars participants used Google Drive personal files that could be used for the consolidation of the material covered and for future reference. An emphasis was placed on the work done during online sessions while home tasks were usually short since students (some of whom were married women) were preoccupied with their college assignments and household work.

## Dependent Variables

In this research, the definitions of dependent variables are associated with participants' perceptions of the significance of logical thinking in various contexts their actual argumentation skills. Two variables reflect participants' understanding of argumentation from some of the aspects of the cognitive and dispositional dimensions of HOTS. These variables include the following categories generated from the questionnaire items:

1. Understanding of logical thinking and argumentation from the cognitive and metacognitive aspects of HOTS:
   a. logical thinking in organizing and controlling learning process,
   b. transfer of reasoning and argumentation skills, and
   c. logical thinking and argumentation for addressing socio-political issues.
2. Understanding of logical thinking and argumentation from the dispositional dimensions of HOTS:
   a. developing logical thinking and argumentation through teamwork,
   b. logical thinking for self-confidence and self-esteem, and
   c. motivation to study logic.

**Table 2.** Results of Cronbach's coefficient alpha test

| Variables | Questionnaire items | Likert scale | Cronbach's alpha |
|---|---|---|---|
| Understanding of logical thinking from cognitive & metacognitive aspects of HOTS | 1-5 | 1-5 | 0.80 |
| Understanding of logical thinking from dispositional dimensions of HOTS | 6-10 | 1-5 | 0.68 |
| Total | 1-10 | 1-5 | 0.81 |

**Table 3.** Results of Kolmogorov-Smirnov test

| Variables | Control group | | Intervention group | |
|---|---|---|---|---|
| | Pre-test | Post-test | Pre-test | Post-test |
| Understanding of logical thinking from cognitive & metacognitive aspects of HOTS | 0.16 | 0.22 | 0.03 | 0.09 |
| Understanding of logical thinking from dispositional dimensions of HOTS | 0.02 | 0.05 | 0.58 | 0.74 |

In the first variable, categories are associated with the three aspects of cognitive and metacognitive domains: controlling and modifying learning processes (metacognition), applying logical thinking skills acquired in school to perform everyday routine tasks (skill transfer), and problem solving skills used for addressing socio-political problems thorough argumentation discourse. These theme was prompted by the fact that in the Israeli Arab community, too often social and political problems are addressed not by means of constructive dialogue, but through using threats and physical violence (partially because of the rivalry between different family clans) (Lang, 2013; Nohad & Levin-Chen, 2019). The categories of the second variable refer to the three aspects of the dispositional domain: preparedness to develop logical thinking collaboratively, issues of self-confidence and self-esteem, and participants' motivation to continue studying logic. Participants' actual skills in reasoning and construction of arguments were also measured as dependent variables.

## Data Collection Methods

### *Questionnaire*

Following the principle behind the previously developed scales used to examine HOTS of the Israeli Arab teachers and students (Seif, 2017, 2020; Weiss, 2010), the mixed-item questionnaire (ten closed and two open-ended statements) was designed to measure participants' understanding of logical thinking and argumentation prior to and after the intervention. The questionnaire items are organized as follows: first five items correspond to the cognitive domain of HOTS (categories 1-3) and the following five items refer to the dispositional domain (categories 4-6). Participants rated the items by using a 5-point Likert-scale: "strongly disagree" (1), "disagree" (2), "undecided" (3), "agree" (4), and "strongly agree" (5). Both positively and negatively worded items were used to offset any affirmation/negation response bias. The open-ended items of the scale were expected to elicit participants' comprehension of logical reasoning and argumentation and whether reasoning and argumentation performed in classes make an impact on students' everyday thinking practices. The responses were expected to provide the qualitative data, which might give details that quantitative data alone could not reveal.

The questionnaire was pre-tested with the help of student teachers not involved in the study. It was altered further on the basis of the pilot data and recommendations of "critical friends" who had the knowledge of logic. The internal consistency reliability of the part of the scale including closed items was examined by using Cronbach's coefficient alpha. The results showed that the instrument had good internal reliability (**Table 2**).

### *Pre- and post-intervention tests and current tests*

The pre- and post-intervention tests for examining participants' actual reasoning and argumentation skills included exercises on valid and invalid categorical syllogisms as well as fallacies of weak induction (**Appendix B**). Participants had to provide responses by agreeing with or refuting the conclusions to arguments and justify their answers by constructing their own arguments. Current tests were performed in the form of quizzes and a variety of writing exercises. In this study, developing the argumentation competence of participants was restricted to instilling conceptual knowledge of argumentation and teaching them to construct single arguments. Collaborative discourse took place during teacher-student interactions at the time of explanation or consolidation of the material covered, and participants' behavior during collaborative discourse was not assessed.

### *Analysis of quantitative data*

Data distributions of the variables were tested for normality by using the Kolmogorov-Smirnov test (**Table 3**). Tests for normality are used to determine whether data follows a normal distribution. Null hypothesis of the above test implies that the data distributions do not differ from a normal distribution N (0, 1). The dependent variables were measured prior to and after the intervention program implementation. The results of the test demonstrated that both variables differed significantly ($p>0.05$) from a normal N (0, 1) and therefore null hypothesis was rejected. Since the variables did not meet the assumptions of parametric tests, it was decided to use the non-parametric Mann-Whitney U test to compare differences between two small and statistically independent samples.

### *Discourse analysis tools*

Discourse analysis tools included thematic analysis and argument evaluation. The former was selected to analyze the responses to open-ended items and provide qualitative data. This type of the text analysis is considered a flexible tool that can describe the data in rich detail and can be used within different theoretical frameworks (Braun & Clarke, 2006). A simple sentence (either a standalone sentence or as subordinate clause) was treated as a meaning unit for text encoding. Many of the responses were coded with more than one code, so that two more themes were generated from one response. The theme prevalence was determined by the number of the responses from which a theme was generated.

In the pre- and post-intervention tests of argumentation skills, the responses of the control and intervention group were assessed, as follows: the participants had to determine whether the conclusions of arguments in the tests were correct or not and then justify their decisions by constructing their own arguments. The latter were

**Table 4.** Pre-intervention results for measures of central tendency & interquartile range of parameters for control & intervention groups

| Variables | Control group (n=16) | | Intervention group (n=16) | | U |
|---|---|---|---|---|---|
| | Md | IR | Md | IR | |
| **Perception of logical thinking from cognitive & metacognitive aspects of HOTS–total scores** | **3.75** | **1.75** | **3.70** | **1.20** | **-0.235** |
| Logical thinking in organizing & controlling learning process | 4.00 | 1.75 | 4.00 | 1.88 | -0.124 |
| Transfer of reasoning & argumentation skills | 2.75 | 1.75 | 3.00 | 2.75 | -0.482 |
| Logical thinking & argumentation for addressing socio-political issues | 2.50 | 1.75 | 2.50 | 0.88 | -0.379 |
| **Perception of logical thinking from dispositional dimensions of HOTS–total scores** | **3.50** | **0.95** | **3.75** | **1.00** | **-0.126** |
| Developing logical thinking through teamwork | 3.25 | 1.38 | 3.00 | 1.50 | -1.106 |
| Logical thinking for self-confidence & self-esteem | 4.00 | 2.35 | 4.00 | 2.00 | -0.533 |
| Motivation to study logic | 4.00 | 0.88 | 4.00 | 0.88 | -0.641 |

Note. Md: Median; IR: Inter-quartile range; & U: Calculated U-test statistic

**Table 5.** Pre- & post-intervention results for measures of central tendency & interquartile range of parameters for control group

| Variables | Control group (n=16) | | Intervention group (n=16) | | U |
|---|---|---|---|---|---|
| | Md | IR | Md | IR | |
| **Perception of logical thinking from cognitive & metacognitive aspects of HOTS–total scores** | **3.75** | **2.75** | **3.50** | **2.00** | **-0.85** |
| Logical thinking in organizing & controlling learning process | 4.00 | 1.75 | 4.00 | 1.88 | 0.00 |
| Transfer of reasoning & argumentation skills | 2.75 | 1.75 | 3.25 | 2.75 | -2.79 |
| Logical thinking & argumentation for addressing socio-political issues | 2.50 | 1.75 | 3.00 | 0.88 | -1.25 |
| **Perception of logical thinking from dispositional dimensions of HOTS–total scores** | **3.50** | **0.95** | **3.50** | **1.00** | **-0.44** |
| Developing logical thinking through teamwork | 3.25 | 1.38 | 3.50 | 2.00 | -1.40 |
| Logical thinking for self-confidence & self-esteem | 4.00 | 2.35 | 4.00 | 1.75 | -0.87 |
| Motivation to study logic | 4.00 | 0.88 | 4.50 | 0.88 | -3.25 |

Note. Md: Median; IR: Inter-quartile range; & U: Calculated U-test statistic

evaluated by employing the method inspired by Toulmin's (2003) argument model and used by some of the researchers (Haro et al., 2020; Stegmann et al., 2012) for measuring the quality of single arguments. For current research, two definitions were borrowed from the study by Haro et al. (2020): simple claims (segments that do not function as grounds or qualifiers for other claims) and grounded claims that use evidence and keywords, such as "because", "since", "therefore", etc. In current study, correct responses were grounded claims, or arguments consisting of one or more statements (premises) and conclusion.

## FINDINGS

The results of this study fall into three groups: results of the statistical analysis of the data collected through the closed questionnaire's questions; results of thematic analysis of the text obtained from open-ended questions, and results of the pre-and post-intervention tests of argumentation.

### Results of Statistical Analysis

Four tests (1-4) were conducted by employing Mann-Whitney U test in order to make comparisons between pre- and post-intervention scores for the control and intervention participant groups and between the scores for each group. We display scores of the variables generated from the questionnaire closed items. These reflect participants' perceptions of the use of logical reasoning and argumentation from some of the cognitive and dispositional aspects of HOTS.

#### *Test 1. Pre-intervention comparison of responses of control group participants with intervention group participant responses*

The results in **Table 4** suggest that there is no statistically significant difference between control and intervention groups in pre-intervention phase. These data suggest that both groups began at the same starting point with regard to their perceptions of the significance of logical thinking and argumentation in various life contexts.

#### *Test 2. Comparison of pre- and post-intervention responses of control group participants*

**Table 5** shows that there is no statistically significant difference between the pre- and post-intervention scores for the control group. These findings suggest that since the control group participants have not been trained in logic, there is no significant changes in their understanding of logical thinking.

#### *Test 3: A comparison of pre- and post- intervention responses of intervention group participants*

The results in **Table 6** indicate a statistically significant difference between pre- and post-intervention scores for almost all the variable categories. The parameters for the post-intervention participants' perceptions of the role of logical thinking in addressing socio-political issues and transfer of logical thinking skills are significantly higher than those for the pre-intervention period. So are the parameters for all the categories in the dispositional dimensions of HOTS.

#### *Test 4: A comparison of post- intervention responses of control group participants with intervention group participants' responses*

The results in **Table 7** show that the post-intervention medians for the intervention group are higher than those for the control group. However, they do not reach the level that allows to suggest that the intervention group participants' perceptions of logical thinking significantly differ from those of the control group (except for the parameters indicating the role of logical thinking for increasing one's self-confidence and self-esteem and motivation to study logic). Further interpretation of the above statistical results is provided later.

### Results of Thematic Analysis

This section presents the results of the thematic analysis of participants' responses to the open-ended items. Themes are listed in a descending order, according to the theme prevalence indicated by the number of responses. The pre-intervention results are provided by the quotations of respondents from both groups for the purpose of a better

**Table 6.** Pre- & post-intervention results for measures of central tendency & interquartile range of parameters for intervention group

| Variables | Control group (n=16) | | Intervention group (n=16) | | U |
|---|---|---|---|---|---|
| | Md | IR | Md | IR | |
| **Perception of logical thinking from cognitive & metacognitive aspects of HOTS–total scores** | **3.70** | **1.20** | **4.50** | **2.00** | **-0.75*** |
| Logical thinking in organizing & controlling learning process | 4.00 | 1.88 | 4.50 | 1.75 | -2.52 |
| Transfer of reasoning & argumentation skills | 3.00 | 2.75 | 3.75 | 1.75 | -2.99* |
| Logical thinking & argumentation for addressing socio-political issues | 2.50 | 0.88 | 3.25 | 1.38 | -1.03* |
| **Perception of logical thinking from dispositional dimensions of HOTS–total scores** | **3.75** | **1.00** | **4.50** | **1.00** | **-0.44*** |
| Developing logical thinking through teamwork | 3.00 | 1.50 | 4.00 | 1.75 | -1.40* |
| Logical thinking for self-confidence & self-esteem | 4.00 | 2.00 | 5.00 | 1.75 | -0.87* |
| Motivation to study logic | 4.00 | 0.88 | 5.00 | 0.88 | -3.45* |

Note. *p<0.05; Md: Median; IR: Inter-quartile range; & U: Calculated U-test statistic

**Table 7.** Pre- & post-intervention results for measures of central tendency & interquartile range of parameters for control & intervention groups

| Variables | Control group (n=16) | | Intervention group (n=16) | | U |
|---|---|---|---|---|---|
| | Md | IR | Md | IR | |
| **Perception of logical thinking from cognitive & metacognitive aspects of HOTS–total scores** | **3.50** | **2.00** | **4.50** | **2.00** | **-1.99** |
| Logical thinking in organizing & controlling learning process | 4.00 | 1.75 | 4.50 | 1.75 | -2.42 |
| Transfer of reasoning & argumentation skills | 3.25 | 1.75 | 3.75 | 1.75 | -3.99 |
| Logical thinking & argumentation for addressing socio-political issues | 3.00 | 1.38 | 3.25 | 1.38 | -2.23 |
| **Perception of logical thinking from dispositional dimensions of HOTS–total scores** | **3.50** | **1.00** | **4.50** | **1.00** | **-2.34** |
| Developing logical thinking through teamwork | 3.50 | 1.75 | 4.00 | 1.75 | -1.60 |
| Logical thinking for self-confidence & self-esteem | 4.00 | 1.75 | 5.00 | 1.75 | -3.87* |
| Motivation to study logic | 4.50 | 0.88 | 5.00 | 0.88 | -3.25* |

Note. *p<0.05; Md: Median; IR: Inter-quartile range; & U: Calculated U-test statistic

illustration of the way participants think. Ellipses indicate the omission of part of the text that is not related to the theme (many of the responses were coded iteratively, so that two more themes were generated from one response). There are less quotations given for the post-intervention themes in order not to overload the text with verbatim data (**Table 8** and **Table 9**).

The analysis of pre-intervention responses revealed that the definitions produced by the two participant groups were very similar in terms of both the content of responses and number of responses per theme. Some of the participants from both groups have rather unclear understanding of the meanings of logical thinking and argumentation. The majority of responses (50 responses from both groups) relate logical thinking to the demonstration of cognitive skills (themes 1-3). Theme 4 and theme 5 indicate that logical thinking and argumentation are referred to such thinking dispositions as self-confidence (20) and prudence in making judgements (nine). Responses (seven) for theme 6 indicate pervasiveness as the most important feature in argumentation while theme 7 indicates a possibility of reaching a compromise decision between parties (five). Finally, four participants from both groups (theme 8) downplay the significance of logical thinking and argumentation in everyday life, suggesting particularly that one cannot rely on logic when dealing with violence and corruption.

In general, participants' responses convey an impression of uncertainty regarding an application of the reasoning and argumentation skills learned in school in everyday decision making. The majority (26 responses from both groups) suggests that there is some impact on the quality reasoning in everyday routine, but participants were not entirely sure about how this occurred. More that the half of the responses (17) clearly manifest an uncertainty regarding the above impact. Around one third of all the responses (11) understand the transfer of reasoning and argumentation abilities as the use of the knowledge obtained by studying specific subject matters in everyday life, but they do not refer expressly to the logical thinking skills developed by studying these subjects. There is also a belief (eight) in an increasing role of the web in the acquisition of knowledge, including thinking skills.

The post-intervention results for the intervention group differ significantly from the pre-intervention ones. With regard to the first open-ended item, the participants associated logical reasoning and argumentation with the cognitive and metacognitive activity performed by following the rules of logic. The following themes emerged: awareness of the process of inference ("to reason logically means not just to explain things clearly but make conclusions based on relevant evidence") (12 responses), difference between inductive and deductive inferencing (10), using precise definitions of things ("quite often, people do not distinguish between essential and inessential characteristics of things …") (eight). Themes pertaining to the comprehension of argumentation refer to the ability of constructing valid and sound arguments (14), identifying fallacies in arguments ("it is important to analyze the speeches of politicians because they often use fallacious arguments …" (10), having topic knowledge to support arguments ("… to build a good argument you have to understand what you are talking about") (eight), and argumentation as the process of persuading another party to accept given evidence ("argument is the means we use to persuade people …" (eight). It is noteworthy to mention that the theme related to finding a common point in a debate (**Table 8**, theme 7) became much sounder because more that the third of participants (six) mentioned to the Rogerian argument model.

As to the second open-ended item, the majority of the post-intervention responses (10) from the intervention group suggest that some transfer of reasoning and argumentation skills learned in school takes place ("the training of brain we do in school might help us think clearer in other situations"). There is also an acknowledgement that the transfer of reasoning and argumentation skills might take place in the application of the knowledge obtained through studying subject matters (eight) while two respondents do not believe in the transfer ("we obtain knowledge in different domains, but it is unlikely that school teaches us to think more logically").

**Table 8.** Pre-intervention results of thematic analysis of participants' responses to first open-ended item ("how do you understand the meanings of logical thinking & argumentation?")

| No | Theme | Quotations | | Number of responses | |
|---|---|---|---|---|---|
| | | Control group (16) | Intervention group (16) | Control group | Intervention group |
| 1 | Ability to speak clearly & orderly | Logical reasoning & argumentation mean speaking orderly… | Being logical means speaking clearly… | 10 | 9 |
| 2 | Providing relevant evidence to back up opinions | First of all, logical reasoning means using relevant facts to support what you say… | … To reason logically, one must use right evidence to back up judgements. | 8 | 9 |
| 3 | Ability to understand one's own thought processes | To be logical, people must have control on what they say. | … Also, one must be sober-minded & able to assess their thoughts. | 7 | 6 |
| 4 | Ability to speak & act with self-confidence | … It also means being confident in what you say. | … Speaking logically & provide arguments means delivering your ideas with confidence. | 7 | 5 |
| 5 | Being prudent in making statements | … In conversation, two parties should take time & consider well their statements. | … One should weight their judgements to maintain conversation. | 4 | 4 |
| 6 | Ability to persuade people, regardless of evidence | This is way of reasoning that make others believe you, even if they have contradicting opinions. | ... It is most important to be persuasive in your reasoning. | 4 | 3 |
| 7 | An ability to establish common grounds between conflicting parties | … It includes an ability to reach a decision that satisfies two parties. | … It is also a way to find a common solution in a debate. | 3 | 2 |
| 8 | Little or no importance of logical reasoning & argumentation in everyday contexts | … But logic is not important in place I live in. Logical thinking cannot withstand use of weapons. Logical reasoning does not decide in our society life. Other things are more influential–having useful connections with authorities, for example. | This is a style of expression, which is more specific to academic environment than everyday life. | 3 | 1 |

**Table 9.** Pre-intervention results of thematic analysis of participants' responses to second open-ended item ("do you believe that logical thinking & argumentation skills you obtain in class have an impact on your everyday thinking practices?")

| No | Theme | Quotations | | Number of responses | |
|---|---|---|---|---|---|
| | | Control group (16) | Intervention group (16) | Control group | Intervention group |
| 1 | Belief that obtaining reasoning skills in class had some impact | It is possible that learning first-order logic helped me think more orderly… | There should be some impact. Why else did we go to school? | 12 | 14 |
| 2 | Uncertainty about impact of skills learned in class | I am really not sure about this impact… | I am uncertain whether school really helped us think better in our everyday life… | 8 | 9 |
| 3 | An application of knowledge obtained through studying subject matters knowledge in everyday practices | … It is possible that an understanding of laws in physics, chemistry, or biology may help in life. | Studying humanities make us better understand the world around us… | 6 | 5 |
| 4 | Obtaining logical reasoning abilities from online content, including social networks | … Today, more than ever we can learn from web, including how to think correctly. | On web, you can meet a lot of people who share their experiences & learn from each other. Sometimes, web helped me more than teachers in school. | 4 | 4 |

There were almost no changes in the post-intervention responses provided by the control group. The majority of responses (13) associated logical reasoning with thinking and speaking in a clear, orderly manner, without making difference between constructing single arguments and argumentation as communication. About a third (five) of responses showed that speaking with confidence and persuasion was important.

The idea of conflict resolution was highlighted by two respondents ("it is not always important to show that you are right. Sometimes, it pays more to find a common point"). Two respondents downplayed the significance of logical thinking in the way similar to that in the pre-intervention responses. Four responses express a belief that there is a transfer of skills learnt in school ("by acquiring knowledge in different subject fields, we develop our thinking and can use this ability anytime") while other responses manifest uncertainty regarding the transfer of logical thinking skills.

## Results of Argument Analysis

**Table 10** lays out the results of the argumentation tests performed prior to the intervention (**Appendix B**). Part "a" and part "b" represent the responses to the two arguments: syllogisms of the first and third figures, valid and invalid moods, respectively. Part "c" includes the responses to a fallacy of weak induction. The results in **Table 10** show that the participants from the control and interventional groups provided correct responses in test "a", but around a half of the respondents in each group did not meet the established criteria because grounded claims were not provided. In test "b", more than the half of the responses were incorrect and in the form of simple claim. In test "c", many of the responses from both groups were grounded claims, mostly in the form of immediate inference. Compared to the pre-intervention responses, the intervention group participants demonstrate the knowledge of the material covered: students evaluated correctly both syllogisms and provided grounded claims to back up their responses:

**Table 10.** Responses to pre-intervention argumentation tests

| No | Types of arguments | Quotations | | Number of responses | |
|---|---|---|---|---|---|
| | | Control group (16) | Intervention group (16) | Control group | Intervention group |
| a | Grounded claim | Conclusion is correct because we talk about all S. In first sentence & all M. in second sentence is part of S. So, all M. are P. | M. are P. because they belong to all S. & all S are P. | 9 | 10 |
| | Simple claim | I believe that M are P. | Answer is correct: M are P. | 7 | 6 |
| b | Grounded claim | Conclusion is incorrect because some of S. are M., but some are not. M. can be P. if they belong to all S. | Conclusion is incorrect since M. could be P. only if they would belong to all S. & here only some S. are M. | 7 | 5 |
| | Simple claim | It is possible that M are P. Some of M. are P. | Part of M could be P. | 9 | 11 |
| c | Grounded claim | We cannot make a right conclusion because we have not enough information to decide. | It is possible that those who do not ask questions do not want to make a bad impression on teacher. There might be also other reasons. We cannot conclude thus that all students are ready for test. | 10 | 9 |
| | Simple claim | It is impossible to know. | It is possible that these students are ready for test. | 6 | 7 |

> This is the first figure, an invalid mood EIE, instead of EIO. The first premise is negative and the second one is a particular proposition. Therefore, the conclusion must be a particular proposition and it must be a negative one.

In contrast to the pre-intervention test "c", two thirds of the participants (12) provided several reasons to back up their responses while the rest were grounded claims in the form of immediate inference ("We cannot make such a conclusion because we have to do many things in order to live a long life").

The control group respondents wrote that conclusion in test "a" was correct, providing mostly simple claims. In test "b", nine answers were correct and similar to those displayed in **Table 10**. The majority of the responses (11) for the test "c" were simple claims ("to live a long life, it is not enough to eat healthy food").

## DISCUSSION

Prior to discussing the findings of this study, some issues should be noted regarding the methodology and implementation of the current program. The sample size for this research project is too small to permit large generalizations, but using a randomized sampling technique, good internal validity of the questionnaire and employing appropriate data analysis tools were expected to increase the internal and external validity of this study. In order to ensure the interpretive validity of the research findings, a big amount of verbatim data were provided to display participants' thinking patterns. Statistical and qualitative data on participants' understandings of logical thinking were compared with the results of argumentation tests that illustrated participants' actual logical thinking and argumentation skills.

The pre-intervention data obtained from open-ended items suggested that many of the participants from both groups had an unclear understanding of logical thinking and argumentation, which included such characteristics as speaking with self-confidence, prudence in making decisions, and as the process of debate and persuasion. An uncertainty prevailed in participants' standpoints on the transfer of logical thinking and argumentation skills. In addition, there was a disbelief in the importance of argumentative discourse for addressing conflicting situations. Statistical results demonstrated that the medians relating to the role of logical thinking in organizing and controlling learning process were relatively high in both groups (4.00 and 4.00, respectively). So were the results that referred to the role of logical thinking in increasing one's self-confidence and self-esteem and in the motivation to study logic. One can suggest that participants associated logical thinking and argumentation with the cognitive, metacognitive and dispositional dimensions of HOTS and they wanted to demonstrate their awareness of the importance of HOTS for learning and other contexts.

A vague understanding of reasoning and argumentation processes converges with the results of the pre-intervention argumentation tests, which indicated that many of the participants had weak competence in logical reasoning and argumentation. A large amount of their responses were in the form of so-called "simple claims" (Haro et al., 2020), suggesting an inability, or perhaps low motivation in trying to perform acts of inference and argument construction. Since both groups of participants consisted of the Arab youth who just started their studies in colleges, the results might give an idea of the level of logical thinking and argumentation skills students had at the beginning of their tertiary education. One can suggest that participants had little experience in evaluating and constructing arguments in a systematic way because their teachers contributed insufficiently to the development of this aspect of student HOTS. This suggestion is supported by the fact the parameters related to the transfer of reasoning and argumentation skills are modest (2.75 and 3.00) and there are low medians for the significance of logical thinking and argumentation for addressing socio-political issues (2.50 and 2.50). The latter is supported with the qualitative data obtained from open-ended items (**Table 8**, theme 8) and is compatible with the research literature that concerns the problems in the Israeli Arab society (Lang, 2013; Nohad & Levin-Chen, 2019) There are modest parameters that refer to the habits of developing logical thinking in teamwork (3.25 and 3.00). This allows to suggest that participants were not used to develop thinking skills collaboratively.

There is a significant difference between the pre- and post-intervention medians related to the intervention group participants' perceptions. It concerns the transfer of logical thinking skills ($U=-2.99$ $p<0.05$) and role of logical thinking and argumentation for addressing conflicting situations ($U=-1.03$ $p<0.05$). There were also significant changes in the post-intervention parameters related to the collaborative way of developing logical thinking ($U=-1.40$ $p<0.05$), importance of the knowledge of logic to one's self-confidence and self-esteem ($U=-0.87$ $p<0.05$), and the wish to study logic ($U=-3.45$ $p<0.05$). Qualitative findings suggest that the intervention group participants associate

logical reasoning and argumentation with cognitive and metacognitive activities and make a distinction between the construction of single arguments and argumentation as a process of communication. Positive changes are seen in the argumentation test results, which indicate that this group of participants provided responses in the form of grounded claims. However, it is too early to decide that the above positive results demonstrate that students can apply reasoning and argumentation skills effectively. It is widely acknowledged (Cerbin, 1988; Leighton, 2006; Noroozi et al., 2018) that much time is required to foster students' logical thinking and argumentation skills, and there is a need of frequent opportunities to receive teachers' feedback on their work. An increase in the understanding of the role of collaborative work could be explained by an intensive teacher-student interaction during the meetings. At the beginning of the intervention, the majority of students acknowledged that such interactions were quite rare in school, and they were required to sit quietly during the lessons and listen to a teacher. Similarly, the higher parameters on skill transfer and significance of argumentative discourse for addressing social and political problems can be explained by some influence of the current intervention, but further learning is required to obtain a sound comprehension of these issues.

An opinion prevails that explicit teaching about reasoning and argumentation patterns should be integrated into the teaching of a specific subject matter (Asterhan & Schwarz, 2016; Sadler et al., 2007; Zohar & Nemet, 2007). This often create a difficult instruction problem because it is unlikely to cover sufficient amount of content knowledge and also teach reasoning and argumentation skills effectively (Cerbin, 1988; Csapo, 1999). In fact, the above perspectives are part of a longstanding debate on whether students should foster HOTS as general, universal skills (Ikuenobe, 2001) or teaching HOTS should be infused in the subject matter instruction (Csapo, 1999; Seif, 2017). By drawing upon the empirical evidence, Marin and Halpern (2011) point out to the success of the content-independent instruction of thinking skills. In support of the latter standpoint, voices are raised periodically (Bringing Logic Course to High Schools, n. d.; Duman, 2019; Genesereth & Chaudhri, n. d.) to teach logic as a standalone subject in order to increase the reasoning and argumentation skills of students. It is held (Baronett, 2018; Copi et al., 2014) that proper definitions of terms in a proposition are needed to identify and eliminate ambiguities in reasoning and help to resolve verbal disputes. Training in syllogistic logic may significantly improve students' level of deductive reasoning (Leighton, 2006).

## CONCLUSIONS

The purpose of this intervention was restricted to acquainting participants with the conceptual knowledge of some of the fundamentals of formal and informal logic and giving them pointers to foster their logical thinking and argumentation skills. An acquisition of conceptual knowledge in logic is necessary not only for producing immediate good results in performance, but also for a long-lasting retention of reasoning and argumentation skills. It enables movement from unreflective use of argument patterns to the meaningful process of argumentation. This is of great importance to personal development and raising the level of constructive argumentative discourse in the Israeli Arab social and political reality. In order to retain and improve logical thinking and argumentation skills, much practice is required, and a question is raised, therefore, as to how to combine an acquisition of a sufficient amount of the conceptual knowledge of logic with an extensive practice of reasoning and argumentation.

The author of this paper (who works as a public school teacher and a lecturer in a teacher college) advocates teaching the foundations of formal and informal logic in Israeli high schools and in the system of teacher education as well. A separate general course in logic might be good at the beginning of secondary education (when students are less busy with the matriculation tests) and during the first or second academic years in teacher colleges prior to students' engagement in pre-service practices. But it is important that students do not end up practicing logic after the accomplishment of the course. This should be a continuous goal for the entire period of education. In a separate course, the use of an ample number of examples from curriculum subject matters in construction of arguments may assist in solving the problem of isolated learning of skills and contribute to cross-curricular learning and transfer of thinking skills in different contexts. Concurrently, an enhancement of skills could be done through the use of the content-based (infusion) approach implemented across curriculum subjects.

In order to introduce the course of logic in high schools, teachers need to be trained to deliver the material. While it is unlikely that in the visible future logic will be included into the school and teacher college curricula, extra-curricular activities can be useful in order to facilitate learning and teaching on logic. The framework of teacher professional development could be used in training teachers of different disciplines to instruct logic. Today, online learning environments provide a broad range of learning and instructional options, which are used for studying logic. The way logic could be integrated into the Israeli system of secondary and teacher education requires a consolidation of efforts at regulatory and institutional levels and is the matter of the future research.

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**Declaration of interest:** The author declares no competing interest.

**Data availability:** Data generated or analysed during this study are available from the author on request.

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## APPENDIX A

Below, there is a part of the webinar transcript. At the previous meetings, students were already acquainted with types of definition and principles of connotation and denotation in the term definition and learned about the definition by genus and difference. The text below describes the revision of the topic that refers to the definition by genus and difference prior to an explanation of essential and accidental properties. Pseudonyms are used instead of students' real names and identify me as a "teacher". The lesson starts with greetings, and a couple minutes are spent on fixing technical problems.

Teacher: So, let's see what you remember from the last lesson. How would you define genus, Nadia?

Nadia: This is a class of things that includes other things, which are called species.

Teacher: "Other" is an incorrect word. What would you say, Ayah?

Ayah: Genus means a class, which includes subclasses or species.

Teacher: How would you complete this definition? [I am waiting, but it seems she has nothing to add]. Who would help? Maybe you, Dana?

Dana: This is a class of things, which includes subordinated classes. To be the members of genus, species should have common characteristics, but also have features by which one species differs from another.

Teacher: Good. So, according to Aristotle, the definition of a species consists of … [I am waiting, looking at students].

Rami [raises his hand]: The definition of a species consists of the closest class, which is called "genus proximum", and specific difference.

Teacher: This is correct. Specific difference is a characteristic or attribute, which distinguish it from other members of the class. Please show me examples you have prepared at home [Students show pieces of paper on which the examples of the definition by genus and difference are written in bright colors]. Some of the examples are illustrated below: **vehicle**: bus, car, scooter, bike, etc.; **car**: truck, sedan, wagon, crossover, etc.; **natural sciences:** chemistry, physics, biology, geology, astronomy, etc.; **chemistry**: organic, inorganic, physical, analytical, and biochemistry.

Teacher: Tell me, Maram, how we can complete the characteristic of the definition by genus and difference according to the schemes we see?

Maram: According to these schemes, we … [she stops and keeps on silent].

Rami [raises his hand]: Genus and species are relative terms. Any class may be a genus with regard to its own subclasses. It can be a species with regard to some larger class to which it belongs [he stops for a couple of seconds].

Teacher: Except for … [I am almost certain that he had more to say, but I want to involve more students into the revision of material. So, I smile to him and point to another student who raises her hand].

Jannah: The summum genus cannot be a subclass and infima species is the lowest subclass.

[Several students raise their hands].

Teacher: Please, Manal!

Manal: We cannot apply it to the notions like "being", "darkness", "humor", or other abstract notions because there are no more elementary elements that can be subclasses of these names.

Teacher: What about the notion of "feeling"?

Rami: What kind of?

[Students are laughing].

Manal: We cannot divide a feeling in subclasses. How would you divide happiness or anger in subclasses?

Teacher: OK. Let's remember that Aristotle's logic is a logic of classes, or categories, and relationships between those classes. We have already learned about the types of the words that we can use as terms and the subject and predicate in a proposition. So, if we regard a term

as a name of a class, it can be divided in subclasses. You remember and example I have showed you: “Historians are people who study or write about history”. The subject denotes a group of people who are experts in history. In grammar, such words are identified as “countable general nouns”. The same applies to “feelings” if we consider them a class of reactions in our mind to the world around us.

[Students provide examples].

Teacher: We have learned about the connotation of a term, or as we also call it, “the intension of a term”. What does it mean?

Manam: It defines the essence of a term.

Teacher: fine. If that term is a name of a class, it defines the essence of that class. (I show them a poster on which there is a scheme presenting the connotation and denotation of the term “curricula” and point to a number of characteristics of the school curriculum). The denotation of a class means … (I make a pause).

Rami: It refers to a range of sub-classes or members within that class.

[Further, I start an explanation of essential and accidental properties].

## APPENDIX B: PRE- AND POST-INTERVENTION TESTS OF ARGUMENTATION SKILLS

Please answer whether the conclusions to the arguments are correct or wrong. Please justify your answers with arguments.

### Pre-Intervention Tests

1. First figure, mood AAA: All S are P. All M are S. Therefore, all M are P.
2. Third figure, mood AIA (invalid): All S. are P. Some of the S. are M. Therefore, all M. are P.
3. Fallacy of weak induction: On the eve of the test, all students in the class have no questions concerning the topics studied. These students are ready for the test.

### Post-Intervention Tests

1. First figure, mood EAE: No S are P. All M. are S. Therefore, no M. are P.
2. First figure, mood EIE (invalid): No S. are P. Some of the M. are S. Therefore, all M. are P.
3. Fallacy of weak induction: If you eat a healthy food, you will live a long life.