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# Innovativeness in Science Education: An Examination of Secondary School Students' Perceptions

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**ABSTRACT** As innovation has gained importance worldwide, educating students as individuals with innovative qualities has become imperative. Therefore, identifying students' perceptions of innovativeness in science lessons has become an issue of concern. The aim of this study was to determine secondary school students' perceptions of innovativeness. The research was conducted according to the survey method. 'Perceptions of Innovative Thinking Scale,' was revised, and necessary scale development steps were followed. Accordingly, secondary school students' general innovative thinking perceptions and the relationships of the scale subdimensions with the variables were determined with single and correlational survey models. After the responses that 831 students gave to the scale were analysed, it was determined that the students' perceptions of innovativeness were high and that gender excepted, grade level, achievement in the subject of science, participation in the TÜBİTAK 4006 science fair, and the case of receiving programming training created significant differences in the subdimensions. The research findings were discussed according to the literature. It was recommended that STEM and programming be included in science courses and that teachers guide these processes.

**Keywords** Science Education, Innovativeness in Science Education, Perceptions of Innovativeness

## 1. INTRODUCTION

As the world's resources decrease, countries' ability to innovate to gain an advantage in a competitive environment and their labor force increases indicates that adopting innovations is important (Yılmaz-Öztürk, 2015). Therefore, training individuals who possess innovative qualities have also become state policy (Açıkgöz-Ersoy & Muter-Şengül, 2008; Öğüt, Aygen, & Demirsel, 2007). Innovativeness, which is defined as 'the state of being open to innovations,' is the ability to take risks, renew oneself, use new technologies, produce new ideas, cooperate, think creatively, and contribute to the change or development of existing situations (Demirel & Seçkin, 2008). Besides keeping pace with changes by using innovations, individuals themselves must also be able to contribute to the changes (Kılıçer & Odabaşı, 2010).

With the constant drive for innovation in the world's economy and the increasing demand for graduating students who are more innovative contributors to society, interest in defining and measuring individual innovativeness is growing (Menold, Jablokow, Purzer, Ferguson, & Ohland, 2014; Yenice & Alpak Tunç, 2019; Weis, Scharf, & Gryl, 2017). Accordingly, teaching programs must be prepared in such a way as to serve to educate individuals who can investigate, inquire, solve the problems they encounter, and benefit themselves and society; in short, who are qualified to respond to the needs of contemporary society (Menold et al., 2014). For this purpose, it is seen that to keep up in the innovation race, the subject of 'Engineering and Design Skills' was added to the 2018 Turkish Science Curriculum. These skills allow students to examine problems from an interdisciplinary perspective, attain a level at which they can invent and innovate, and create products by using the knowledge and skills they have acquired (MoNE, 2018). Therefore it is considered the most important means for students to acquire perceptions towards innovative thinking first, and later innovativeness itself.

It is expected that individuals be open to innovations, adopt innovations, and closely follow developments in technology. Moreover, individuals differ in terms of adopting innovations, and it is seen that they are separated into five categories, namely innovative, traditionalist,

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pioneering, inquiring, and sceptical (Rogers, 1995). It is also known that individuals' socioeconomic levels and different demographic characteristics influence their adoption of innovations (Daghfous, Petrof, & Pons, 1999).

In the literature, although in some studies it was expected that creativity, which is stated to be closely related to innovativeness, would not differ according to gender (Baysal, Kaya, & Üçüncü, 2013; Midilli, 2019; Polat, 2017; Ulusoy-Yılmaz & Yıldız, 2019). In other studies, it is seen that a difference was revealed in favor of women (Barışık, 2019; Gök & Erdoğan, 2011; Rıza, 1999). Studies conducted concerning innovativeness determined that total mean scores increased from 6th grade to 8th grade. Moreover, it was revealed that 5th-grade students' total means innovativeness scores were higher than 6th-grade students' scores (Deveci & Kavak, 2020). It is known that students who are high achievers in science also have high levels of creativity (Kılıç & Tezel, 2012) and that students with high general academic achievement also have high levels of innovativeness (Deveci & Kavak, 2020). When considering students' creativity scores, differences were determined between students with high end-of-term grades in science and those with low grades, favoring those with high achievement (Kılıç & Tezel, 2012). Regarding innovativeness, differences were determined between students with high academic achievement and those with low achievement in favor of the high achievers (Deveci & Kavak, 2020). It is known that states of participation in the project preparation process, which allows students to acquire several skills and to develop these skills, enables their creativity to develop positively and allows them to generate new ideas (Atalmış, Selçuk, & Ataç, 2018; Seechaliao, 2017; Siew & Ambo, 2018). Furthermore, it has been determined that giving students the chance to develop their creativity and the ability to produce innovations has benefits such as gaining self-confidence and learning to cooperate (Avcı, Su-Özenir, & Yücel, 2016) and that at the end of the process, students present different project ideas (Soyuçok, 2018). In programming, which is one of the skills expected from students in the 21st century, students can solve problems by figuring them out and using their creativity. At this point, it is stated that in students who learn programming, the development of their problem solving, logical reasoning, creativity, and innovativeness will also be affected positively (Aytekin, Çakır, Yücel, & Kulaözü, 2018; Yoon, 2018). By this means, in programming, students will have the opportunity to put their ideas into practice by thinking creatively and innovatively. They will also be able to develop their innovativeness in a technological sense.

Literature indicates that many factors can influence students' innovative thinking as mentioned above. Educational policies and schools need to create learning environments to foster innovative thinking. Therefore, this contribution seeks to give insight into kinds of innovative thinkers and provide teachers to evaluate students' perception of innovativeness levels, and enable them to improve their teaching to promote students' innovativeness. By revealing which variables affect students' perceptions of innovative thinking and to what extent, it will be possible to offer students innovative thinking and learning environments.

### 1.1. Aim and Importance of the Study

Considering the literature, it can be thought that secondary school students' gender, grade level, success grades in the subject of science, project preparation process, and programming training may influence their perceptions of innovative thinking. Consequently, it is necessary to determine students' perceptions of innovativeness and the variables that positively affect them.

It has been seen that innovativeness studies gained importance worldwide. It is stated that students at all stages of education students need to possess this skill, and measures are taken for this purpose. As the concept of innovativeness has gained so much importance and it is also clearly stated in the Science Curriculum in Turkey (MoNE, 2018), the position of students attending secondary schools has become an issue of concern. Accordingly, the fact that there are an inadequate number of studies at the secondary school level in the literature is regarded as a deficiency. When the literature is examined, the limited number of studies, and the fact that they have generally been conducted on innovativeness in teachers, preservice teachers, school administrators, and academicians in different branches, is striking (Aldahdouh, Nokelainen, & Korhonen, 2020; Atamanova & Bogomaz, 2021; Bayrakçı & Eraslan, 2014; Demir-Başaran & Keleş, 2015; Kasapoğlu, 2018; Kinay & Suer, 2020; Sarı & Kartal, 2018; Webster et al., 2020). It is striking that studies related to innovativeness mainly collect around teachers and in higher education (Bautista, 2021; Mikhailova, 2019; Kinay & Suer, 2020; Nguyen, Pietsch, & Gümüş, 2021; Öztürk, Önder, & Güven-Yıldırım, 2019; Parlar, Polatcan, & Cansoy, 2019; Polat, 2017). Almost no studies have been conducted about secondary school students' innovativeness (Akkaya, 2016; Deveci & Kavak, 2020; Kavacık, Yanpar-Yelken, & Sürmeli, 2015;). Among these studies, very few have been carried out on perceptions of innovative thinking, while in one study conducted according to a mixed method (Deveci & Kavak, 2020), students' general innovativeness was examined. Therefore, this study in which secondary school students' innovativeness is examined is thought to contribute to the science education. The current study differs from studies in the literature in that it examines the effect of different variables on students' perceptions of innovative thinking based on subfactors and includes a detailed research process for revealing the existing state of their innovativeness. Moreover, it is considered that the study will serve as a guide for other researchers who will research in the field of science education.

This study attempts to determine secondary school students' perceptions of innovativeness. In line with this primary aim, the study's research questions are as follows.

1. What is the level of secondary school students' perceptions of innovativeness?

2. Is there any differences between the secondary school students' 'Innovator,' 'Traditionalist,' and 'Open to Inquiry' scores according to their gender?

3. Is there any differences between the secondary school students' 'Innovator,' 'Traditionalist,' and 'Open to Inquiry' scores according to grade level?

4. Is there any differences between the secondary school students' 'Innovator,' 'Traditionalist,' and 'Open to Inquiry' scores according to success in science?

**Table 1** Distribution of demographic characteristics of secondary school students

| Variables | Groups | Frequency (f) | Percentage (%) |
|---|---|---|---|
| Gender | Female | 432 | 52 |
| | Male | 399 | 48 |
| Grade Level | 6th grade | 255 | 30.7 |
| | 7th grade | 290 | 34.9 |
| | 8th grade | 286 | 34.4 |
| Achievement in Science | 0-49.99 (fail) | 24 | 2.9 |
| | 50-59.99 (pass) | 40 | 4.8 |
| | 60-69.99 (average) | 70 | 8.4 |
| | 70-84.99 (good) | 198 | 23.8 |
| | 85-100 (excellent) | 499 | 60 |
| Mother's Education Level | Primary and secondary | 245 | 29.5 |
| | High school | 326 | 39.2 |
| | Bachelor's and above | 260 | 31.3 |
| Mother's Occupation | Housewife | 500 | 60.2 |
| | Teacher/lecturer | 94 | 11.3 |
| | Engineer | 14 | 1.7 |
| | Healthcare employee | 71 | 8.5 |
| | Civil servant | 67 | 8.1 |
| | Worker | 85 | 10.2 |
| Father's Education Level | Primary and secondary | 190 | 22.9 |
| | High school | 304 | 36.6 |
| | Bachelor's and above | 322 | 40 |
| Monthly Income (TL) | 0-1500 | 64 | 7.7 |
| | 1501-3000 | 331 | 39.8 |
| | 3001 and over | 436 | 52.5 |
| Area of Residence | City | 601 | 72.3 |
| | Village or town | 210 | 27.7 |
| Level of Liking of Science | Yes | 613 | 73.8 |
| | Partial | 194 | 23.3 |
| | No | 24 | 2.9 |
| State of Reading Scientific Journals | Yes | 295 | 35.5 |
| | No | 536 | 64.5 |
| Participation in TÜBİTAK | Yes | 206 | 24.8 |
| | No | 625 | 75.2 |
| Use of Smartboard in Class | Yes | 743 | 89.4 |
| | No | 88 | 10.6 |
| State of Receiving STEP Education | Yes | 42 | 5.1 |
| | No | 789 | 94.9 |
| Length of STEP Education | None received | 789 | 94.9 |
| | Less than one semester | 18 | 2.2 |
| | One semester-two semester | 13 | 1.6 |
| | More than one year | 11 | 1.3 |
| State of Receiving Programming Training | Yes | 295 | 35.5 |
| | No | 536 | 64.5 |
| Length of Programming Training | None received | 536 | 64.5 |
| | Less than one year | 135 | 15 |
| | More than one year | 170 | 20.5 |
| | More than one year | 170 | 20.5 |

5. Is there any difference between the secondary school students' 'Innovator,' 'Traditionalist,' and 'Open to Inquiry' scores according to participation in the TÜBİTAK (The Scientific and Technological Research Council of Turkey)?

6. Is there any differences between the secondary school students' 'Innovator,' 'Traditionalist,' and 'Open to Inquiry' scores according to receiving programming training?

## 2. METHOD

### 2.1. Research Model

In this study survey method was applied to determine students' perceptions of innovativeness. Quantitative data were collected to reveal secondary school students' perceptions of innovative thinking and the relationship with different variables. By determining the secondary school students' perceptions towards innovative thinking and the relationship of these with various variables according to the survey method of quantitative research methods, an attempt was made to reveal the general states of the students in terms of their perceptions of innovative thinking.

A single survey model revealed a general situation related to the participants' perceptions of innovative thinking. In contrast, a correlational survey model was used to determine whether their perceptions of innovative thinking differed significantly regarding different variables.

### 2.2. Study Group

It is known that the project preparation process allows students to generate new ideas, develops their creativity positively, and has benefits for students such as gaining self-confidence by producing innovations and learning how to cooperate (Atalmış et al., 2018; Avcı et al., 2016). Therefore, the study's quantitative data were collected from the participants consisting of 6th, 7th, and 8th-grade students who prepared projects for the TÜBİTAK 4006 science fair and attended secondary schools participating in the fair during the first semester of the 2018-2019 academic year.

**Table 2** Rotated factor loading values and item-total correlation values

| Item No. | Rotated Factor Loading Values | | | Item-Total Correlation Values |
|---|---|---|---|---|
| | Innovative Individual | Traditional Individual | Inquiring Individual | |
| 2 | .74 | | | .63 |
| 1 | .73 | | | .59 |
| 29 | .65 | | | .55 |
| 20 | .62 | | | .56 |
| 13 | .60 | | | .57 |
| 18 | .60 | | | .43 |
| 31 | .60 | | | .49 |
| 28 | .58 | | | .59 |
| 22 | .56 | | | .56 |
| 3 | .55 | | | .45 |
| 14 | .54 | | | .53 |
| 23 | .45 | | | .53 |
| 27 | | .67 | | .52 |
| 16 | | .62 | | .52 |
| 30 | | .59 | | .44 |
| 24 | | .57 | | .50 |
| 15 | | .55 | | .40 |
| 21 | | .53 | | .41 |
| 32 | | .51 | | .47 |
| 9 | | | .68 | .55 |
| 11 | | | .65 | .53 |
| 7 | | | .62 | .25 |
| 8 | | | .62 | .37 |
| 10 | | | .56 | .40 |
| 19 | | | .54 | .43 |
| Eigenvalues | 7.74 | 1.93 | 1.49 | |
| Percentage of explained variance | 30.96 | 7.74 | 5.97 | |
| Cronbach's alpha | .88 | .76 | .74 | |
| Explained variance for total scale | 44.68 | | | |
| Cronbach's alpha for total scale | .90 | | | |

Accordingly, to collect the quantitative data of the research, the scale was first administered to a total of 1190 students at five different secondary schools in the center of a city and its districts located in the Black Sea Region. The responses given by 176 students to the scale were considered inconsistent and formed a pattern, which was excluded from the analysis. Moreover, after outliers were also excluded to ensure normal distribution, the data obtained from 831 students were analyzed, and as a result, the study's quantitative findings were obtained as tabulated in Table 1.

## 2.3. Data Collection Tools

### Development of Perceptions of Innovative Thinking Scale

Within the scope of the research, the 32-item 'Perceptions of Innovative Thinking Scale,' developed aimed at determining secondary school students' perceptions of innovativeness, was used. However, the large number of items in this scale may decrease students' motivation, and this situation may prevent the likelihood of obtaining valid and correct responses. Considering the age group for whom the scale was developed and the response time of the scale, it was decided to reduce the number of scale items to obtain correct answers (Büyüköztürk, 2005; Erkuş, 2016). An attempt was made to make the item density more readable without impairing the integrity of the items included in the subdimensions by reducing the number of items from 32 to 25. As it is recommended that in scale development, the implementation should be made with a number of participants between 5 and 10 times the number of items (Büyüköztürk, 2002), the scale with the reduced number of items was administered to 320 students outside the scope of the actual study. As a result of the exploratory factor analysis, it was determined that the scale, which was reduced to 25 items, met the conditions of validity and reliability. As in its original form, it was made up of three subdimensions.

The Kaiser-Meyer-Olkin (KMO) value and Bartlett's test were considered to determine whether the data were suitable for factor analysis. A KMO value of 0.90 was found. This shows that the sample size was excellent. The result of Bartlett's test ($p < 0.05$) showed that factor analysis could be performed with the items in the data set (Pallant, 2020). The factor loading values and item-total correlation values obtained from the exploratory factor analysis are presented in Table 2.

As can be seen in Table 2, items 1, 2, 3, 13, 14, 18, 20, 22, 23, 28, 29 and 31 are grouped under factor 1, items 15, 16, 21, 24, 27, 30 and 32 are grouped under factor 2, and items 7, 8, 9, 10, 11 and 19 are grouped under factor 3, respectively. Item-total correlation values range between 0.25 and 0.63. Values greater than 0.30 show that the items are differentiated, while cases where values are between 0.20 and 0.30 indicate that the items need to be found based on a requirement in the test or that they need to be revised (Bursal, 2017; Büyüköztürk, 2018). Since the total correlation value of item 7 ('I am afraid of taking risks') was below 0.30, by obtaining expert opinion, it was changed in such a way as to bear the same meaning to 'I do not feel the need to continually seek different ways to solve a problem.' The rotated factor loading values ranged between 0.47 and 0.68. Seven items were removed when giving the scale its final form (4, 5, 6, 12, 17, 25, and 26). According to Table 2, the Cronbach alpha values of the total scale and its subdimensions were 0.90, 0.88, 0.76, and 0.74, respectively. Based on these findings, it can be said that the reliability level of the broad-scale and its subfactors are high (Büyüköztürk, 2018). The scale's subfactors that were reduced to 25 items were revised as 'Innovator,' 'Traditionalist,' and 'Open to Enquiry.' The rating statements and their equivalent scores are as follows: Strongly Disagree 1, Disagree 2, Somewhat Agree 3, Agree 4, and Strongly Agree 5. There are 12 positive items (1, 2, 3, 9, 10, 13, 15, 17, 18, 21, 22, 24) and 13 negative items (4, 5, 6, 7, 8, 11, 12, 14, 16, 19, 20, 23, 25) in all.

Since the first factor contains statements with which an individual can be characterized as innovative, such as being open to innovations, being able to generate new ideas, being self-confident, being able to use new technologies, and considering social benefit and the national economy, it is given the name 'Innovator'. Examining the second factor, it is considered to recall an individual who can be characterized as a traditionalist. Traditionalist individuals show considerable resistance to innovation and change and regard change, renewal, and innovation as unnecessary. They are characterized by being content with their present situation. They are very uncomfortable with disrupting their habits or conventions, and they display an attitude of indifference to innovations in particular. Considering that its items evoke the characteristics of a traditional individual, the second factor is given the name 'Traditionalist'. When the items belonging to the third subdimension are considered, it is seen that they contain statements such as 'I am undecided about using innovations and new technologies, or 'I worry about trying out new ideas.' It can be seen that these items contain anxiety, indecision, and fear towards innovation and that there is worry and caution regarding innovations. Therefore, the third factor representing these items is 'Open to Inquiry.' Worry and indecision towards an innovation indicate the necessity to question or ponder that innovation. This situation recalls individuals with inquiring characteristics in terms of thinking for a long time and feeling the need for other people's ideas when encountering an innovation.

## 2.4. Data Analysis

The quantitative data obtained in the scope of the research were analyzed on a computer. The data were coded and computerized, and care was taken to code the negative items in reverse. To analyze the data obtained from the 'Perceptions of Innovative Thinking Scale' for secondary school students, a normality test was performed to determine whether the data showed a normal distribution. Tabachnick and Fidell (2013) stated that variables taking skewness and kurtosis values between -1.5 and +1.5 could be accepted as showing normal distribution. In order to determine whether or not the secondary school students' perceptions of innovative thinking differed significantly according to the different demographic variables, the parametric MANOVA test was applied since the scale contains three subfactors. To enable the MANOVA test to be performed, multivariate normality wa s tested in line with the general normality analysis results. By examining the skewness and kurtosis values for normality of the distributions of the dependent variables according to the independent variable categories, the distributions were determined to be normal. The' Mahalanobis distance ' was examined to ensure the condition of multivariate normality. The threshold value was set as 7.815 (Pallant, 2020). The process was repeated by excluding data sources taking values above this value. After the assumption of multivariate normality was met, it was determined that the condition was enabled by examining the appropriateness of the correlation between the dependent variables (< 0.90). Equality of covariance was ensured for each independent variable. Finally, as a result of Levene's test, it was determined that the variances for each independent variable were homogeneous. A one-way analysis of variance was performed to determine the source of differences for variables, including more than two groups for which significant differences were determined due to MANOVA analysis. Scheffe's test was used to determine which paired groups there were differences. In order to determine the effect size of the relationship established for the variables, the eta-squared values were examined.

According to Cohen's recommendation, effect sizes of 0.01 are evaluated as small, 0.06 as medium, and 0.14 as large. An attempt was made to explain with tables the mean scores and standard deviation values obtained by the secondary school students participating in the research from the general 'Perceptions of Innovative Thinking Scale' and its subfactors. Moreover, the relationship of the scores obtained by the secondary school students from the 'Innovator', 'Traditionalist', and 'Open to Inquiry' subfactors of the scale with the determined independent variables were examined. The independent variables are gender (1: Female, 2: Male), grade level (1: sixth grade, 2: seventh grade, 3: eighth grade), success grade in science (1: fail, 2: pass, 3: average, 4: good, 5: excellent), participation in the TÜBİTAK science fair (1: participated, 2: did not participate), and state of receiving programming training (1: received, 2: not received). The total innovativeness score was obtained from the scale, and in turn, the scores related to the subdimensions were determined. The lowest score that can be obtained from the scale was determined to be 25, while the highest obtainable score was determined as 125. To specify intervals in the name of determining the total score obtained from the scale, a standard unit was calculated by dividing the sequence width of the highest and lowest scores obtainable from the scale by the number of options [(125-25)/5 = 20], and the intervals were determined approximately according to this unit. Scores obtained from a scale of 86 and over were accepted as high perceptions of innovation by the secondary school students.

In contrast, scores of 85 and below were considered low perceptions of innovation by the students. In terms of the subdimensions of the scale, scores obtained for the 12-item 'Innovator' dimension of 40.7 and below were evaluated as negative, while scores of 40.8 and above were assessed as positive. Concerning the 7-item 'Traditionalist' dimensions, scores of 23.7 and under were assessed as negative, while scores of 23.8 and over were evaluated as positive. Finally, for the 'Open to Inquiry' dimension consisting of 6 items, scores of 20.3 and below were negative, while scores of 20.4 and above were regarded as positive.

## 3. FINDINGS

### 3.1. Findings Related to Levels of Secondary School Students' Perceptions of Innovative Thinking

The mean scores and standard deviation values obtained by the students participating in the study from the Perceptions of Innovative Thinking Scale in general and its subfactors were examined.

Descriptive statistical information related to the general distribution of the scores obtained by the students from the 'Perceptions of Innovative Thinking Scale' and its subdimensions is provided in Table 3.

In light of the findings, it was determined that the mean scores obtained by the secondary school students from the Perceptions of Innovative Thinking Scale and its subdimensions were 105.41, 49.85, 30.87, and 24.59,

**Table 3** Descriptive statistical information related to perceptions of innovative thinking scale mean scores

| | No. of Items | No. of Participants | Mean | Standard Deviation | Min. | Max. |
|---|---|---|---|---|---|---|
| Perceptions of Innovative Thinking | 25 | 831 | 105.41 | 11.01 | 77 | 125 |
| Innovator | 12 | 831 | 49.95 | 6.58 | 33 | 60 |
| Traditionalist | 7 | 831 | 30.87 | 3.26 | 22 | 35 |
| Open to Inquiry | 6 | 831 | 24.59 | 2.99 | 17 | 30 |

respectively, and that the scores were high. Moreover, while the lowest score obtained from the whole scale was 77, the highest was 125.

The correlation matrix, which presents the correlations of the factors and the factor total, is given in Table 4.

Examination of Table 4 shows that the subfactors are correlated with the total score in amounts ranging between .74 and .93. In the related literature, in determining inter-factor correlations, a correlation coefficient between .70 and 1 indicates a high correlation, while a coefficient between .70 and .30 shows moderate correlation (Büyüköztürk, 2018). Accordingly, each factor has a high positive correlation with the factor total, while the subfactors are moderately correlated with each other.

### 3.2. Findings Related to Examination of Secondary School Students' Perceptions of Innovativeness According to Gender

Multivariate analysis of variance (MANOVA) was performed to examine differences between the secondary school students' 'Innovator', 'Traditionalist' and 'Open to Inquiry' scores according to their gender. The findings obtained are presented in Table 5.

The assumption of multivariate normality, which is the precondition of the MANOVA test, was met (Box M Test = 4.933, p = 555). When Table 5 is examined, it is seen that the group effect of both the 'Innovator' scores [Wilks'$\lambda$ = 0.988, $F_{(1.829)}$ = 1.411, $p > 0.05$] and the 'Traditionalist' scores [Wilks'$\lambda$ = 0.988, $F_{(1.829)}$ = 0.607, $p > 0.05$] of the secondary school students is not significant. In other words, a significant difference was not found between boys' and girls' 'Innovator' or 'Traditionalist' scores. On the other hand, it is seen that the group effect of the secondary school students 'Open to Inquiry' scores is significant [Wilks'$\lambda$ = 0.988, $F_{(1.829)}$ = 4.686, $p < 0.05$]. However, the effect size value ($\eta 2$ = 0.006) was found to be very low. When the mean scores are examined for the source of the difference, it can be seen that males' 'Open to Inquiry' scores ($\underline{X}$ = 24.83) are higher than those of females ($\underline{X}$ = 24.38), albeit to a minimal extent.

### 3.3. Findings Related to Examination of Secondary School Students' Perceptions of Innovativeness According to Grade Level

Multivariate analysis of variance (MANOVA) was carried out to examine differences between the 'Innovator', 'Traditionalist', and 'Open to Inquiry' scores of the secondary school students at different grade levels. The findings obtained are shown in Table 6.

The assumption of multivariate normality, which is the precondition of the MANOVA test, was met (Box M Test = 0.859, p = 0.589). Examination of Table 6 reveals that the group effect of both the 'Innovator' scores [Wilks'$\lambda$ = 0.978, $F_{(2.828)}$ = 6.726, $p < 0.05$] and the 'Traditionalist' scores [Wilks'$\lambda$ = 0.978, $F_{(2.828)}$ = 6.473, $p < 0.05$] of the secondary school students is significant. However, the group effect of the students' 'Open to Inquiry' scores was not found to be significant [Wilks'$\lambda$ = 0.978, $F_{(2.828)}$ = 2.333, $p > 0.05$]. The effect size value of both the 'Innovator' ($\eta 2$ = 0.016) and the 'Traditionalist' ($\eta 2$ = 0.015) scores was found to be low. When the mean scores are examined for the source of the difference, 6$^{th}$-grade secondary school students' 'Innovator' scores ($\underline{X}$ = 51.01) do not differ significantly from 7$^{th}$-grade students' scores ($\underline{X}$ = 50.01). However, they differ significantly from 8$^{th}$-grade secondary

**Table 4** Correlation matrix for factors and factor total factor

| | Innovator | Traditionalist | Open to Inquiry |
|---|---|---|---|
| Innovator | 1 | .62 | .55 |
| Traditionalist | .62 | 1 | .47 |
| Open to Inquiry | .55 | .47 | 1 |
| **Total** | .93 | .80 | .74 |

**Table 5** MANOVA results for 'innovator', 'traditionalist', and 'open to inquiry' scores according to gender variable

| | KT | Sd | KO | F | p | η2 |
|---|---|---|---|---|---|---|
| Innovator | 61.176 | 1 | 61.176 | 1.411 | 0.235 | 0.002 |
| Traditionalist | 6.467 | 1 | 6.467 | 0.607 | 0.436 | 0.001 |
| Open to Inquiry | 41.957 | 1 | 41.957 | 4.686 | 0.031* | 0.006 |

*p < 0.05

**Table 6** MANOVA results for 'innovator', 'traditionalist', and 'open to inquiry' scores according to secondary school students' grade level

| | KT | Sd | KO | F | p | η2 |
|---|---|---|---|---|---|---|
| Innovator | 575.700 | 2 | 287.850 | 6.726 | 0.001* | 0.016 |
| Traditionalist | 136.175 | 2 | 60.088 | 6.473 | 0.002* | 0.015 |
| Open to Inquiry | 41.830 | 2 | 20.915 | 2.333 | 0.098 | 0.006 |

*p < 0.05

school students' 'Innovator' scores ($\bar{X}$ = 48.94). The reason for this is that 6th-grade secondary school students' 'Innovator' scores were found to be higher than 8th-grade secondary school students' 'Innovator' scores. When examined in terms of the 'Traditionalist' scores, it is seen that 6th-grade secondary school students' scores ($\bar{X}$ = 31.32) do not differ from 7th-grade students' scores ($\bar{X}$ = 31.00), whereas they differ significantly from 8th-grade students' scores ($\bar{X}$ = 30.34). It was determined that 6th-grade students' 'Traditionalist' scores are higher than 8th-grade students' 'Traditionalist' scores.

### 3.4. Findings Related to Examination of Secondary School Students' Perceptions of Innovativeness According to Success Grades in the Subject of Science

Multivariate analysis of variance (MANOVA) was performed to examine whether there were differences between the 'Innovator', 'Traditionalist' and 'Open to Inquiry' scores of the secondary school students who had different success grades in the subject of science. The findings obtained are presented in Table 7.

The assumption of multivariate normality, which is the precondition of the MANOVA test, was met (Box M Test = 0.621, p = 0.923). When Table 7 is examined, it is seen that the group effect of all the 'Innovator' [Wilks'$\lambda$ = 0.922, $F_{(4.826)}$ = 10.564, $p < 0.05$], 'Traditionalist' [Wilks'$\lambda$ = 0.922, $F_{(4.826)}$ = 13.565, $p < 0.05$] and 'Open to Inquiry' [Wilks'$\lambda$ = 0.922, $F_{(4.826)}$ = 9.156, $p < 0.05$] scores is significant. The effect size value of both the 'Innovator' ($\eta2$ = 0.049) and 'Open to Inquiry' ($\eta2$ = 0.041) scores were found to be low, while that of the 'Traditionalist' ($\eta2$ = 0.062) scores was found to be moderate. When the mean scores are examined in terms of the source of the difference, the 'Innovator' scores of students with average grades in science ($\bar{X}$= 48.82) differ significantly from scores of students who failed ($\bar{X}$ = 43.75). The 'Innovator' scores of students with good grades in science ($\bar{X}$ = 48.97) differ significantly from scores of students who failed ($\bar{X}$ = 43.75). Finally, the 'Innovator' scores of students with excellent grades in science ($\bar{X}$= 50.91) also differ significantly from scores of students who failed ($\bar{X}$ = 43.75). Examination of the 'Traditionalist' scores reveals that the 'Traditionalist' scores of secondary school students with average grades in science ($\bar{X}$ = 30.15) differ significantly from students who failed ($\bar{X}$= 27.58). The 'Traditionalist' scores of secondary school students with good grades in science ($\bar{X}$ = 30.30) also differ significantly from scores of students who failed ($\bar{X}$= 27.58). The 'Traditionalist' scores of secondary school students with excellent grades in science ($\bar{X}$ = 31.42) differ significantly from scores of students who failed ($\bar{X}$ = 27.58), scores of those with average grades ($\bar{X}$ = 30.15), and scores of those with good grades ($\bar{X}$ = 30.30). When the 'Open to Inquiry' scores are examined, it can be seen that the 'Open to Inquiry' scores of secondary school students with excellent grades in science ($\bar{X}$= 25.04) differ significantly from scores of students with good grades ($\bar{X}$ = 24.14), scores of those with pass grades ($\bar{X}$ = 23.35), and scores of those who failed ($\bar{X}$ = 22.70). It was determined that secondary school students with excellent grades in science have higher 'Open to Inquiry' scores than secondary school students with good and pass grades and students who failed.

### 3.5. Findings Related to Examination of Secondary School Students' Perceptions of Innovativeness According to State of Participation in TÜBİTAK Science Fair

Multivariate analysis of variance (MANOVA) was carried out to examine whether there were differences between the 'Innovator', 'Traditionalist' and 'Open to Inquiry' scores of the secondary school students according to whether or not they had participated in the TÜBİTAK 4006 science fair. The findings obtained are shown in Table 8.

The assumption of multivariate normality, which is the precondition of the MANOVA test, was met (Box M Test = 1.431, p = 0.198). Examination of Table 8 shows that the

**Table 7** MANOVA results for 'innovator', 'traditionalist', and 'open to inquiry' scores according to science success grades variable

| | KT | Sd | KO | F | p | η2 |
|---|---|---|---|---|---|---|
| Innovator | 1752.494 | 4 | 438.123 | 10.564 | 0.001* | 0.049 |
| Traditionalist | 545.245 | 4 | 136.311 | 13.565 | 0.000* | 0.062 |
| Open to Inquiry | 316.923 | 4 | 79.231 | 9.156 | 0.000* | 0.041 |

*p < 0.05

**Table 8** MANOVA results for 'innovator', 'traditionalist', and 'open to inquiry' scores according to variable of participation in tübitak 4006 science fair

| | KT | Sd | KO | F | p | η2 |
|---|---|---|---|---|---|---|
| Innovator | 1334.216 | 1 | 1334.216 | 31.898 | 0.000* | 0.037 |
| Traditionalist | 201.124 | 1 | 201.124 | 19.289 | 0.000* | 0.023 |
| Open to Inquiry | 108.724 | 1 | 108.724 | 12.253 | 0.000* | 0.015 |

*p < 0.05

**Table 9** MANOVA results for 'innovator', 'traditionalist', and 'open to inquiry' scores according to variable of receiving programming training

| | KT | Sd | KO | F | p | η2 |
|---|---|---|---|---|---|---|
| Innovator | 532.343 | 1 | 532.343 | 12.440 | 0.000* | 0.015 |
| Traditionalist | 65.907 | 1 | 65.907 | 6.223 | 0.013* | 0.007 |
| Open to Inquiry | 59.037 | 1 | 59.037 | 6.609 | 0.010* | 0.008 |

*p < 0.05

group effect of all the 'Innovator' [Wilks'$\lambda$ = 0.961, $F_{(1.829)}$ = 31.898, p < 0.05], 'Traditionalist' [Wilks'$\lambda$ = 0.961, $F_{(1.829)}$ = 19.289, p < 0.05] and 'Open to Inquiry' [Wilks'$\lambda$ = 0.961, $F_{(1.829)}$ = 12.253, p < 0.05] scores is significant. The effect size value of all the 'Innovator' ($\eta$2 = 0.037), 'Traditionalist' ($\eta$2 = 0.023) and 'Open to Inquiry' scores ($\eta$2 = 0.015) was found to be low. When the mean scores are examined in terms of the source of the difference, it is seen that the scores of the students who took part in the science fair are higher than scores of those who did not participate with regard to their 'Innovator' scores ($\underline{X}$= 52.16, $\underline{X}$= 49.22, respectively), 'Traditionalist' scores ($\underline{X}$ = 31.73, $\underline{X}$ = 30.59, respectively), and 'Open to Inquiry' scores ($\underline{X}$= 25.22, $\underline{X}$= 24.39, respectively).

### 3.6. Findings Related to Examination of Secondary School Students' Perceptions of Innovativeness According to State of Receiving Programming Training

Multivariate analysis of variance (MANOVA) was carried out to examine differences between the 'Innovator', 'Traditionalist' and 'Open to Inquiry' scores of the secondary school students according to whether or not they had received programming training. The findings obtained are presented in Table 9.

The assumption of multivariate normality, which is the precondition of the MANOVA test, was met (Box M Test = 0.347, p = 0.912). When Table 9 is examined, it is seen that the group effect of all the 'Innovator' [Wilks'$\lambda$ = 0.984, $F_{(1.829)}$ = 12.440, p < 0.05], 'Traditionalist' [Wilks'$\lambda$ = 0.984, $F_{(1.829)}$ = 6.223, p < 0.05] and 'Open to Inquiry' [Wilks'$\lambda$ = 0.984, $F_{(1.829)}$ = 6.609, p < 0.05] scores is significant. The effect size value of the 'Innovator' ($\eta$2 = 0.015) scores was found to be low, while in terms of the 'Traditionalist' ($\eta$2 = 0.007) and 'Open to Inquiry' scores ($\eta$2 = 0.008), it was found to be very low. When the mean scores are examined in terms of the source of the difference, is can be seen that the scores of the students who received programming training are higher than scores of those who did not receive it in terms of their 'Innovator' scores ($\underline{X}$= 51.03, $\underline{X}$= 49.35, respectively), 'Traditionalist' scores ($\underline{X}$ = 31.25, $\underline{X}$ = 30.66, respectively), and 'Open to Inquiry' scores ($\underline{X}$= 24.95, $\underline{X}$= 24.40, respectively).

## 4. DISCUSSION

In this study, which was conducted to determine the innovativeness of secondary school students in their science lessons, it was determined that the secondary school students' perceptions towards innovative thinking were high and that in terms of the subdimensions, their mean scores in the 'Innovator', 'Traditionalist' and 'Open to Inquiry' subdimensions were also positive and high. This finding corresponds with the findings of the study by Deveci and Kavak (2020), in which 46% of students showed a high innovative thinking tendency. Accordingly, it can be said that the students in the sample were generally open to innovation and change. The increase in students' interest in technology nowadays can be given as a reason for this. Therefore, it is considered that teachers should have innovative characteristics and that they can frequently include innovative teaching methods-techniques and technology in their classes. Moreover, factors such as parents' knowledgeableness and high-income levels due to their professions may also come into play.

When examined in terms of the gender factor, it was determined that while there was no significant difference for the 'Innovator' and 'Traditionalist' factors, there was an effect on the 'Open to Inquiry' factor in favor of boys albeit at a very low level. Similar to these findings, it was revealed that gender did not make a significant difference to innovativeness (Deveci & Kavak, 2020), creativity (Dilek, 2013; Kanlı, 2017; Midilli, 2019), entrepreneurship (Deveci, 2018), problem-solving skills (Özbulak, Aypay, & Aypay, 2011), or critical thinking (Akar & Kara, 2016). However, the fact that significant differences were determined in secondary school students' creativity (Barışık, 2019), 21st-century learning skills (Bozkurt & Çakır, 2016), scientific inquiry perceptions (İnel-Ekici, 2016), and critical thinking skills (Köksal & Çöğmen, 2018), in favor of females, conflicts with the findings of this study. Öztürk et al. (2019) stated the reason why the entrepreneurial characteristic does not differ significantly according to gender, that together with the increase in their education level, females are claiming their place in the world of entrepreneurship, and that in the 21st century, families in our country are offering similar opportunities without gender discrimination.

The fact that gender did not significantly differ from the 'Innovator' and 'Traditionalist' scores may be because the students had more or less the same opportunities in the areas where they grew up. Moreover, rather than gender, the family's education level, school facilities, and teachers' and administrators' innovative characteristics may have affected the 'Innovator' and 'Traditionalist' scores. Therefore, it can be thought that families with a high education level will also have high levels of innovativeness, and their children will also have high innovativeness levels.

When the grade level variable was examined, it was determined that while there was a significant difference concerning the 'Innovator' and 'Traditionalist' subdimensions, a significant difference did not occur regarding the 'Open to Inquiry' subfactor. Sixth-grade students' 'Innovator' and 'Traditionalist' scores were determined to be higher than eighth-grade students' scores. In the literature, the finding that the use of 21st-century skills decreased as grade level increased (Bozkurt & Çakır, 2016) corresponds with the finding of this study. However, the fact that creativity (Barışık, 2019), perceptions towards problem-solving skills (Tunç & Taşgın, 2018), and critical thinking skills (Çakırlar-Altuntaş, Yılmaz, & Turan, 2017) did not vary according to grade level conflicts with this finding. One of the reasons why the secondary school students' 'Innovator' scores decreased as grade level increased may be the fact that secondary school students focus on solving tests rather than activities and experiments in their lessons in order to prepare for the high school placement examinations (Bozkurt & Çakır, 2016). It can be thought that teachers and parents also encourage students mainly to prepare for the examinations.

When considered in terms of the 'Innovator' dimension, it was determined that the 'Innovator' scores of students with high success grades in the subject of science differed significantly from the scores of those with other success grades. When the literature is examined, it was stated in the literature that creativity levels were high in students with good science grades (Erdoğdu & Şirin, 2018; Kılıç & Tezel, 2012; Baysal et al., 2013), entrepreneurship tendencies were high in students with high academic achievement (Deveci, 2018), problem-solving skills were high in students with high achievement in science (Durgun & Önder, 2019), and innovativeness tendencies were high in students with high perceptions of scientific inquiry skills (İnel-Ekici, 2016) and in academically successful students (Deveci & Kavak, 2020). These findings correspond with the findings of the present study. Deveci and Kavak (2020) reported that successful students asked more questions than others. Since they generated creative ideas, the fact that their tendencies towards innovative thinking were also high was an expected result. İnel-Ekici (2016) stated that perceptions towards innovativeness were high since teachers included inquiry-based activities in their lessons and that students who were highly successful in science also showed active participation in this process.

When examined in terms of participation in the TÜBİTAK 4006 science fair, a significant difference was found in students' 'Innovator', 'Traditionalist' and 'Open to Inquiry' mean scores in favor of those who took part in the science fair. Similar to this finding, Yıldırım (2018) revealed that problem-solving skills developed in students who participated in science festivals, Çavuş, Balçın, and Yılmaz (2018) reported that science fair activities increased secondary school students' perceptions of problem-solving skills, and Soyuçok (2018) stated that communication and creativity skills developed in students who created projects by taking part in science fairs. It was determined that science fairs reduce students' anxiety towards the subject of science and also have a positive effect on their motivation (Keskin, 2019), that they have positive benefits for students' inquiry skills, and that they increase students' interest and achievement in the subject of science (Soyuçok, 2018). Project-based learning methods will support the education of students as individuals who are curious, investigate, inquire, solve the problems they encounter, and think critically and creatively (Avcı & Su-Özenir, 2018; Seechaliao, 2017, Siew & Ambo, 2018). Accordingly, the fact that 'Innovator' and 'Open to Inquiry' scores were high is an expected result. The reason why the 'Traditionalist' scores of students who participated in the science fair were also high maybe because innovative thinking skills had only recently been added to the curriculum.

The 'Innovator', 'Traditionalist' and 'Open to Inquiry' scores of students who had received programming training were higher than those who had not received it. This finding shows similarity with the findings that for students receiving programming training, their problem-solving, creative, and innovative thinking skills developed (Başarmak & Hamutoğlu, 2019). In addition, the training enabled their creativity and digital thinking skills, ability to identify problems and solve the problems they identified, design skills, and ability to think multilaterally (Göksoy & Yılmaz, 2018). Considering the interest in technology shown by students nowadays, it can be thought that the programming training they received also attracted their interest. Therefore, the process was experienced productively. On the other hand, the reason why the 'Traditionalist' scores of students who received programming training were also high maybe because some teachers were not sufficiently equipped (Mıhcı-Türker & Pala, 2018), that some school principals did not have adequate knowledge (Ünsal, 2019), and that reasons such as these led students to regard programming as a simple game.

## CONCLUSION

It was determined that the students generally possessed innovative personality traits, paid regard to social benefit, and were open to innovation and development. Findings reveal that the secondary school students were open to innovation and change, possessed innovative traits, and gave importance to social benefit; in short, they were innovators.

Moreover, it was concluded that the increasing importance given to innovativeness nowadays, project-based learning aimed at developing innovativeness in the education process, different teaching practices such as STEM, and the inclusion of technology in the process, have positive effects on students' innovativeness.

It was revealed that sixth-grade students' 'Innovator 'scores were higher than those of eighth grade students. It can be said that because students prepared for high school placement examinations and focused on answering test questions, their innovativeness decreased as grade level increased. Considering the positive effect on innovativeness of involvement in project work, practices towards finding solutions to everyday problems can be included in eighth grade students' lessons to contribute positively to their innovativeness.

Although the students who took part in the study were at ages when abstract thinking skills began to develop, concrete products are essential for their better interpretation. Consequently, experiencing the process of including STEM or programming activities and project work is important for contributing to students' innovativeness. Therefore, it can be recommended that science teachers provide the necessary opportunities.

Teachers should serve as a guide to students in their activities such as project preparation and should not help them achieve results by gravitating towards highly successful students in lessons and offering them ready-made project ideas. Instead, more encouragement should be given, especially to students with low achievement in lessons and whose creative and innovative thinking skills are not sufficiently developed. Moreover, in the process, students should be given opportunities to generate ideas such as identifying the problem, developing solution suggestions, and putting these ideas into practice.

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