Contact details

Fitting the STEM interests of middle school children into RIASEC structural space

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This research was supported by Croatian Science Foundation grant IP-09-2014-9250 -STEM career aspirations during primary schooling: A cohort-sequential longitudinal study of relations between achievement, self-competence beliefs, and career interests (JOBSTEM).

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Introduction

At the begging of new the millennium, many European countries have seen declining numbers of students choosing to pursue the study of physical sciences, engineering and mathematics at university (European Commission, 2004; Osborne & Dillon, 2008). Consequently, the majority of EU Member States have experienced recruitment difficulties in relation to STEM skilled labor force in recent years (Caprile, Palmén, Sanz, & Dente, 2015). This is a serious societal issue, raising the question when and how interest toward careers in STEM are structured and formed.

Researchers in this area often use the metaphor of the "leaky pipeline" to describe the finding that children initially have a high level of interest in STEM area but lose their interest as they progress through the educational system. This metaphor is found to be especially applicable for girls, who are losing their interest along their educational or career pathway (e.g. Blickenstaff, 2005; Mitchell & Hoff, 2006; Riegle-Crumb, Moore, & Ramos-Wada, 2011).

This paper aims to explain interest in STEM careers of middle school children in important stage of their interests' formation. We studied STEM interests of children in grade 7 (age 13 years) and try to fit it in the broader context of general development of vocational interests. There are several reasons for that: a) the age of 13 seems to be a turning point in formation of interest structure (discussed later); b) in Croatian educational system students at that age have to start thinking about their future educational path and career choice they have to make in eight grade; c) school career counselors should be informed about the adequacy of general RIASEC interest model for capturing and depicting STEM career interests. Accordingly, we used Holland's model of vocational personalities and work environments (Holland, 1959, 1997), as numerous authors consider it as a main model for conceptualizing and studying interests (Borgen, 1986; Rounds, 1995; Rounds & Day, 1999). We wanted to explore STEM interests more deeply and to understand how and where they fit into Holland's interest themes. Holland's model is well-known and systematically explored, and examination how STEM interests relate to RIASEC types could provide new findings. Fitting STEM interests within an existent, verified model will enable better understanding of the differences between STEM fields, gender differences in STEM interests, and developmental issues related to formation of STEM interests.

The Holland's model

Holland's (1959, 1997) theory is based on the Person–Environment fit paradigm which assumes that interests directly influence educational and career choices and that people incline toward academic or work environments that are congruent with their interests. Congruence between an individual's interests and work environment leads to greater satisfaction and stability in career. Holland (1959, 1997) proposed six categories for classifying individuals and work environments: Realistic, Investigative, Artistic, Social, Enterprising, and Conventional, also referred to as the RIASEC model. RIASEC interest types and work environments are organized in a circular hexagonal model that implies equal distances between the types. Interests and work environments which are adjacent (e.g. RI) are more similar than those which are alternate (e.g. RA), while alternate types are more similar than the opposite types (e.g. RS). Prediger (1982) proposed two bipolar dimensions that underlie the RIASEC model: People-Things, which distinguish Social and Realistic types, and the orthogonal dimension Data-Ideas, which differentiate Conventional and Enterprising from Investigative and Artistic types.

The hexagonal structure of interest types has been found to fit most of US adolescents and adult samples (Day & Rounds, 1998; Tracey & Rounds, 1993), but was less well established in international contexts (Rounds & Tracey, 1996). However, the application of the RIASEC interests structure to the European samples appeared to be appropriate (e.g. Einarsdóttir, Rounds, Ægisdóttir, & Gerstein, 2002; Hedrih, 2008; Nagy, Trautwein, & Lüdtke, 2007; Šverko, 2008; Šverko & Babarović, 2006). In particular, Šverko (2008) confirmed acceptable fit of hexagonal model in high-school and college students' samples in Croatia, as well as in gender sub-samples.

Concerning the development and formation of interests, some research indicated that hexagonal structure of interests may not be valid for children under 14 years old (Tracey & Ward, 1998). Authors examined the structure of interests of fourth and fifth graders, sixth through eighth graders, and university students, and found that the RIASEC circular structure fit the college students well, the middle school students moderately, and the elementary school students poorly. Regarding the stability and invariance of interests, few longitudinal studies showed that interests become stabile and invariant also after the age of 14 (Tracey, 2002a; Tracey, Robbins & Hofsess, 2005).

STEM and RIASEC interests

With reference to the previous research, the major divergence in interests in STEM careers can be expected along the People-Things dimension. It has been found that People-Things orientation is good predictor of a choice of STEM college majors (Woodcock et al., 2012), while Lubinski and Benbow (2006) argued that gender differences on the People-Things interest dimension contributes to the poor representation of women in STEM occupations. Su, Rounds and Armstrong (2009), in their comprehensive meta-analysis, demonstrated that sex differences in STEM interests are largest along the People-Things dimension. *Things* work activities involve tasks that do not include other people but involve working with tools or machines, while *People* work tasks involve other persons, and activities like caring for others or teaching. Many disciplines in natural sciences, such as physical science, astronomy, and chemistry heavily involve Realistic interests placed on the Things pole within the hexagon (Su & Rounds, 2015). Thus, it is expected that majority of STEM occupations are saturated with

Realistic features of working environment. On the other hand, Investigative interest, by definition, captures an interest in science and research, and should also be an indicator for interest in STEM careers.

While it is expected that most STEM occupations have strong Realistic and Investigative components, and to incline closely towards the Things pole of the hexagon, STEM is a broad term with heterogeneous sub-disciplines (Su et al., 2009). According to the List of STEM Occupations in O*NET Database (Shatkin, 2011) there are clusters of STEM occupations that have other dominant RIASEC codes. There are STEM occupations with strong Artistic (e.g. Landscape Architects – AIR), Social (e.g. Postsecondary Chemistry Teachers – SIR), Enterprising (e.g. Engineering Managers – ERI), and Conventional (e.g. Financial Analysts – CIE) components.

Development of STEM interests

Childhood and adolescence are important periods for developed and formation of vocational interests. In the early childhood, the interests for male and female activities were first developed (Gottfredson, 1996; Tracey & Ward, 1998; Tracey 2001). In the elementary school, children develop interests for school and out-of-school activities (Tracey & Ward, 1998). In the adolescence, parallel to the development of higher cognitive functions, interests typical for adults are beginning to form (Tracey & Ward, 1998, Tracey 2001). Correspondingly, developmental theories stress that the adolescence, in particularly age 13 to 14, is the crucial period in the process of interests' formation (Super, 1953, Gottfredson, 1996). However, two systematic reviews of the literature on children's career development (Hartung, Porfeli, & Vondracek, 2005; Watson & McMahon, 2005) criticized age-graded approach and too extensive research focus on adolescence. Furthermore, in the more recent review, Watson, Nota & McMahon (2015), suggested the need to focus on career development of younger children.

The research on the early formation of STEM interests are scarce. There were fewer studies reporting findings on the middle school students' STEM interest compared to what is known on secondary and postsecondary level (Usher, 2009). Researchers were mostly focused in high-school age, finding it the most critical time for formation of STEM interests (Olson, 2009). The major findings showed that during the high-school years girls have overall less interest in STEM careers and that there is a lower retention of interests in STEM careers among girls (Brotman & Moore, 2008; Sadler, Sonnert, Hazari, & Tai, 2012). Tracey (2002a) reported that gender differences in STEM interests became more pronounced with the shift from elementary school into middle school, and that these gender differences in interests persist through the entry into college (Tracey & Robbins, 2005). Tai, Liu, Maltese & Fan (2006) found that roughly half of the students followed through on their eighth-grade science career choices. Sadler et al. (2012) demonstrated that the key factor in predicting STEM career interests at the end of high school were STEM interest at the start of high school. It is obvious that children's STEM interests are formed at the middle school and remain stable. Thus, a key period in STEM interest development appears to be placed within the middle school age. These findings are in line with findings on structural stability and invariance of RIASEC interests from the age of 14, mentioned earlier.

The aims of this research are to find out how middle school children's STEM interests are structured, to what extent children differentiate their interests between the STEM fields (science, technology, engineering and mathematics), and where they situate their STEM interests within the general RIASEC model. We expect that STEM interests will mostly incline towards the Things pole of the RIASEC hexagon, with some difference between STEM fields. In particular, we expect that the interests for Science will lean, to some degree, to Investigative interests and Ideas pole.

Method

Participants

The participants in this study were 627 middle school students from Grade 7 (age 13; M_{age} = 12.80; sd_{age} = .37). They were equally distributed by gender, comprising 54% of boys. Students attended schools in city of Zagreb and its surroundings representing mostly urban population. The parental educational level generally corresponded to educational level of urban population in Croatia. The dominant educational level of students' mothers was first stage of tertiary education (28.6%), followed by upper secondary education (19.9%). Similarly, predominant level of fathers' education was first stage of tertiary (31.1%), followed by upper secondary level (18.4%). It should be noticed that 21.4% of children at that age did not know the mothers' educational level, and 18.9% of children did not know fathers' educational level.

Measures

We used measures for students' RIASEC interests, as well as for their specific STEM-related interests:

For the purpose of this study we developed *Children Vocational Interests Inventory* (CVII). The questionnaire is short and simple instrument for assessing the RIASEC interests of middle school children (age 10 to 14). It consists of 48 occupations, well-known to children and frequent in the world of work, divided into 6 RIASEC types with eight occupations representing each type (e.g. truck driver – R; veterinarian – I; sculptor – A; kindergarten teacher – S; lawyer – E; cashier – C). Children need to estimate how much they like each occupation on the five-point Likert-type scale. In CVII development, we relied on two RIASEC interest measures developed in Croatian context that were previously applied to middle school samples – Pictorial-Descriptive Interest Inventory PDII (Šverko, Babarović & Međugorac, 2014) and Vocational Interest Questionnaire (UPI-96, Černja, Babarović & Šverko, 2017). In CVII we included 25 occupations from PDII and UPI-96 that we found well known to children as young as ten years. For selecting other suitable occupations, we have consulted Personal Globe Inventory (PGI) – short version (Tracey, 2002b; 2010; Šverko, 2008), Holland's SDS (Holland, 1985; Šverko & Babarović, 2006), and O*NET database of occupations (The Occupational Information Network).

The reliability of the CVII's RIASEC scales was high, ranging from α_I= .74 to α_S= .85. The expected three dimensions underlying the RIASEC types were obtained by PCA. Three dimensions explained 83.8% of variance of RIASEC types, where the first component resembled the general factor of interests. The two subsequent components, after the 25° rotation clearly reflected Prediger's (1982) *People–Things* and *Data–Ideas* dimensions (r = .95 and r = .84, respectively). Randomization testing (Hubert & Arabie, 1987; Rounds, Tracey, & Hubert, 1992) show mediocre fit of data to hexagonal structure (*CI* = .47, *p* = .02). The magnitude of this fit is equal to the number of predictions met in the data matrix minus the number of predictions violated over the total number of predictions made. A CI of .00 indicates a chance ordering of variables, while a CI of .50 indicates that 75% of predictions have been met (Sodano, 2001). This mediocre model-data fit is partly expected due to the respondents' age (Tracey, 2001; Tracey & Rounds, 1993; Tracey & Ward, 1998), and it corresponds to the CI indices found for other interest inventories developed for children (Tracey & Caulum, 2015). Moreover, it corresponds to the fit indices obtained with UPI-96 applied at the similar age group of respondents (Černja et al., 2017) and it is a bit lower than those reported for PDII applied on 15 years old children (Šverko et al., 2014).

STEM interests inventory for children (STEM-IIC) was developed for the purpose of this study. It consists of two subscales: scale of interest in STEM occupations and scale of interest in STEM activities. The scale of interest in STEM occupations has been formed on the basis of the List of STEM occupations in O*NET Database (Shatkin, 2011). In doing so, special attention was paid to all STEM occupations that are a) known to children at age 10 to 14, b) present in the Croatian labor market, and c) listed in the National Classification of Occupations (corresponding to ISCO-08). The examples of STEM occupations in the STEM-ICC are: mathematician, computer programmer, biologist, astronomer, medical doctor etc. The scale of interest in STEM activities is derived from the description of activities in STEM occupations within the O*Net, Croatian Occupational Outlook Handbook (Šverko, 1998), and the latest job descriptions provided by Croatian Employment Service. During the development of activities descriptors, special care was taken to describe most important tasks within a given STEM occupation, to be brief and concise, and to use expressions and wording suitable to children's ages. The examples of STEM activities in the questionnaire are: Studying the celestial bodies, planets, stars and galaxies; Maintain engines, instruments and control systems of the aircraft; Exploring the structure of living organisms with microscope. The occupational scale and the activities scale consist of 13 items each. The task of respondents is to estimate how much they like each occupation and activity on a five point, Likert-type scale. The STEM-IIC showed clear one factor structure (PCA), with the variance accounted for by a general factor of 37.7%, and all item-factor loadings exceeding .35. The Cronbach alpha for the complete scale was α =.93, indicating high reliability.

STEM careers interest survey – short, measures interest in specific areas of STEM (science, technology, engineering, and mathematics). It is an adaptation of the STEM Career Interest Survey (STEM-CIS) (Kier, Blanchard, Osborne, & Albert, 2014). The adapted version retains the 16 items, four for each of the STEM areas. It examines the extent to which students wish to engage in STEM areas in their career, whether they are interested in these occupations and activities, and whether they have the support of parents in such a choice. The questionnaire was created as a list of statements, and the task of the respondents is to estimate how much he/she agrees with the statement at the five point, Likert-type scale. The PCA revealed a clear four factor structure with high item loadings (all exceed .70) on designated factors after Oblimin rotation. The correlations between factor scores range from .22 to .54, indicating relative divergence between STEM areas. The reliabilities of the four STEM areas scales were: α_S = .91, α_T = . 93, α_E = .95, α_M = . 89, showing high reliability of scales of interest in STEM.

Procedure

This research is a part of wider longitudinal survey, *STEM career aspirations during primary schooling: A cohort-sequential longitudinal study of relations between achievement, self-competence beliefs, and career interests* (further information at www.jobstem.eu), conducted in 16 Croatian schools participating for four years in the survey. All schools were from the city of Zagreb and its soundings. The half of the schools were urban schools and other half were from the outskirts of the city. The data collection procedure was organized at the school level and scheduled during regular classes. All students were tested by trained research assistants in group assessment by paper and pencil method, and testing sessions lasted for two successive class periods (2 x 45 minutes) with a short 5-minute break in-between.

Data analyses

We have applied the Property Vector Fitting (PVF) procedure (Jones & Koehly, 1993; Kruskal & Wish, 1978) to integrate STEM interests into the RIASEC structural space. The PVF enables the visualization of structural relations by indicating the orientation and relation of other constructs in the RIASEC interest structure (Armstrong, Su, & Rounds, 2011). Firstly, we determined the location of the RIASEC types in a two-dimensional space by calculating the set of coordinates that adhere to the circular structure; coordinates for six RIASEC types represent Holland's RIASEC circumplex model with equal distances between adjacent types and are calculated to obtain vector lengths equal to 1: R (1.00, .00), I (.50, .87), A (-.50, .87), S (-1.00, .00) E (–.50, –.87), C (.50, -.87). Then, STEM interests were fitted into RIASEC space. The property scores were calculated for each STEM interest using a linear multiple regression procedure to regress scores for each STEM interest over the two coordinates in the circumplex. The salience of the STEM interests in the RIASEC structure was assessed by the variance accounted for (R^2) in the multiple regression procedure, which indicates how effectively STEM interests can be integrated into the RIASEC structure. We followed Kruskal and Wish's (1978) recommendation on the desirable strength of multiple correlations (desirable over .90, sufficient .70-.80) and adopted the cut-off point of $R > .70$ (or $R^2 > .49$) for a property sufficiently well integrated in the circumplex structure. Thus, only STEM interests for which vector length exceeded this cutting point are well integrated into RIASEC structure. In the final step, the vector's location (dimension loadings) of the property in the circumplex was calculated.

Results

As expected, girls expressed more Artistic and Social interests than boys, whereas boys had more interest in Realistic careers. This findings also support the construct validity of CVII as RIASEC interest measure used in this study. Regarding the measure of general STEM interests, it was found that boys have more interest in STEM occupations and activities than girls. In the four STEM fields, the biggest difference in interests was found in Technology and Engineering in favor of boys. A small but significant difference in favor of boys was found in Mathematics, and no gender difference in interests was observed in the Science field (Table 1).

Table 1. About here

The correlations between RIASEC interests and STEM interests were all positive and moderate (Table 2). These findings were to be expected due to the existence of a general factor of interests in all interest scores (Darcy & Tracey, 2003; Prediger, 1982; Rounds & Tracey, 1993). However, comparing the magnitude of the correlations, it can be observed that interest in Science was mostly related to Investigative interest in both gender samples. The same was true for STEM interest in Math and Technology. For the Engineering field the correlations with RIASEC domains are all similar and moderate. The general interest in STEM is mostly related to Investigative and then Realistic interests. The pattern of relation between STEM and RIASEC interests is very similar in the boys' and girls' samples, indicating that boys' and girls' correlation matrices do not differ substantially. The Log determinants for boys' and girls' variance-covariance matrices were -5.45 and -4.72, respectively, and the Spearman correlation between correlation coefficients in two matrices was $\rho = .843$. Consequently, the integration of STEM interests into RIASEC two-dimensional circumplex space was examined on combined sample data.

Table 2. About here

We wanted to examine how well and where STEM interests fit within a two-dimensional RIASEC circumplex. Therefore, we had to test the existence of Prediger's dimensions in RIASEC interest scores. The Principal Components analysis of RIASEC scores yielded three components, where the first one represents a general factor of interests with high loadings of all RIASEC scores (Table 3). The second and third components, after the rotation of 25°, correlate highly with the People-Things and Data-Ideas theoretical dimensions.

Table 3. About here

The results of Property Vector Fitting suggested that fitting the STEM interests within RIASEC space mostly repose along *People-Things* dimension (Table 9, Figure 1). However, only overall STEM interests, and interests in two STEM fields – toward careers in Technology and Engineering met the R^2 fit criteria, and can be well described by RIASEC two-dimensional circular model. It also should be noted that interests in careers in Science departure from other STEM measures. The interest in Science have directional cosine directed toward Ideas pole of circumplex and more to Investigative than Realistic interests.

Table 4. About here

Figure 1. About here

Considering that in the PVF method RIASEC coordinates represent perfect circumplex model, and that only mediocre fit of our data to hexagonal structure was observed, we have also fitted the STEM interests into empirically-given RIASEC space. We used RIASEC positions on second and third principal components (Table 3) and fitted the STEM interests into this two-dimensional space. In this empirical model (Figure 2) the positions of STEM interests were very similar to those in circumplex. Overall STEM interests and interests toward Engineering and Technology had high loadings on Things pole of People-Things dimension. The Math interests were located between Investigative and Realistic interests. The interests toward

Science moved off from other STEM interests and inclined more to Ideas pole of Data-Ideas dimension.

Figure 2. About here

Discussion

As expected, in general, boys expressed more interest in STEM occupations and activities than girls. The biggest difference in interests was found in Technology and Engineering, and a small but significant difference in favor of boys was found in Mathematics. These results mostly resemble findings of previous studies where gender differences in engineering interests had a very large effect size, whereas differences in science and mathematics were much smaller (Su et al., 2009). However, we did not observe significant gender difference in Science interests. That could be explained by the position of Science interests in the two-dimensional RIASEC space (Figure 1 & 2). The interests in Science depart from the People-Things dimension and incline more to the Ideas pole of RIASEC models. Lippa (1998) concluded that gender differences are strongly linked to the People–Things but not to the Ideas–Data dimension. Therefore, the absence of gender difference in Science interest in our results sounds logical.

The correlations between RIASEC and STEM interests were all positive and moderate. This finding can reasonably be interpreted as a consequence of existence of The General Factor of Interest (GFI) that can be found in many interest measures (Rounds & Tracey, 1993). Knowing that GFI accounts for approximately 40% of the variance in different scale scores (Prediger, 1982), moderate positive correlations were expected. However, some expected pattern of STEM – RIASEC correlations can be found. The overall interest in STEM was mostly related to Investigative and then Realistic interests. Interest in Science, Math and Technology had the highest correlation with Investigative interests. Relation between STEM interests and Holland's Investigative code were highly expected. As stated by Su and Rounds (2015), Investigative interests are the best indicator for interest in pursuing education or careers in STEM fields.

To more clearly relate STEM interests to RIASEC two-dimensional, *People-Things*, *Data-Ideas* structural space, we applied PVF procedure (Jones & Koehly, 1993). The PVF results suggested that STEM interests mostly lay along the *People-Things* dimension within RIASEC space. The relation between STEM interests and the People-Things pole of general interests is largely expected (e.g. Lubinski & Benbow, 2006; Woodcock et al., 2013). However, only general STEM interest and interest in Technology and Engineering careers met the R^2 fit criteria, and can be well described by the RIASEC two-dimensional model. Only 33% of career interest in the field of Mathematics, and only 39% of interests in Science can be explained by the RIASEC model. It also should be noted that interest in careers in Science departs from other STEM measures. It is directed toward the Ideas pole and inclines more to Investigative interest.

In the two-dimensional space derived from the empirical data, similar positions of STEM interests were observed. It seems that somewhat misshapen hexagon did not influence the basic structural relations between underlying RIASEC dimensions and interests in STEM areas.

It can be concluded that primary school children do not perceive STEM interests as a uniform field of vocational interests. They differentiate between interests in Science, Technology, Engineering and Mathematics, and fit them in wider zone around the Realistic and Investigative types in two-dimensional interest space. This finding corresponds to occupational codes (Gottfredson & Holland, 1996; Holland, 1985) whereby most STEM-related occupations are described by investigative and realistic dominant codes (i.e. RI or IR codes), but it also reveals that some STEM occupations can include elements of conventional or even artistic work environment.

Moreover, it was shown that the People-Things and Data-Ideas dimensions were not sufficient to adequately represent all STEM areas. Therefore, some other models that include more dimensions could be considered to better integrate STEM interests in the general vocational interest space. The Spherical Model of Interests (Tracey, 2002b) which includes the third dimension of Prestige may be promising. The high prestige of many STEM professions is obvious in the list of occupation codes related to prestige (Hout, Smith, & Marsden, 2015). Within the top 20 prestigious occupations, 13 are from the STEM field. Hence, it can be expected that Prestige dimensions of interest will account for a substantial portion of variance in STEM interests, beyond the People-Things dimension. It could be especially true for interests toward careers in fields of Science and Mathematics.

Some limitations of our findings should be noted. First, some of the instruments applied in this study were just developed and not yet cross-validated in other studies. They certainly capture a lot of sample-specific, or method variance in addition to substantial one. Method variance can artifactually inflate the observed correlations, between and within the constructs, which can lead to inaccurate conclusions on instruments' validity and relations to other constructs. However, method variance related to self-reported measures is not expected to be found in some more objective variables like gender, resulting in less likely inflated correlation with these variables (Spector, 2006). In this survey, we have found similar effect sizes of gender on interests as those reported in other studies (eg. Su et al., 2009; Su & Rounds, 2015). Furthermore, the general factor of RIASEC interest found in our data, which can be interpreted as method variance (Tracey, 2000), have similar eigenvalue to the general factors obtained on comparable samples (Šverko, 2008; Šverko & Babarović, 2006; Šverko et al., 2014). Those similarities also suggest that the method variance is not overrepresented in this study. However, further studies are needed for cross-validation of these instruments and reexamination of the findings.

The structure of interest of children aged 13 years is not yet fully formed, as it should be after the age of 14 (Low & Rounds, 2007; Low, Yoon, Roberts & Rounds, 2005, Šverko & Babarović, 2006, Tracey 2002a, Tracey & Rounds, 1993). The Randomization test applied to our sample yielded mediocre fit of data to the hexagonal structure, indicating some departures from the expected model. Thus, our PVF analysis, conducted in order to fit STEM interests into hypothetical two-dimensional circular RIASEC space, should be taken with caution. However, the positions of STEM interests in empirical RIASEC space were very similar to those in circumplex model. These findings suggest that misshaped structure of RIASEC interests do not substantially affect structural relations between STEM and RIASEC interests. Moreover, the positions of STEM interests in both RIASEC spaces are expected and logical and therefore support the general validity of the findings. It is hoped that, because the results presented in this paper are only a part of our wider longitudinal survey in which students' age cohorts are being followed and assessed during three consecutive years, the stability or variability these findings will be observed during the critical years of children's interest development.

In the end, we see several practical implications of these findings for career counselling and guidance in middle schools. The first is that middle-school children do not perceive STEM interests as a uniform group of interests. Children at that age differentiate their interests in Science, Technology, Engineering and Mathematics, and each STEM interest should be measured or assessed separately. This conclusion is in line with recent Rottinghaus, Falk & Park (2018) review on career assessment and counselling in STEM. The authors advocate that interests' measures should go beyond STEM as a monolithic domain to more specialized areas and more granular analysis. Secondly, gender differences in STEM interests among middle-school children were not very large, and were manifested mainly in the field of Engineering and Technology. Therefore, girls, in accordance with their interests, could easily be directed towards areas of Science and Mathematics. The small gender differences in STEM interests at age of 13, and notion that interests at are not jet fully structured can be a signal for career counsellors to invest efforts in retaining girls in the STEM field. Providing the gender-responsive counselling and guidance by promoting non-stereotypical education and career pathways can be a useful approach (Broadley, 2015; Rodríguez, Inda, & Fernández, 2016). Further on, based on STEM interests' positions within the RIASEC model, it is apparent that STEM interests cover a wide range of interests, from Conventional to almost Artistic. It is therefore possible to direct children of different RIASEC interests into STEM occupations that include some elements of desirable working environments. The O*NET list of STEM occupations expands the traditional definition of STEM fields by including related interdisciplinary areas, and therefore can serve as a useful tool for career counsellors. Finally, our results showed that RIASEC interest measures cannot explain equally well different types of STEM interests. Therefore, we suggest that in career counselling practice measuring interests towards Science and Mathematics should not exclusively rely on RISAEC based instruments.

References

Armstrong, P. I., Su, R., & Rounds, J. (2011). Vocational interests: The road less traveled. *The Wiley-Blackwell handbook of individual differences*, 608-631. DOI: 10.1002/9781444343120

Blickenstaff, J. (2005). Women and science careers: leaky pipeline or gender filter?. *Gender & Education, 17*(4), 369-386. DOI: 10.1080/09540250500145072

Borgen, F. H. (1986). New approaches to the assessment of interests. In W. B. Walsh & S. H. Osipow (Eds.), *Advances in vocational psychology: Vol. 1. The assessment of interests* (pp. 83- 125). Hillsdale, NJ: Erlbaum.

Broadley, K. (2015). Entrenched gendered pathways in science, technology, engineering and mathematics: engaging girls through collaborative career development. Australian *Journal of Career Development, 24* (1), 27-38. DOI: 10.1177/1038416214559548.

Brotman, J. S., & Moore, F. M. (2008). Girls and science: A review of four themes in the science education literature. *Journal of research in science teaching, 45*(9), 971-1002. DOI: 10.1002/tea.20241

Caprile, M., Palmén, R., Sanz, P., & Dente, G (2015) *Encouraging STEM studies: Labour Market Situation and Comparison of Practices Targeted at Young People in Different Member States.* European Parliament's Committee on Employment and Social Affairs. Brussels. European Commission.

Černja, I., Babarović, T., & Šverko, I. (2017) Mogu li diferenciranost i konzistentnost interesa biti pokazatelji profesionalne zrelosti osnovnoškolaca? [Could differentiation and consistency of interests serve as career maturity indicators of elementary school children?] *Društvena istraživanja, 26* (1), 41-58. doi:10.5559/di.26.1.03

Darcy, M., & Tracey, T. J. (2003). Integrating abilities and interests in career choice: Maximal versus typical assessment. *Journal of Career Assessment, 11*(2), 219-237. DOI: 10.1177/1069072703011002007

Day, S. X., & Rounds, J. (1998). Universality of vocational interest structure among racial and ethnic minorities. *American Psychologist, 53*(7), 728. DOI: DOI: 10.1037/0003-066X.53.7.728

Einarsdóttir, S., Rounds, J., Ægisdóttir, S., & Gerstein, L. H. (2002). The structure of vocational interests in Iceland: Examining Holland's and Gati's RIASEC models. *European Journal of Psychological Assessment, 18*(1), 85-95. DOI: 10.1027//1015-5759.18.1.85

European Commission. (2004). *Europe needs More Scientists: Report by the High Level Group on Increasing Human Resources for Science and Technology*. Brussels. European Commission.

Gottfredson, G. D., & Holland, J. L. (1996). *Dictionary of Holland occupational codes (3rd Ed.)*. Odessa, FL: Psychological Assessment Resources.

Gottfredson, L. S. (1996). Gottfredson's theory of circumscription and compromise. In D. Brown & L. Brooks (Eds.), *Career choice and development* (3rd ed., pp. 179-232), San Francisco: Jossey-Bass.

Hartung, P. J., Porfeli, E. J., & Vondracek, F. W. (2005). Child vocational development: A review and reconsideration. *Journal of Vocational Behavior, 66*, 385-419. DOI: 10.1016/j.jvb.2004.05.006

Hedrih, V. (2008). Structure of vocational interests in Serbia: Evaluation of the spherical model, *Journal of Vocational Behavior, 73*, 13-23. DOI: 10.1016/j.jvb.2007.12.004

Holland, J. L. (1959). A theory of vocational choice. *Journal of Counseling Psychology, 6*, 35-45. DOI: 10.1037/h0040767

Holland, J. L. (1985). *The Self Directed Search: Specimen Set.* Psychological Assessment Resources.

Holland, J. L. (1997). *Making vocational choices: A theory of vocational personalities and work environments (3rd ed.).* Odessa, FL: Psychological Assessment Resources, Inc.

Hout, M., Smith, T.W. & Marsden, P.W. (2015). *Prestige and Socioeconomic Scores for the 2010 Census Codes.* (GSS Methodological Report No. 124). Retrieved from http://gss. norc. org/get-documentation/methodological-reports.

Hubert, L., & Arabie, P. (1987). Evaluating order hypotheses within proximity matrices. *Psychological Bulletin*, 102, 172–178. DOI: 10.1037/0033-2909.102.1.172

Jones, L. E., & Koehly, L. M. (1993). Multidimensional scaling. In G. Kern & C. Lewis (Eds.), *A handbook for data analysis in the behavioral sciences: Methodological issues* (pp. 95–163). Hillsdale, NJ: Erlbaum.

Kier, M. W., Blanchard, M. R., Osborne, J. W., & Albert, J. L. (2014). The development of the STEM career interest survey (STEM-CIS). *Research in Science Education, 44*(3), 461-481. DOI: 10.1007/s11165-013-9389-3

Kruskal, J. B., & Wish, M. (1978*). Multidimensional scaling (Vol. 11).* Sage.

Lippa, R. (1998). Gender-related individual differences and the structure of vocational interests: The importance of the people-things dimension. *Journal of Personality and Social Psychology, 74*, 996–1009. DOI: 10.1037/0022-3514.74.4.996

Low, K. S. D., & Rounds, J. (2007). Interest change and continuity from early adolescence to middle adulthood. *International Journal for Educational and Vocational Guidance, 7*(1), 23-36. DOI: 10.1007/s10775-006-9110-4

Low, K. S. D., Yoon, M., Roberts, B. W., & Rounds, J. (2005). The stability of vocational interests from early adolescence to middle adulthood: A quantitative review of longitudinal studies. *Psychological Bulletin*, *131*(5), 713-737. DOI:10.1037/0033-2909.131.5.713

Lubinski, D., & Benbow, C. P. (2006). Study of mathematically precocious youth after 35 years: Uncovering antecedents for the development of math-science expertise. *Perspectives on psychological science, 1*(4), 316-345. DOI: 10.1111/j.1745-6916.2006.00019.x

Mitchell, S., & Hoff, D. (2006). (Dis)Interest in Science: How Perceptions About Grades May Be Discouraging Girls. *Electronic Journal of Science Education*, *11*(1), 10-21.

Nagy, G., Trautwein, U., & Lüdtke, O. (2007). The structure of vocational interests in Germany: Different methodologies, different conclusions. Journal of Vocational Behavior, DOI: 10.1016/j.jvb.2007.07.002

Olson, M. (2009). *The logic of collective action (Vol. 124).* Harvard University Press.

O*NET. The Occupational Information Network, US Department of Labor/Employment and Training, Retrieved from https://www.onetonline.org

Osborne, J., & Dillon, J. (2008). *Science Education in Europe: Critical Reflections*. London: The Nuffield Foundation.

Prediger, D. J. (1982). Dimensions underlying Holland's hexagon: Missing link between interests and occupations? *Journal of Vocational Behavior, 21*, 259-287. DOI: 10.1016/0001-8791(82)90036-7

Riegle-Crumb, C., Moore, C., & Ramos-Wada, A. (2011). Who wants to have a career in science or math? Exploring adolescents' future aspirations by gender and race/ethnicity. *Science Education, 95*(3), 458-476. DOI: 10.1002/sce.20431

Rottinghaus, P. J., Falk, N. A., &.Park, C. J. (2018). Career assessment and counseling for. STEM: A critical review. *Career Development Quarterly, 66*(1), 2-34. DOI: 10.1002/cdq.12119

Rodríguez C., Inda, M., & Fernández, M.C. (2016). Influence of social cognitive and gender variables on technological academic interest among Spanish high-school students: testing social cognitive career theory. *International Journal for Educational and Vocational Guidance, 16*(3), 305-325. DOI: 10.1007/s10775-015-9312-8

Rounds, J. B., & Tracey, T. J. G. (1993). Prediger's dimensional representation of Holland's RIASEC circumplex. *Journal of Applied Psychology, 78*, 875-890. DOI: 10.1037/0021-9010.78.6.875

Rounds, J. B., Tracey, T. J. G., & Hubert, L. (1992). Methods for evaluating vocational interest: Structural hypotheses. *Journal of Vocational Behavior*, 40, 239–259. DOI: 10.1016/0001-8791(92)90073-9

Rounds, J., & Day, S. X (1999). Describing, evaluating, and creating vocational interest structures. In M. L. Savickas & A. R. Spokane (Eds.), *Vocational interests: Their meaning, measurement and use in counseling* (pp. 103-133). Palo Alto, CA: Davies-Black

Rounds, J., & Tracey, T. J. G. (1996). Cross-cultural structural equivalence of RIASEC models and measures. *Journal of Counseling Psychology*, *43*, 310-329. DOI: 10.1037/0022-0167.43.3.310

Rounds, J.B. (1995). Vocational interests: Evaluating structural hypotheses. In D. Lubinski & R.V. Dawis (Eds.), *Assessing individual differences in human behavior: New concepts, meth- ods, and findings* (pp. 177-232). Palo Alto, CA: Consulting Psychologists Press.

Sadler, P. M., Sonnert, G., Hazari, Z., & Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study, *Science Education, 96(3)*, 411-427. DOI 10.1002/sce.21007

Shatkin L. (2011). *STEM Careers Inventory - Administrator's Guide*. Indianapolis, IN: JIST Publishing.

Sodano, S. M. (2011). Integrating vocational interests, competencies, and interpersonal dispositions in middle school children. *Journal of Vocational Behavior, 79*, 110-120. DOI: 10.1016/j.jvb.2010.12.013

Spector, P. E. (2006). Method Variance in Organizational Research: Truth or Urban Legend? *Organizational Research Methods, 9*(2), 221-232. DOI: 10.1177/1094428105284955

Su, R., & Rounds, J. (2015). All STEM fields are not created equal: People and things interests explain gender disparities across STEM fields. *Frontiers in psychology*, 6, 189. DOI: 10.3389/fpsyg.2015.00189

Su, R., Rounds, J., Armstrong, P. I. (2009). Men and things, women and people: A meta-analysis of sex differences in interests. *Psychological Bulletin, 135*, 859-884. DOI: 10.3389/fpsyg.2015.00189

Super, D. E. (1953). A theory of vocational development. *American Psychologist, 8*(5), 185-190. DOI: 10.1037/h0056046

Šverko, B. (Ed.) (1998). *Vodič kroz zanimanja* [*Careers Guide*]. Zagreb: Razbor.

Šverko, I. (2008). Spherical model of interests in Croatia. *Journal of Vocational Behavior, 72*(1), 14-24. DOI: 10.1016/j.jvb.2007.10.001

Šverko, I., & Babarović, T. (2006). The validity of Holland's theory in Croatia. *Journal of Career Assessment, 14*, 490-507. DOI: 10.1177/1069072706288940

Šverko, I., Babarović, T., & Međugorac, V. (2014). Pictorial assessment of interests: Development and evaluation of Pictorial and Descriptive Interest Inventory. *Journal of Vocational Behavior, 84*(3), 356-366. DOI: 10.1016/j.jvb.2014.02.008

Tai, R. T., Liu, C. Q., Maltese, A. V., & Fan, X. T. (2006). Planning early for careers in science. *Science*, *312*, 1143-1144. DOI: 10.1126/science.1128690

Tracey, T. J. G., & Caulum, D. (2015). Minimizing gender differences in children's interest assessment: Development of the Inventory of Children's Activities-3 (ICA-3). *Journal of Vocational Behavior, 87*, 154-160. DOI: 10.1016/j.jvb.2015.01.004

Tracey, T. J. G. & Rounds, J. B. (1993). Evaluating Holland’s and Gati’s vocational interest models: A structural meta-analysis. *Psychological Bulletin*, *113*(2), 229-246. DOI: 10.1037/0033-2909.113.2.229

Tracey, T. J. G. (2000). Analysis of circumplex models. In H. E. A. Tinsley & S. D. Brown (Eds.), *Handbook of applied multivariate statistics and mathematical modeling* (pp. 641-664). San Diego, CA, US: Academic Press.

Tracey, T. J. G. (2001). The development of structure of interests in children: Setting the stage. Journal of Vocational Behavior, 59, 1-16. DOI: 10.1006/jvbe.2000.1787

Tracey, T. J. G. (2010). Development of an abbreviated Personal Globe Inventory using item response theory: The PGI-Short. *Journal of Vocational Behavior, 76*(1), 1-15. DOI: 10.1016/j.jvb.2009.06.007

Tracey, T. J. G. (2002a). Development of interests and competency beliefs: A 1-year longitudinal study of fifth- to eighth-grade students using the ICA-R and structural equation modeling. *Journal of Counseling Psychology, 49*, 148–163. DOI: 10.1037/0022-0167.49.2.148

Tracey, T. J. G. (2002b). Personal Globe Inventory: Measurement of the spherical model of interests and competence beliefs. *Journal of Vocational Behavior, 60*, 113-172. DOI:10.1006/jvbe.2001.181

Tracey, T. J. G., & Robbins, S. B. (2005). Stability of interests across ethnicity and gender: A longitudinal examination of Grades 8 through 12. *Journal of Vocational Behavior, 67,* 335-364. DOI:10.1016/j.jvb.2004.11.003

Tracey, T. J. G., Robbins, S. B., & Hofsess, C. D. (2005). Stability and change in adolescence: A longitudinal analysis of interests from grades 8 through 12. *Journal of Vocational Behavior, 66*, 1–25. DOI: 10.1016/j.jvb.2003.11.002

Tracey, T. J. G., & Ward, C. C. (1998). The structure of children's interests and competence perceptions. *Journal of Counseling Psychology, 45*(3), 290. DOI: 10.1037/0022-0167.45.3.290

Usher, E. L. (2009). Sources of middle school students' self-efficacy in mathematics: A qualitative investigation. *American Educational Research Journal, 46(1)*, 275–314. DOI: 10.3102/0002831208324517

Watson, M., & McMahon, M. (2005). Children's career development: A research review from a learning perspective. Journal of Vocational Behavior, 67, 119-132. DOI:10.1016/j.jvb.2004.08.011

Watson, M., Nota, L., & McMahon, M. (2015). Evolving stories of child career development. *International Journal for Educational and Vocational Guidance, 15*, 175-184. DOI: 10.1007/s10775-015-9306-6

Woodcock, A., Graziano, W. G., Branch, S. E., Habashi, M. M., Ngambeki, I. & Evangelou, D. (2013). Person and thing orientations: Psychological correlates and predictive utility. *Social psychological and personality sciences. 3*(2), 116-123. DOI: 10.1177/1948550612444320

Figure

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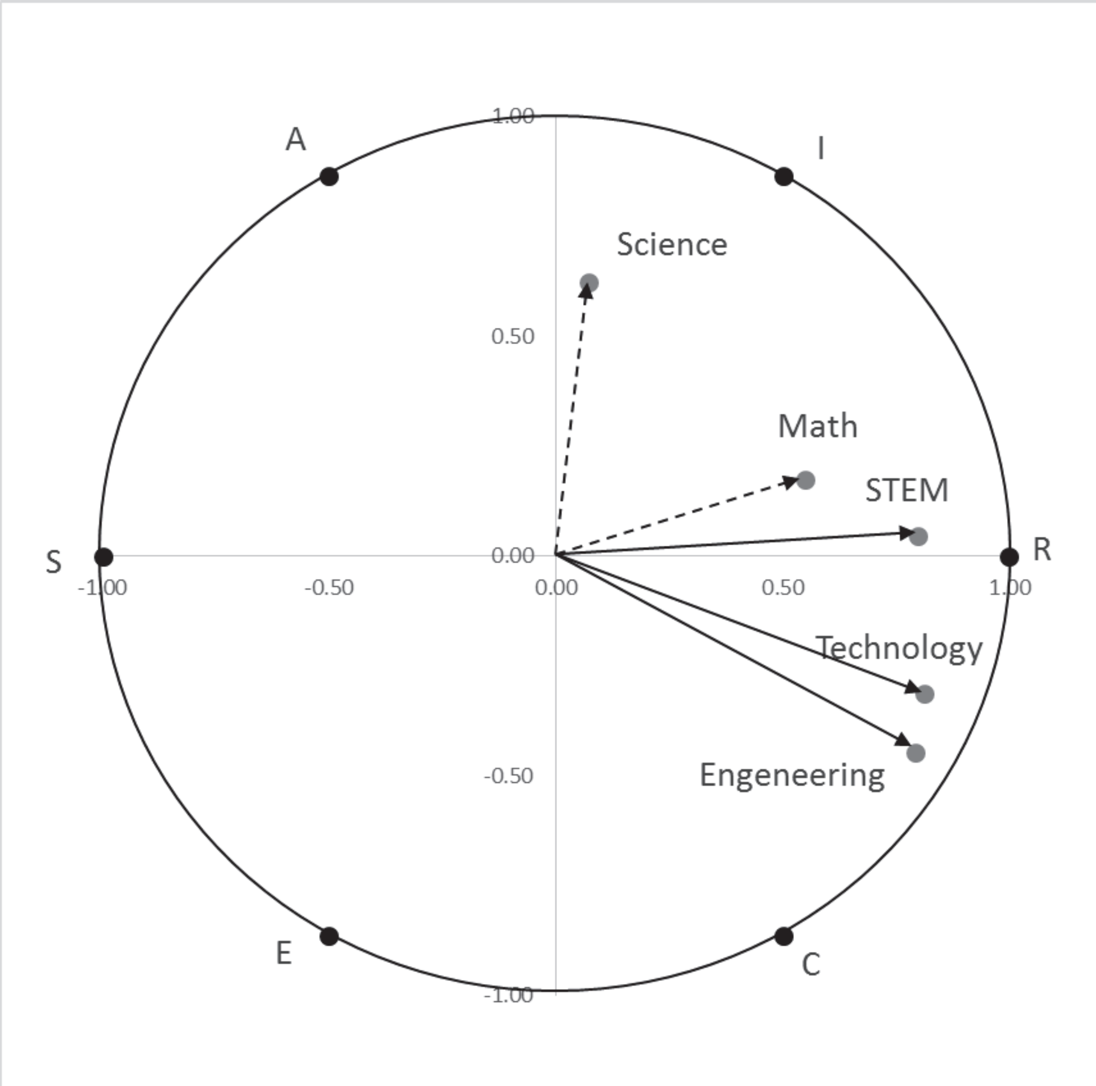

Figure 1. STEM interests integrated into a two-dimensional RIASEC interests' circumplex (Property vector fitting).

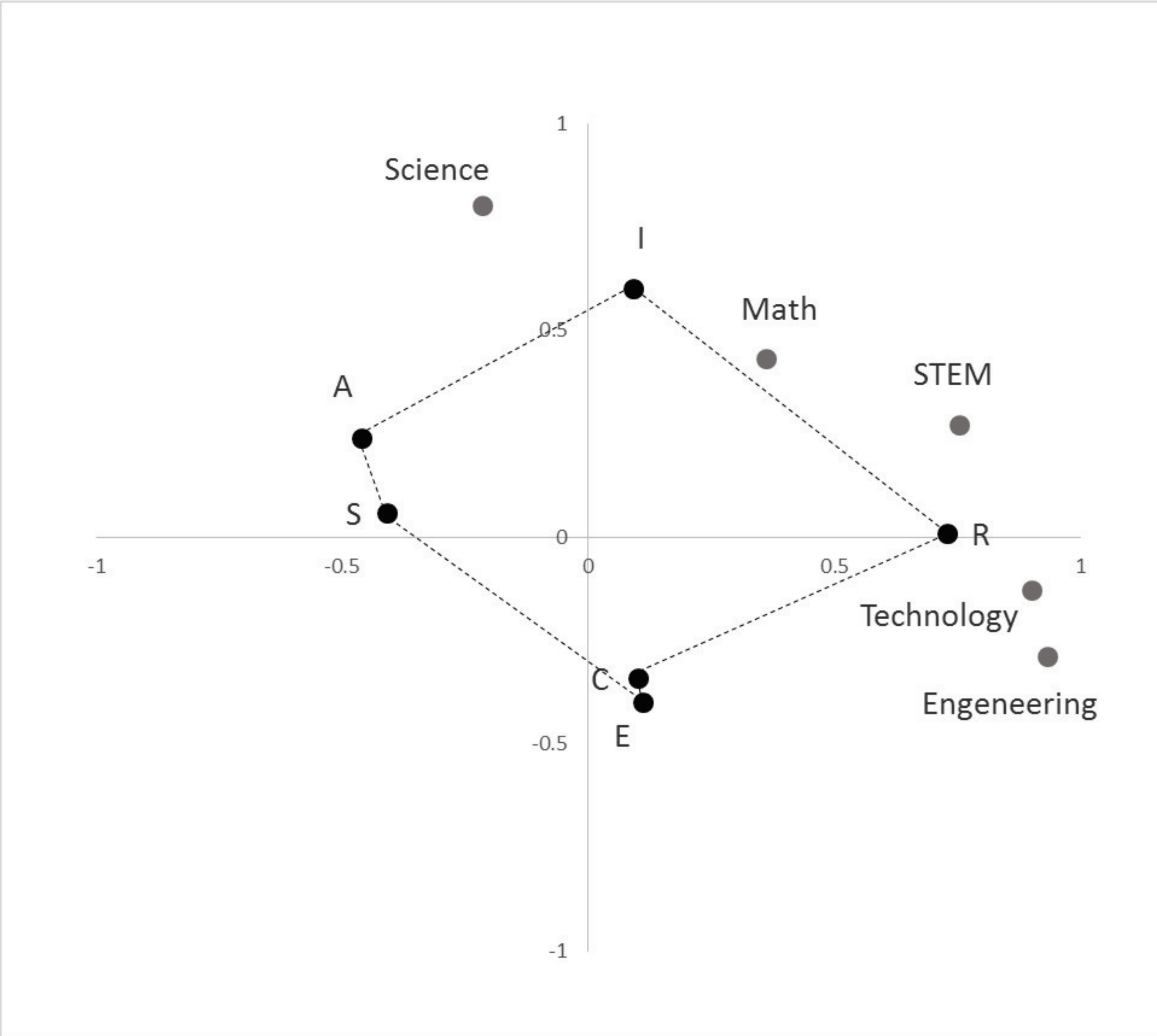

Figure 2. Position of STEM interests in empirically-given two-dimensional RIASEC interests' space.

Table 1. *Elementary school students' RIASEC and STEM interests by gender* (n_m=336; n_f=291, listwise)

	Gender	*M*	*SD*	*t-test*	*p*	*Partial* η^2
R	M	2.13	.87	9.35	.001	.117
	F	1.57	.61			
I	M	2.83	.90	-.64	.523	.001
	F	2.87	.77			
A	M	2.13	.89	-13.09	.001	.220
	F	3.05	.87			
S	M	2.07	.88	-1.93	.001	.165
	F	2.85	.90			
E	M	2.57	.96	1.37	.172	.003
	F	2.47	.82			
C	M	2.19	.90	-.54	.650	.001
	F	2.23	.83			
Science	M	2.79	1.25	-1.00	.320	.002
	F	2.89	1.15			
Math	M	2.84	1.22	2.50	.013	.010
	F	2.61	1.05			
Technology	M	3.52	1.20	8.83	.001	.111
	F	2.69	1.16			
Engineering	M	2.89	1.31	8.34	.001	.097
	F	2.11	1.02			
STEM interests	M	2.75	.86	8.00	.001	.089
	F	2.26	.69			

Table 2. *Correlations between RIASEC and STEM interests* (n_m=336; n_f=291, listwise)

	R	I	A	S	E	C	Science	Math	Tech.	Engin.	STEM
R	*(.85)*	.41	.38	.41	.47	.54	.14	.23	.30	.34	.56
I	.32	*(.74)*	.44	.52	.36	.40	.61	.48	.38	.20	.76
A	.42	.52	*(.85)*	.44	.38	.29	.17	.12	.17	.06	.38
S	.39	.59	.69	*(.85)*	.58	.59	.13	.15	.17	.07	.36
E	.48	.46	.56	.63	*(.84)*	.81	.06	.26	.33	.31	.40
C	.52	.50	.60	.71	.82	*(.85)*	.04	.30	.33	.31	.43
Science	.09	.75	.32	.38	.23	.28	*(.91*	.42	.28	.26	.59
Math	.15	.52	.18	.19	.18	.24	.51	*(.89)*	.47	.38	.53
Technology	.29	.36	.19	.19	.26	.28	.28	.43	*(.93)*	.50	.56
Engineering	.38	.42	.30	.31	.36	.39	.37	.45	.51	*(.95)*	.45
STEM	.49	.73	.38	.41	.42	.47	.63	.48	.52	.56	*(.93)*

*Correlations for the male sample are below the main diagonal, and for the female sample are above the main diagonal; all correlations are significant at p < .01 level. Reliability coefficients for the scales (Cronbach Alphas) are in brackets in the main diagonal.

Table 3. *Factor structure of RIASEC interests: factor loadings and correlation with Prediger's theoretical dimensions*

		Components			After 25° rotation	
		1	2	3	2	3
Realistic		.66	.57	.34	.73	.01
Investigative		.76	-.11	.49	.09	.60
Artistic		.70	-.56	.04	-.46	.24
Social		.84	-.33	-.09	-.41	.06
Enterprising		.84	.26	-.33	.11	-.40
Conventional		.87	.19	-.31	.10	-.34
Prediger's theoretical dimensions	*Tings - People*				.949	-.295
	Ideas - Data				.111	.841

Table 4. *Dimension loadings and R^2 values for STEM interests in two dimensional RIASEC interest space (Property Vector Fitting)*

	dimension 1 *Things-People*	dimension 2 *Ideas-Data*	R^2
Science	.07	.62	.39
Math	.55	.17	.33
Technology	.82	-.32	.76*
Engineering	.80	-.45	.83*
STEM	.80	.05	.64*

* Exceeds the cut-off criteria of R^2 >.49, indicating sufficient loadings