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Acid-Base Chemistry and Societal, Individual, and Vocational Aspects of Students' Learning

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Abstract

This study examined how the relevance of teaching the unit "acids and bases" affected the societal, individual, and vocational aspects of students' learning. The sample included four high-school classes and the study focused on analyzing the differences between students who had studied the unit "acids and bases" through the High Relevance Approach (HRA) method and those who had studied it using a more traditional method (the Low Relevance Approach, LRA). A total of 112 students participated in the study, 57 (51%) of whom were from the experimental class (HRA) and 55 (49%) from the control class (LRA). The study was conducted through questionnaires to determine whether a close connection exists between the relevance of teaching the topic acids and bases and the societal, individual, and vocational dimensions of student achievement. Regarding the individual aspect, the teacher develops skills and increases the students' motivation and enjoyment and improves their achievements. Regarding the vocational aspect, the teacher utilizes innovation and skills to achieve relevant learning; regarding the societal aspect, the relationship between the students in the classroom is strengthened and their positive self-experience increases.

Keywords

Relevant Learning, Science Education, High Relevance Approach (HRA), Low Relevance Approach (LRA), Acids-Bases Chemistry

1. Introduction

Relevance to the student refers to getting the student more interested; student interest is a significant motivating factor in learning. Students learn better when they are more interested, and their readiness to learn increases when the subject being studied is related and relevant to their lives in a particular way (e.g., personal, cognitive, and environmental). It can be implied from the above that interest can be used relevantly as a learning incentive. When a student is exposed to a theory without a relevant context, the subject being studied is accepted by him but without motivation. In contrast, when the teacher creates relevant relationships that are appropriate for the student, there is a high probability that the student's motivation will increase (Kember, Ho, & Hong, 2008; Redding, 2019).

According to Gilbert (2006), in chemistry classes the entire collection of contexts used will enable chemistry to become more relevant because of its relevance to students' lives. Gilbert (2006) believes that chemistry classes should "resonate" in students' lives at best, and at worst, they should be interesting enough to arouse interest and commitment on the part of students. Marcelle and Michael (2003) linked relevance to changes and developments in the personal lives of students and ultimately in society. The educational process aims to provide students with a sense of growth, value and ability, success and personal fulfillment, an experience of discovery and response to their curiosity as well as develop them as whole people (Mrunalini, 2010).

Many studies have presented a bleak picture regarding styles of learning science, especially at the high-school level. Some of these studies indicate that students are not sufficiently interested in chemistry or are unmotivated to learn chemistry concepts. Students often view chemistry as irrelevant to both themselves and to the society in which they live (Marcelle & Michael, 2003; Holbrook, Kask, & Rannikmäe, 2008; Meydan, 2021).

According to Bretz (2017) there is no evidence to support the hypothesis that instruction designed in response to students' learning requirements can improve achievement. On the other hand, Towns (2001) described how Kolbe's learning styles were particularly well suited to learning in a chemistry lab. Pashler and colleagues (2008) reported that learning is tailored when instruction is appropriate for the students' preferences and abilities.

Therefore, science teachers in general, and chemistry teachers, should strive to make their lessons more relevant, to improve students' motivation and to interest them in the subject (Gilbert, 2006; Nuora & Välisaari, 2020). One of the ways to make science topics more interesting to learn and to raise students' level of motivation is to link experiments and learning activities to the problems, solutions, and challenges of daily life (Green, 2020). However, teachers may not know what is meant by "making science more relevant." The connections (or differences) between terms such as relevance, interest, and motivation may need clarification (Holbrook, 2003). In 2013, Stuckey and colleagues (2013) published a review on the subject, and Eilks and Hofstein (2015) edited a book in which they analyzed the concept of relevance and proposed a schematic framework relevant to scientific learning.

Three relevant aspects of science education have been proposed: societal, individual, and vocational (Stuckey, Mamlok-Naaman, Hofstein, & Eilks, 2013). These dimensions are neither entirely complementary nor contradictory; rather, they are connected to each other and partially overlap. For example, focusing on career orientation may develop personal curiosity as well as meet the future demand for more scientists and engineers. The latter is directly related to the idea of a thriving economy and the effective development of a company, for example.

It is generally agreed that to make learning more relevant to both the students' lives and the society in which they live, it is important to change the content and the pedagogy of chemistry teaching (Stuckey et al., 2013; Eilks & Hofstein, 2015). During the 1980s, there was a movement to base experiments on real life, and consequently, experiments in some courses were based on students' daily lives (Garforth, 1986).

The model of Eilks and Hofstein (2015) clarifies the interpretation of various dimensions (societal, individual, and vocational) with respect to science education. Burmeister and colleagues proposed using appropriate modules and pedagogies in an attempt to make chemistry learning more relevant and interesting (Burmeister, Rauch, & Eilks, 2012). These modules and pedagogies are integrated into the development of teaching units and their implementation in schools, in order to promote the professional development of chemistry teachers (Marchak, Shvarts-Serebro, and Blonder, 2021).

The chemistry topics taught in schools should help students understand and use basic chemical concepts as well as relate these concepts to real-world topics. In addition, lessons should demonstrate how chemistry applies to familiar topics such as food chemistry, climate change (e.g., acid rain), and more (Childs, Hayes, & O'Dwyer, 2015; Hugerat, Mamlok-Naaman, Eilks, & Hofstein, 2015). Hugerat and colleagues (2018) analyzed how the chemistry concepts learned by tenth-grade students aligned with their daily lives and compared two teaching approaches: the low relevance approach (LRA) and the high relevance approach (HRA). The HRA method is a progressive process based primarily on students' life experiences-for example, kitchen chemistry, food chemistry, and so forth and LRA is a traditional process. It was clear that using relevant experiments in chemistry significantly contributed to the learning and that teaching chemistry topics using the HRA method led to an improvement in student motivation, awareness, and performance as well as improved their attitudes toward science and its learning, compared with the LRA method (Hugerat, Najami, Abu-Much, Khatib, & Hofstein, 2018).

According to a study by Fensham and colleagues (1994), this type of science education helps students learn and understand the relationships between science and society as well as develops skills that will encourage them to participate in future scientific discussions and decision-making processes as well-informed citizens (Varis, Jäppinen, Kärkkäinen, Keinonen, & Väyrynen, 2018). With this type of science education, the students are also required to learn challenging scientific skills (Abadi & Kashtan, 2001).

Comparison between a Progressive and a Traditional Process: Making Acid-Base Concepts More Relevant

Learning through the HRA method reinforces the three aspects—societal, individual, and vocational—which allows students to learn topics or concepts relevant to their daily lives. Using common materials to explore the chemistry of everyday objects (for example, for the acid-base topic, using vinegar and baking acid as acids and baking soda as the base (Hugerat et al., 2018) raises the students' curiosity and cultivates in them different personal skills. Relevant science studies encourage independent leadership in society by better understanding the interaction between society and science (Cooper et al., 2016; Varis, Jäppinen, Kärkkäinen, Keinonen, & Väyrynen, 2018). Regarding the vocational aspect, this method provides an orientation to future professions and careers as well as preparation for academic or future professional training and opens professional career opportunities.

In contrast, using a traditional LRA method does not reinforce the three aspects. For example, the student learns about acids and bases participating in the lesson's activities and learning content during the course, but the materials used are not encountered in students' outside lives (Hugerat & Basheer, 2001; Hugerat, 2006; Dayal & Ali-Chand, 2022).

Siegel and Ranney's (2003) research had two objectives: 1) design and test new tools capable of reflecting changes in attitudes toward science over time and 2) determine the effect of two similar curricular treatments on the attitudes of two classes. The basic results showed that, on average, students started with a slightly positive outlook to science; however, it became more positive during the semester. In addition, qualitative analysis using a head scale showed that the gains in both classes were modest but appreciable. These findings are interesting, not only because they indicate the success of the curricula, but also because they show that students' beliefs about the relevance of science can change even within one semester, simply by educators' use of realistic, interest-oriented scientific activities. This is particularly critical because students' attitudes affect their future involvement and performance in science classes and in their careers (Siegel & Ranney, 2003; Musengimana, Kampire, & Ntawiha, 2021).

Teachers' Perceptions of How to Teach the Topic Acids and Bases

Lembens and Reiter (2017) argued that in order to teach about acids and bases, teachers should rely on (among other things) a proper understanding, and think in terms of models, and deal with different historical approaches as well as plan and design appropriate experiments (Lembens & Reiter, 2017). In addition, teachers need to know how students perceive the teaching and learning of this topic. Therefore, teacher educators should receive proper training as well as apply and reflect on the knowledge and skills needed to build and sustain teachers' professional knowledge and skills (Darling-Hammond, Flook, Cook-Harvey, Barron, & Osher, 2020).

Unfortunately, many students still have misconceptions about acids and bases and often confuse different models (Kala, Yaman, & Ayas, 2013; Cooper, Kouyoumdjian, & Underwood, 2016). The next steps towards developing and providing opportunities for effective education in the context of acids and bases are 1) to review the most common textbooks used for primary and secondary chemistry studies, 2) conduct interviews with experienced chemistry teachers to further validate the analytical framework for micro-text analysis of specific areas, 3) identify and characterize teachers' main barriers, 4) develop, examine, and refine effective learning sequences, and 5) create a didactic program based on fruitful and effective teaching in the context of acids and bases.

The importance of teaching and learning in general and the teaching of science specifically is to instill a significant change in the attitude towards the scientific subjects and over-involvement of the students in everyday life. Therefore, this research comes to propose an innovative study method that links the theoretical subject with the practical everyday life. In this article, these two approaches (HRA vs. LRA) were compared statistically, and it was concluded that chemistry teachers should make chemistry education more relevant in order to increase student motivation. A teaching unit was prepared; it consists of a series of chemistry (time unit) lessons dealing with the subject of "acid-base". The teaching unit was comprehensively integrated into the curriculum and was successfully carried out, starting from its introduction to its assessment. In general, teaching units have been developed with the aim of promoting the optimal implementation of the curriculum and demonstrating diverse options for achieving the educational goals. Teaching units are intended for teachers who teach in schools. In each unit, various challenges and considerations are discussed in teaching the subject. This study addresses three questions that examine the relationship between the relevance of teaching acids and bases in chemistry class (eighth graders) and their impact on the societal, individual, and vocational aspects.

The main research question is "*whether and how an* '*acid-base*' *teaching method based on relevance to everyday life has an impact on aspects*, *individual*, *vocational*, *and societal*; *among middle school students* (8th *grade*)".

Sub-question 1: How does the relevance of teaching the "acids and bases" chemistry class affect the individual aspect?

Sub-question 2: How does the relevance of teaching the "acids and bases" chemistry class affect the vocational aspect?

Sub-question 3: How does the relevance of teaching the "acids and bases" chemistry class affect the societal aspect?

2. Methodology and the Participants

Research question

The main question of the study is as follows:

How does the relevance of teaching the "acids and bases" chemistry class affect the individual, vocational, and societal aspects?

At the beginning of the study, the researchers focused on the following points:

- Building the intervention plan in coordination with the school's standards in teaching chemistry
- Coordination with the teachers at the school
- Activities with acids and bases are based on the curriculum and the school's standards using materials that are relevant and familiar to students.

An acid and base study unit (an intervention plan) was built that included six 45-minute lessons on the following topics:

1) Acid-base definitions (Lessons 1 and 2)

2) Producing acids and bases (Lesson 3)

3) pH scale (Lesson 4)

4) Acid-base reactions and neutralization reactions (Lessons 5 and 6).

The study unit was prepared using the LRA and HRA methods.

Low Relevance Approach (LRA)

The student learns about acids and bases in a method featuring a sequence of lessons, activities, and experiments; it covers the content to meet the course requirements. The materials used in the experiments, such as HNO_3, H_2SO_4, NaOH, and HCl, are not from daily life.

Students learn about titration between an acid (HCl) and a base (NaOH) when the indicator is phenolphthalein or litmus paper, materials unfamiliar to them from their everyday life. Additionally, students learn about the pH scale, different types of acids and bases, and the reactions between them; however, the students encounter none of these topics in their daily lives. Students learn how to prepare acids and bases by the reaction between different chemical oxides and water.

High Relevance Approach (HRA)

These students study the acid-base concept in a manner relevant to their everyday lives using materials such as vinegar and baking soda, materials that are used every day or that represent the chemistry of everyday objects. The indicator used to identify acids and bases and when performing titrations is red-cabbage juice, which is derived from red cabbage salad, a popular salad in Israel. It should be emphasized here that students use materials with which they are familiar.

The students also learn about acid production using the acid rain example: SO_2 is emitted because of the burning of fuel oil with a high sulfur content. Chemicals and fertilizers such as nitrogen oxides (NO_x) are emitted during the process of producing HNO_3.

Students build their own pH scale using the obvious visible changes to the red cabbage juice, along with acids and bases from their daily life. In this activity, the social side of the activity is strengthened when the students need to cut the red cabbage and then discover that their hands are stained. They must collaborate to decide how to prepare an indicator solution and they discover that the color varies with the pH of the solution.

Study participants

The semi-experimental study included 112 eighth-grade middle-school students in an Arab village in northern Israel. Two experimental classes (57 students, 51%) studied the subject of acids and bases using the HRA method and two control classes (55 students, 49%) used the traditional LRA method. The sample of students who participated in the study was relatively homogenous in the background variables: gender (almost equal between boys and girls), academic achievements and socioeconomic status. The sampling method was a convenience sample. The selection of the students who participated in the study was made for reasons of convenience and accessibility: students studying science and technology in general, students studying in the 8^{th} grade were sampled, and the measurement refers to relevant material for the science education curriculum.

Collecting and Processing the Data

The study had a mixed design: both quantitative and qualitative. In the quantitative part, data were statistically analyzed using SPSS v23 software. The study was designed to provide causal explanations and predict future behaviors based on the present behavior. In addition, it was designed to gain an understanding of various phenomena, using a comprehensive approach to diverse and fascinating aspects of human behavior and a set of interactions that characterize this behavior.

The quantitative study consisted of a questionnaire for the experimental and control groups, to examine the societal, individual, and vocational aspects. Both studies compared the results before and after the course (pre/post). The questionnaire examined the attitudes of the eighth-grade students who participated in this study, including the experimental and control groups, regarding the societal, individual, and vocational aspects. The questionnaire was constructed based on Stuckey and Eilks' (2014) studies, with improvements to fit the current study, and it was validated in accordance with accepted academic standards. We added some statements to the original questionnaire that would fit the current study regarding three aspects: the personal, professional, and social aspects as well as the validity and reliability were tested, and the alpha Cronbach value was determined accordingly. This questionnaire contains statements about the individual dimension with Cronbach's alpha 0.838 (for example, "topics in science classes are very important to me for my daily life"), statements about the vocational dimension with Cronbach's alpha 0.772 (e.g., "science classes are always about forming and building materials"), and statements about the societal dimension with Cronbach's alpha 0.806 (e.g., "the topics in science classes are very important to society"). The questionnaire did not have opposite items. Students were asked to rate each item on a Likert scale between 1 (strongly disagree) and 5 (strongly agree). The questionnaire was found to be reliable and valid in previous studies (Cronbach's alpha 0.83 - 0.89) (Stuckey & Eilks, 2014); in our research we found reliability to be higher (0.934). The higher the scores on the questionnaire, the more positive the attitudes.

The findings were analyzed according to the mean scores, the differences between the control groups and the experimental groups, and the *t*-test calculations as well as Cronbach's alpha and other statistical analyses.

We also completed our investigation with quality data because it is more authentic and deals with the students' learning experience. A structured interview was also conducted. Students were asked to give their opinions regarding the topic they studied and the method of study. Qualitative data were collected regarding the students' questions and responses while implementing the traditional (LRA) and relevant method (HRA): during the activity, the teacher began creatively and used familiar items that inspired students' questions and queried about the context. The students' questions and statements during the lessons were collected and analyzed, to link them with the quantitative results.

3. Results

In both groups, students' grades in chemistry were tested before and after the acid-base topic was studied. The mean score of the students in the LRA control group was lower than that of the students in the HRA group, who scored a mean of 80% on the test.

Table 1 presents the student responses to questions about the individual aspects of their learning. The two groups showed an appreciable difference regarding their personal views regarding the effect of learning useful science on their daily life. That is, relevant science experience improved the individual dimension of students' lives.

Regarding the vocational aspect, according to the results in Table 2, there is again a clear difference in the results between the control group and the experimental group, with the relevant learning method being more successful than traditional learning.

Table 3 shows that the groups differ regarding the societal view of the ability to help and better understand the world through experiments. Statement number 4, "Science will help me understand the effect I have on the environment," revealed a difference between the control group and the experimental group; it

Table 1. Student responses on a likert scale regarding the individual dimension.

Category	Experimental group		Control group		T value (control minus experimental)
	Mean	Standard deviation	Mean	Standard deviation	
Much of what I learn in science classes is useful in my daily life today.	2.5	1.31	2.1	0.45	−2.15*
Learning science can help me when I buy food.	1.9	0.4	2.1	0.37	2.74**
Caring for people can involve a scientific choice, such as using pesticides on plants.	2.05	0.39	1.83	0.4	−2.95**
Science helps me make wise decisions.	1.7	0.29	1.5	0.4	−2.68**
The things I do in science have nothing to do with the real world.	1.74	0.25	1.16	0.3	−11.13***
Science helps me make decisions that affect my body.	2.1	0.9	1.9	0.29	−1.57

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 2. Student responses on likert scale regarding the vocational aspect of learning.

Category	Experimental group		Control group		T value (control minus experimental)
	Mean	Standard deviation	Mean	Standard deviation	
My parents encourage me to continue in science.	4.4	0.73	3.1	0.44	−3.56***
I plan to take more science classes in high school.	3.11	0.02	3.08	0.43	0.52
Science helps me work with others to find answers.	5.3	0.719	4	0.43	11.56***
Classroom science helps me evaluate my work.	4.8	0.66	2.8	0.91	−13.35***
Studying science helps me understand the environment.	5.1	0.69	3.8	0.42	−11.99***
Emotion has no place in science.	2.6	0.82	2.1	0.32	−4.22**
Science will help me understand and judge other people's perspectives.	6.2	0.9	5.9	0.6	−2.06*
Science will help me understand more about problems around the world.	4.3	0.27	5.1	0.7	−8.03***
Science has nothing to do with life outside of school.	4.2	0.57	2.3	0.36	−21***
Experiments in science help me learn with a group of peers.	6.3	0.9	6.1	0.8	−1.24
Science teaches me to help others make decisions.	1.1	0.2	0.7	0.19	−10.84***
Knowledge of science will not help me in sports.	5.1	0.6	3.3	0.95	−12.03***
Science has nothing to do with buying things, such as food and a car.	5.3	0.75	5.1	0.66	−1.5
Knowing science will make it easier for me to repair a bicycle.	6.1	0.84	6.3	0.9	1.21
Science teaches me to think less clearly than I already do.	5.5	0.79	6.32	0.95	4.97***
Making a good decision is a scientific process.	6.1	0.6	6.3	0.89	1.4
In class, science will help prepare me for college.	4.2	0.62	6.3	0.9	14.42***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

had a more positive response in the experimental group than in the control group. According to these findings, the HRA method is more successful and more positively affects the students than the LRA method.

In addition to the quantitative data produced by the questionnaires, a structured interview was conducted; students were asked to give their opinions about the topic they studied and the method of study. For this purpose, 4 students from each group (HRA, LRA) were interviewed. The interview was aimed at reinforcing the findings obtained in the structured questionnaire and hearing more students talk and express themselves about the topic and the method of study.

Comments that were repeatedly given about the LRA include the following:

Student **1**: "The method by which I studied acids and bases did not affect me so much because I do not see myself dealing with a subject related to future science."

Table 3. Student responses on likert scale regarding the societal aspect of learning.

Category	Experimental group		Control group		T value (control minus experimental)
	Mean	Standard deviation	Mean	Standard deviation	
Classroom science helps me work with others to make decisions.	5	0.61	3.1	0.44	−18.84**
Scientific experiments can help me better understand the world.	6.2	0.83	3.9	0.59	−16.85***
Knowledge of science can help me protect the environment.	3.9	0.42	5.1	0.63	11.89***
Science will help me understand the effect I have on the environment.	6.2	0.83	5.9	0.79	−1.96
Science helps me ask others for help with my work.	6.1	0.83	6.3	0.911	1.22
Science should be required in school.	6.7	0.94	6.1	0.8	−3.63***
I am interested in a career as a scientist or engineer.	5.3	0.7	5.1	0.64	1.58
I have received support from others to excel in science.	5.9	0.69	6.2	0.89	2*
Learning science can help me understand things that affect people's health.	5.1	0.75	5.3	0.68	1.48

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

***Student* 2**: "In the method I learned things about acids and bases that I did not know in my closed environment; it was interesting, but I did not feel related to the subject."

***Student* 3**: "This is an interesting topic, but the truth is I did not understand why we study this material at all and what the connection is to our daily lives."

***Student* 4**: "I do not like chemistry; it is a very boring subject and I feel disconnected to it in the classroom."

Comments that were repeatedly given about the HRA include the following:

Student 1: "Science helps in getting a better understanding of life and events. It had a positive effect on my understanding of chemistry."

Student 2: "Giving examples from everyday occurrences can help students gain a better understanding; connecting the subject with life."

Student 3: "It makes me want to implement things in daily life; it exposes me to a variety of different topics, how they are used, their dangers, and their effects."

Student 4: "I will continue to study science. It had a very positive influence and increased my motivation and satisfaction; perhaps I might even become a chemistry teacher or scientist in the future."

Common answers from the students that studied acid-base concepts using the LRA indicate that many students are not very interested in the chemistry lessons. In fact, they wonder why they need to be familiar with chemistry concepts. Implementation of the HRA method, however, improved students' attitudes toward chemistry and its study. The students' answers indicate their attitudes in the three personal, professional, and social aspects; specifically, they indicate that there is full agreement among all students that studying the subject "acids and bases" by the relevance method changed their attitudes regarding the three personal, professional, and social aspects. This result reinforced the quantitative findings, which showed that a difference exists in the attitudes of students who studied acids and bases by the relevance method, i.e., the experimental group (HRA), compared to the attitudes of students who studied by the conventional method, i.e., the control group (LRA).

The overall results of our research clearly show the students' interest in the studied subject, and this is in full agreement with the quantitative results presented above. The answers of the students about their willingness to continue studying science and even to move to the professionalization stage prove that the proposed method has an influence that leads to positive results.

4. Discussion

***Sub-question* 1: How does the relevance of teaching the "acids and bases" chemistry class affect the individual aspect?**

The term "meaningful learning" distinguishes between valuable, experiential learning and memorization learning—memorizing facts that learners do not attach any importance to or practicing skills that learners do not see as necessary—which is often of no value. This type of learning is characterized by engaging the whole person, including their cognition and emotions, in the learning process. Such learning changes the behavior, attitudes, and perhaps even the personality of the learners (Mintzes, Wandersee, & Novak, 1997; Novak, 2002; Valadares, 2013).

The mean score on the chemistry test taken by the two groups was 80% greater in the HRA group than in the LRA control group (50%), indicating the close relationship between relevant learning (experimental) and students' perception and success in the test; this justifies adopting the relevance method for acid-base classroom experiments and the individual aspect.

It can be concluded that relevant learning, combined with experiments, develops analytical and critical thinking as well as decision-making skills, while dealing with complex and realistic problems, and it also improves students' ability to argue and express themselves (Wale & Bishaw, 2020). In addition, it increases learners' motivation and enjoyment and improves their achievement, thinking, expression of ideas and personal views as well as creative self-esteem (a systemic approach in science teaching) (Hugerat et al., 2018).

The results in **Table 1** indicate the significant difference between the two groups; this explains the significant difference in the test results regarding the greater impact of relevant learning than traditional learning. For example, in item 3 ("Caring for people can involve a scientific choice such as using pesticides on plants"), there seems to be a clear difference between the two groups regarding caring when making a scientific choice, which is encouraged more in the experimental group than in the control group.

These results attest to and justify the results of Hofstein and Lunetta (2004): studying science through research is recommended as an effective and authentic method to develop and build a knowledge base and attain a good understanding of scientific ideas and concepts. Moreover, it provides science teachers with a means to improve their teaching, which will lead to an improved learning atmosphere.

The new standards that are being formulated in science education reflect the current vision regarding all that is currently known about content and pedagogy in evaluating the learning atmosphere of students in the classroom and regarding the support needed to ensure quality education for all students.

The educational process aims to give students a sense of growth and value as well as ability, success, and personal fulfillment, in addition to experiencing discovery and responding to their curiosity. It develops them as whole people who can integrate well into society and actively contribute to it. In order for the educational process to achieve its goals, the Ministry of Education promotes meaningful learning while meeting the required achievements, through a systemic, consistent, modern, controlled learning process. This is reflected in the curricula and the characteristics of the teaching-learning processes as well as the assessment and learning environments, in light of the role of adults and the various functions (cognitive, meta-cognitive, intrapersonal, interpersonal, sensory-motor, and managerial) that the education system strives to develop in the students (Jaleel & Premachandran, 2016).

***Sub-question* 2: How does the relevance of teaching the "acids and bases" chemistry class affect the vocational aspect?**

With respect to the vocational aspect, **Table 2** shows that the two groups differed significantly. This proves that a close connection exists between the relevance of acid-base classroom experiments and the vocational aspect.

This justifies the statement of Hofstein and Lunetta (2004), who in their study found that chemistry students who participated in their research were given unique opportunities to be actively involved in a worthwhile learning process. Research experiments in a chemistry lab have been concerned with changing and renewing the way chemistry is taught and learned and the way students are evaluated as well as improving teachers' professional development. The fact that the program grew from three classes to about 90 classes in the school year after the program was implemented provides compelling evidence that teachers, students, and school administrations highly value this program.

***Sub-question* 3: How does the relevance of teaching the "acids and bases" chemistry class affect the societal aspect?**

The findings showed that HRA learning was more successful and had a more positive effect on the students than did the traditional LRA learning; this was reflected by the dominance of the experimental group rather than the control group in all the questionnaire categories (**Table 3**). This proves that a close connection exists between the relevance of acid-base classroom experiments and the societal aspect.

Both groups showed a change regarding the ability to help and better understand the world through experiments. However, science was perceived as helping to understand environmental factors significantly more in the experimental group than in the control group.

One teaching strategy encourages problem-based learning. In the process of problem solving, students learn while they perform a variety of activities, including field trips, projects, and use of computers. The learning process requires self-experience or group work as well as dealing with errors by trial and error. This creates connections and a dialogue between students about chemistry discoveries. It can improve the experimental process as well as the results and it also improves problem solving: working in groups is recommended in science classes in general, and in chemistry in particular.

Another teaching approach encourages research-based learning: learners are supposed to develop critical thinking skills, acquire argumentation skills, analyze data, and compare their findings with those in the literature.

Teaching socially encourages reflective learning: this means identifying and deciphering new situations that develop during learning as well as self-criticizing and re-examining learning while the students talk by themselves and with others in the group (Makar, Bakker, & Ben-Zvi, 2015). This includes utilizing research skills in teaching science and technology from the time that knowledge was constructed, understanding the scientific content, and cultivating higher order thinking and modern collaborative, creative, and critical skills. Teaching research skills and experiencing the entire process of scientific research enhances the motivation and enjoyment of learning science and technology. Teaching-learning-assessment processes integrate scientific research skills at all age groups (Krapp & Prenzel, 2011).

The lessons were constructed creatively so that the students asked questions, raised various issues related to the connection of the topic (acid-base) with different issues (the societal, individual, and vocational aspects). In an example from the HRA method in teaching acid-base concepts, the instructor announced that the lesson would be about "red cabbage juice" as one example of an indicator of acids and bases. The students were asked: "What is the connection between red cabbage juice and the indicator for acids and bases?" This question initiated a context-based learning process. One of the student's reactions was: "Only now do I understand how I will become a different teacher in the future." Another student's reaction was: "Now, I want to be a researcher in the field of food chemistry". These students' reactions clearly indicate that using the HRA method in teaching the acid-base topic supports the vocational dimension.

In another example, the instructor announced that today's lesson would be about acid rain. The students were asked: "What is the connection between acid rain and the production of acids?" This question initiated a context-based learning process. One of the student's reactions was: "I will be more active in the future in the field of environmental protection to save our planet". Another student's reaction was: "I want to be a researcher and develop methods that will reduce the number of gases responsible for acid rain." These students' reactions clearly indicate that using the HRA method in teaching the acid-base topic supports both the social and the vocational dimensions.

In a third example, the instructor announced that today's lesson would address the question "Is every transparent liquid water?" The students were asked: "What is the connection between this topic and the acid-base one?" This question initiated a context-based learning process. One of the student's reactions was: "This topic increased my interest and curiosity to think about the subject of acids and bases." Another student said: "This topic made me think deeply about transparent and acidic fluids encountered in everyday life." These students' reactions clearly indicate that using the HRA method in teaching the acid-base topic supports the individual dimension.

The students' responses led us to conclude that learning chemistry using the HRA approach had a very positive effect: it made them appreciate the subject, made it seem less difficult, and made it more interesting and attractive. Stuckey et al. (2013) reported the contribution to the three dimensions: individual (student 1 and student 2), social (student 3 and student 4), and vocational (student 4). These dimensions raised the level of motivation and satisfaction among the students, mainly because of their more positive attitudes toward chemistry due to the connection made between chemistry and their daily lives.

5. Conclusion

In this study we examined the difference in attitudes between students who learned the topic of "acids and bases" using the high relevance approach (HRA) and students who learned the topic through the low relevance approach (LRA). Students' attitudes were examined with respect to the three dimensions of relevance in the scientific profession (societal, individual, and vocational).

The study findings indicated a significant difference in students' attitudes according to the specific teaching approach (HRA versus LRA) used: concerning their attitudes regarding the societal, individual, and vocational dimensions, the students in the high relevance group (HRA) showed a marked improvement.

From the findings of the study, a key conclusion can be drawn: it is the use of relevant teaching or teaching "in the context" of a scientific topic; this promotes students' positive attitudes towards the subject and its learning.

It can be concluded that relevant learning of acid-base chemistry has a positive impact on the individual, vocational, and social aspects of students' lives, enhancing the achievements and status of each aspect. The personal aspect develops skills, increases the students' motivation and enjoyment of the subject, and improves their achievements. The vocational and societal aspects strengthen the bond between students in the class and increase their self-experience and self-development ability.

Ethical Considerations

It is clear that the students in the treatment group who studied according to the HRA teaching method will benefit from the intervention, whereas those in the control group will not. We contacted the students who studied according to the conventional method (LRA) after conducting the research on the HRA teaching method; after the receiving the results, we performed with them several activities about the acid-base topic according to HRA method to compensate them to some extent.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Abadi, R., & Kashtan, Y. (2001). *Factors of Success in Junior High School Science Studies.* Research Report. MOFET Institute. (In Hebrew)

Bretz, S. L. (2017). Finding No Evidence for Learning Styles. *Journal of Chemical Education, 94,* 825-826. https://doi.org/10.1021/acs.jchemed.7b00424

Burmeister, M., Rauch, F., & Eilks, I. (2012). Education for Sustainable Development (ESD) and Chemistry Education. *Chemistry Education Research and Practice, 13,* 59-68. https://doi.org/10.1039/C1RP90060A

Childs, P. E., Hayes, S. M., & O'Dwyer, A. (2015). Chemistry and Everyday Life: Relating Secondary School Chemistry to the Current and Future Lives of Students. In I. Eilks, & A. Hofstein (Eds.), *Relevant Chemistry Education* (pp 33-54). Sense Publishers. https://doi.org/10.1007/978-94-6300-175-5_3

Cooper, M. M., Kouyoumdjian, H., & Underwood, S. M. (2016). Investigating Students' Reasoning about Acid-Base Reactions. *Journal of Chemical Education, 93,* 1703-1712. https://doi.org/10.1021/acs.jchemed.6b00417

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for Educational Practice of the Science of Learning and Development. *Applied Developmental Science, 24,* 97-140. https://doi.org/10.1080/10888691.2018.1537791

Dayal, P. D., & Ali-Chand, Z. (2022). Effective Teaching and Learning Strategies in a Chemistry Classroom. *New Zealand Journal of Educational Studies, 57,* 425-443. https://doi.org/10.1007/s40841-022-00242-7

Eilks, I., & Hofstein, A. (2015). From Some Historical Reflections on the Issue of Relevance of Chemistry Education towards a Model and an Advance Organizer—A Prologue. In I. Eilks, & A. Hofstein (Eds.), *Relevant Chemistry Education* (pp. 1-10). Sense

Publishers. https://doi.org/10.1007/978-94-6300-175-5_1

Fensham, P. J., Gunstone, R. F., & White, R. T. (1994). *The Content of Science: A Constructivist Approach to Its Teaching and Learning.* Falmer Press.

Garforth, F. (1986). Chemistry through the Looking Glass. In P. E. Childs (Ed.), *Everyday Chemistry* (pp. 4-45). Thomond College.

Gilbert, J. K. (2006). On the Nature of "Context" in Chemical Education. *International Journal of Science Education, 28,* 957-976. https://doi.org/10.1080/09500690600702470

Green, J. (2020). *Powerful Ideas of Science and How to Teach Them.* Routledge. https://doi.org/10.4324/9780429198922

Hofstein, A., & Lunetta, V. N. (2004). The Laboratory in Science Education: Foundations for the Twenty-First Century. *Science Education, 88,* 28-54. https://doi.org/10.1002/sce.10106

Holbrook, J. (2003). Increasing Relevance of Science Education: The Way Forward. *Science Education International, 14,* 5-13.

Holbrook, J., Kask, K., & Rannikmäe, M. (2008). Teaching the PARSEL Way: Students' Reactions to Selected PARSEL Modules. *Science Education International, 19,* 303-312.

Hugerat, M. (2006). The Magic Liquid: A Science Story about Acids and Bases. *Science Education Review, 5,* 111-114.

Hugerat, M., & Basheer, S. (2001). Is Every Transparent Liquid Water? *Journal of Chemical Education, 78,* 10-41. https://doi.org/10.1021/ed078p1041

Hugerat, M., Mamlok-Naaman, R., Eilks, I., & Hofstein, A. (2015). Professional Development of Chemistry Teachers for Relevant Chemistry Education. In I. Eilks, & A. Hofstein (Eds.), *Relevant Chemistry Education* (pp. 369-386). Sense Publishers. https://doi.org/10.1007/978-94-6300-175-5_20

Hugerat, M., Najami, N., Abu-Much, R., Khatib, W., & Hofstein, A. (2018). Making the Learning of Acid-Base Concepts More Relevant—A Research Study. *Journal of Laboratory Chemical Education, 6,* 36-45.

Jaleel, S., & Premachandran, P. (2016). A Study on the Metacognitive Awareness of Secondary School Students. *Universal Journal of Educational Research, 4,* 165-172. https://doi.org/10.13189/ujer.2016.040121

Kala, N., Yaman, F., & Ayas, A. (2013). The Effectiveness of Predict-Observe-Explain Technique in Probing Students' Understanding about Acid-Base Chemistry: A Case for the Concepts of pH, pOH, and Strength. *International Journal of Science and Mathematics Education, 11,* 555-574. https://doi.org/10.1007/s10763-012-9354-z

Kember, D., Ho, A., & Hong, C. (2008). The Importance of Establishing Relevance in Motivating Student Learning. *Active Learning and Higher Education, 9,* 249-263. https://doi.org/10.1177/1469787408095849

Krapp, A., & Prenzel, M. (2011). Research on Interest in Science: Theories, Methods, and Findings. *International Journal of Science Education, 33,* 27-50. https://doi.org/10.1080/09500693.2010.518645

Lembens, A., & Reiter, K. (2017). Pre-Service Chemistry Teachers' Conceptions of How to Teach "ACIDS and BASES". In O. Finlayson, E. McLoughlin, S. Erduran, & P. Childs (Eds.), *E-Book Proceedings of the ESERA 2017 Conference: Research, Practice and Collaboration in Science Education* (pp. 1660-1668). European Science Education Research Association.

Makar, K., Bakker, A., & Ben-Zvi, D. (2015). Scaffolding Norms of Argumentation-Based Inquiry in a Primary Mathematics Classroom. *ZDM, 47,* 1107-1120. https://doi.org/10.1007/s11858-015-0732-1

Marcelle, A. S., & Michael, A. R. (2003). Developing the Changes in Attitude about the Relevance of Science (CARS) Questionnaire and Assessing Two High School Science Classes. *Journal of Research in Science Teaching, 40,* 757-779. https://doi.org/10.1002/tea.10110

Marchak, D., Shvarts-Serebro, I., & Blonder, R. (2021). Teaching Chemistry by a Creative Approach: Adapting a Teachers' Course for Active Remote Learning, *Journal of Chemical Education, 98,* 2809-2819. https://doi.org/10.1021/acs.jchemed.0c01341

Meydan, E. (2021). Investigating Secondary School Students' Motivation for Chemistry Class in Terms of Various Variables. *International Journal of Progressive Education, 17,* 498-512. https://doi.org/10.29329/ijpe.2021.329.31

Mintzes, J. J., Wandersee, J. H., & Novak, J. D. (1997). Meaningful Learning in Science: The Human Constructivist Perspective. In G. D. Phye (Ed.), *The Educational Psychology Series. Handbook of Academic Learning: Construction of Knowledge* (pp. 405-447). Academic Press. https://doi.org/10.1016/B978-012554255-5/50014-4

Mrunalini, T. (2010). *Educational Evaluation.* Neelkamal Publishers.

Musengimana, J., Kampire, E., & Ntawiha, P. (2021). Factors Affecting Secondary Schools Students' Attitudes toward Learning Chemistry: A Review of Literature. *Eurasia Journal of Mathematics, Science and Technology Education, 17,* Article No. em1931. https://doi.org/10.29333/ejmste/9379

Novak, J. D. (2002). Meaningful Learning: The Essential Factor for Conceptual Change in Limited or Inappropriate Propositional Hierarchies Leading to Empowerment of Learners. *Science Education, 86,* 548-571. https://doi.org/10.1002/sce.10032

Nuora, P., & Välisaari, J. (2020). Kitchen Chemistry Course for Chemistry Education Students: Influences on Chemistry Teaching and Teacher Education—A Multiple Case Stud. *Chemistry Teacher International, 2,* Article ID: 20180021. https://doi.org/10.1515/cti-2018-0021

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning Styles: Concepts and Evidence. *Psychological Science in the Public Interest, 9,* 105-119. https://doi.org/10.1111/j.1539-6053.2009.01038.x

Redding, C. (2019). A Teacher Like Me: A Review of the Effect of Student-Teacher Racial/Ethnic Matching on Teacher Perceptions of Students and Student Academic and Behavioral Outcomes. *Review of Educational Research, 89,* 499-535. https://doi.org/10.3102/0034654319853545

Siegel, M. A., & Ranney, M. A. (2003). Developing the Changes in Attitude about the Relevance of Science (CARS) Questionnaire and Assessing Two High School Science Classes. *Journal of Research in Science Teaching, 40,* 757-759. https://doi.org/10.1002/tea.10110

Stuckey, M., & Eilks, I. (2014). Raising Motivation in the Chemistry Classroom by Learning about the Student Relevant Issue of Tattooing from a Chemistry and Societal Perspective. *Chemistry Education Research and Practice, 15,* 156-167. https://doi.org/10.1039/C3RP00146F

Stuckey, M., Mamlok-Naaman, R., Hofstein, A., & Eilks, I. (2013). The Meaning of 'Relevance' in Science Education and Its Implications for the Science Curriculum. *Studies in Science Education, 49,* 1-34. https://doi.org/10.1080/03057267.2013.802463

Towns, M. H. (2001). Kolb for Chemists: David A. Kolb and Experiential Learning Theory. *Journal of Chemical Education, 78,* 1107-1117. https://doi.org/10.1021/ed078p1107.7

Valadares, J. (2013). Concept Maps and the Meaningful Learning of Science. *Journal for Educators, Teachers and Trainers, 4,* 164-179.

Varis, K., Jäppinen, I., Kärkkäinen, S., Keinonen, T., & Väyrynen, E. (2018). Promoting Participation in Society through Science Education. *Sustainability, 10,* Article No. 3412. https://doi.org/10.3390/su10103412

Wale, B. D., & Bishaw, K. S. (2020). Effects of Using Inquiry-Based Learning on EFL Students' Critical Thinking Skills. *Asian-Pacific Journal of Second and Foreign Language Education, 5,* Article No. 9. https://doi.org/10.1186/s40862-020-00090-2