Received: 17 June 2020 | Accepted: 22 February 2021

DOI: 10.1111/bjet.13077

ORIGINAL MANUSCRIPT

British Journal of Educational Technology BERA

Exploring the role of 3D printing and STEM integration levels in students' STEM career interest

Li Cheng[1] | **Pavlo "Pasha" Antonenko**[1] | **Albert D. Ritzhaupt**[1] | **Bruce MacFadden**[2]

[1]School of Teaching and Learning, College of Education, University of Florida, Gainesville, FL, USA

[2]Florida Museum of Natural History, University of Florida, Gainesville, FL, USA

Correspondence
Li Cheng, School of Teaching and Learning, College of Education, University of Florida, 2423 Norman Hall, PO BOX 117048, Gainesville, FL 32611, USA.
Email: licheng@ufl.edu

Funding information
National Science Foundation, Grant/Award Number: 1510410

Abstract

The use of 3D printing in science, technology, engineering and mathematics (STEM) learning is a promising way for integrated STEM education. This study examined the influence of 3D printing infused STEM integration on students' interest in STEM careers, which is essential for students to participate in STEM disciplines and future STEM careers. The participants included 26 teachers across six states in the United States and their 1455 students in primary and secondary classrooms. Teachers' lesson plans were analysed to examine the level of 3D printing and STEM integration. Students' interest in STEM careers was measured using a previously validated career interest scale. Cluster analysis and multiple regression analysis indicated that girls were more interested in empathetic STEM careers, whereas boys were more interested in analytic STEM careers. While 3D printing integration level was not a significant predictor, teachers' STEM integration level positively predicted students' interest in both analytic and empathetic STEM careers.

KEYWORDS

3D printing, STEM career interest, STEM integration

Practitioner notes

What is already known about this topic

- Student career interest in primary and secondary school predicts college degree and career choice.
- 3D printing has the potential to improve students' interest in STEM careers.
- STEM career interest is associated with student gender.

What this paper adds

- This study examined the role of 3D printing and STEM integration level and student gender in students' STEM career interest.
- Teachers' 3D printing integration level was not a significant predictor, but STEM integration level positively predicted students' interest in STEM careers.
- This study confirmed that boys were more interested in Analytic STEM careers, whereas girls were more interested in Empathetic STEM careers.

Implications for practice and/or policy

- Student STEM career interest improves when teachers integrate STEM in their instruction.
- STEM instruction can be made relevant by focusing on empathetic aspects of STEM for girls, but caution should be exercised to minimise stereotyping.

INTRODUCTION

Science, technology, engineering and mathematics (STEM) are critical for a nation's economic development and are fundamental aspects of our lives (National Research Council, 2011). STEM knowledge and skills are used to address global challenges to the 21st-century society, such as global climate change, biodiversity crisis, as well as local, regional and global health issues, energy production and food security for our flat society. Most 21st century jobs require a certain level of STEM knowledge and skills (National Research Council, 2011). There has been an increasing need for an adequately prepared STEM workforce and increasing demand for workers with STEM skills and competencies (Honey et al., 2014). Yet, the percentage of students who choose to major in STEM fields in high schools and universities has been stagnant (George, 2006; Varma, 2010).

Research suggests that students' interest in STEM careers is influential to their STEM learning and future career choices. Specifically, students' interest in STEM leads to continuous engagement in STEM learning (Maltese et al., 2014) and many studies indicate that students' interest in STEM is closely related to their future career choices (eg, Christensen & Knezek, 2017; Maltese & Tai, 2011; Sadler et al., 2012; Tai et al., 2006). Furthermore, students' interest in STEM careers can increase the possibility of selecting STEM careers. All in all, students' interest in STEM careers is essential for students to participate in STEM disciplines and STEM careers.

As one of the subject areas of STEM education, science has been facing a lack of student motivation and engagement, and it is challenging for teachers to keep students engaged in science learning (Schmidt et al., 2018). Since science is a core subject of STEM education and the subjects in STEM are intercorrelated, integrated STEM education in science classrooms has a great potential to enhance students' STEM interest in STEM careers and also to increase student participation and persistence in STEM learning and strengthen the future STEM workforce. Relatedly, the rapid development and greater accessibility of today's technology have resulted in dramatic increases in technology integration to promote integrated STEM learning (Honey et al., 2014; Urban & Favlo, 2016). As an emerging technology in K-12 education, 3D printing has gained attention from teachers, administrators and researchers (eg, Chien & Chu, 2018; Kwon, 2017; Nemorin & Selwyn, 2017; Ng, 2017; Novak & Wisdom, 2018) and many schools have invested in 3D printing technologies (Thornburg et al., 2014). However, the integration of 3D printing in the science curriculum is scarce and little is known about how 3D printing integrated STEM education may influence students' interest in STEM careers, which is essential for students to participate in STEM disciplines and future STEM careers. Given this context, the purpose of this study was to examine how teachers' integration of 3D printing in science classrooms influenced students' interest in STEM careers.

CONCEPTUAL FRAMEWORK

Students' interest in STEM careers

Interest is a relational concept consisting of the relationship between an individual and an object or activity (Krapp, 2002; Schiefele, 2009). Specifically, interest is a psychological state which is "a particular relation of that individual in engagement with that play object/task, relative to the other activities with which he or she engages" (Renninger, 1992, p. 362). Interest can be mediated by the interaction between the individual and the object or activity and both personal factors and environmental factors can influence interest (Mitchell, 1993; Renninger & Hidi, 2002). Research suggests that student interest has a powerful influence on learning in terms of students' attention, goals and levels of learning (Hidi & Renninger, 2006). In short, interest is an essential motivational and driving force for learning (Dewey, 1913).

Interest is also a critical factor in predicting future engagement in STEM activities and careers (National Research Council, 2007). In the context of STEM learning, strong associations have been found amongst students' STEM learning interest, interest in STEM careers and intention to pursue a STEM major or career. For example, Sadler et al. (2012) revealed that students' interest in STEM at the start of high school was a key predictor of their STEM career interest when they graduated. Christensen and Knezek (2017) collected data from over 800 middle school students who participated in a hands-on and real-world application curriculum and examined the relationship between students' STEM interest and their intentions to pursue STEM careers. Results showed that students' interest in STEM positively aligned with their intent to pursue STEM careers. Maltese and Tai (2011) found that eighth-grade students who had an interest in a science career and believed science would be useful in their future were more likely to earn a bachelor's degree in a STEM discipline.

STEM career interest and student gender

STEM careers' interest is known to be mediated by gender differences. For example, DeWitt et al. (2013) conducted a longitudinal mixed-method study of 9000 10–11 year olds in England and found that girls express a greater decline in STEM career interest over their course of study at school. Other scholars report that girls' interest in STEM begins and remains lower than that of boys (Frenzel et al., 2010). Several studies have also revealed that while there exists no measurable STEM achievement gap between girls and boys, girls do tend to express lower interest in STEM careers than boys (Corbett & Hill, 2015; Cunningham et al., 2015). A national study in the United States explored the trajectories of STEM career interest changes during high school with a representative national sample of about 6000 students and showed that little has changed in terms of K-12 students' career aspirations since the first studies of STEM career interest a decade ago (Sadler et al., 2012). Large gender differences in career plans were found, with males showing far more interest in STEM careers. Additionally, Sadler and colleagues (2012) found both lower retention of STEM career interest amongst females and a greater difficulty in attracting females to STEM fields during high school. While the percentage of male high-schoolers interested in a STEM career remained stable (from 39.5 to 39.7), the percentage of girls considering a STEM career declined from 15.7 to 12.7 (Sadler et al., 2012). As we can see, somewhere along the educational pathway many students, particularly girls, lose (or never develop) interest in STEM and by the time students are ready to go to college, only a small percentage actually pursue a degree that will lead to future STEM careers (Whalen & Shelley, 2010).

Research suggests that students' gender differences in STEM careers may align with their preferences of working with people or objects. A strand of research indicates that females are more interested in careers that involve social relations (eg, medicine), while males are more interested in fields that interact with inanimate objects (eg, physics) (Ceci & Williams, 2010). A meta-analysis study (Su et al., 2009) that synthesised the effects of gender differences on career interest found males prefer working with things, while females prefer working with people, with a large effect size ($d = 0.93$). Careers involving working with inanimate objects are conceptualised as analytic STEM careers (Burns et al., 2016) as they typically involve computation and interact with objects to solve problems. STEM careers such as environmental science, biology and medicine are conceptualised as empathetic as they entail empathy for intensive interaction with lives including people and animals, and they are deemed as having significant social value (Burns et al., 2016; Godwin & Potvin, 2015). According to Ceci and Williams (2010), girls choose not to pursue analytic STEM careers such as engineering, physics, mathematics, chemistry, economics and computer science at a young age and few adolescent girls prefer to be engineers or physicists, but instead would like to be medical doctors, veterinarians, biologists, etc. What is more, females are less interested in analytic STEM careers even if they have high math aptitude and better performance in math and science at school (Ceci & Williams, 2010; Lubinski & Benbow, 2006).

Integrating STEM in classrooms using 3D printing

Integrated STEM education is "an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems" (Moore et al., 2014, p. 38). For example, students measure and compare and contrast 3D printed teeth of ancient human beings to learn both math concepts and how ancient human beings' teeth and diet evolved during human revolution (Cheng et al., 2020). Integrated STEM learning experiences can enhance students' interest and motivation in STEM which leads to continuous engagement in STEM learning (Maltese et al., 2014). Integrated STEM activities make learning more connected and relevant for students (Stohlmann et al., 2012), encourage students' imagination and curiosity and increase their motivation to learn (Laboy-Rush, 2011) and support students' interest development (Honey et al., 2014).

The emergence of 3D printing technologies in K-12 education has brought great opportunities for integrating STEM. Three-dimensional (3D) printing is additive manufacturing with the "process of building a physical object, layer by layer, from a three-dimensional digital model" (Gonzalez & Bennett, 2016, p. 11). The 3D digital model can be created with software like Tinkercad or 3D scanners. In this paper, 3D printing is used as an umbrella term to represent all technologies involved in the 3D printing process. In recent years, 3D printing technologies have become more affordable and many schools have 3D printing technologies (Thornburg et al., 2014). Research on the integration of 3D printing technologies in various K-12 disciplines has also started to emerge. A few studies have focused on the integration of 3D printing technology in STEM disciplines, including mathematics (Ng, 2017), science (Grant et al., 2017; Koehler, 2017) and engineering (Chien, 2017; Chien & Chu, 2018; Hsiao et al., 2019; Weber et al., 2017). The integration of 3D printing technology in STEM disciplines showed varied impacts on students' cognitive learning outcomes including learning performance and spatial ability, creativity and technical skills, and also affective learning outcomes such as attitudes, engagement and motivation (Cheng et al., 2020). Bicer et al. (2017) engaged 95 U.S. high schoolers in 3D computer-aided design and 3D printing activities over a two-week summer camp experience and revealed higher level of 3D printing resulted in significant improvements in students' perceptions about creativity (d = 0.61) and problem-solving skills (d = 0.66) required for STEM careers. In another study, Ali and colleagues (2019) examined changes in 276 UAE elementary students' interest in STEM careers as they engaged in STEM 3D printing activities in the classroom. The results of path analyses in this study showed that after accounting for student demographic characteristics, higher level of 3D printing integration was associated with improved perceived usefulness of 3D printing, self-concept in using 3D printing and interest in and enjoyment of using 3D printing technology, which was significantly and positively related with interest in STEM careers amongst female elementary students. Despite these few recent studies, the relationship between 3D printing integration level in the science context and students' STEM career interest has not been explicitly examined.

METHOD

Research questions

Meaningful integration of STEM education using 3D printing is still in its infancy and little is known about the impact of 3D printing integrated STEM education on students' interest in STEM careers. Given the theoretical and empirical background discussed above, this study sought to investigate how 3D printing and STEM integration levels in science classrooms influence girls' and boys' interest in STEM careers. Specifically, this study addressed the following research question:

- To what extent does teachers' 3D printing integration level and STEM integration level influence girls' and boys' interest in STEM careers?

Context

In this study, integration of STEM was achieved using 3D printing in the classroom within the context of a highly relevant but unexplored educational pathway to STEM in most schools—paleontology. Paleontology is a multidisciplinary science that organically integrates concepts and skills from diverse disciplines including biology, environmental science, geology, oceanography and anthropology. It is the only science that can document the immense record of biodiversity in Deep Time, accounting for more than 99% of the species that have ever existed on earth. Through its documentation of earth history, paleontology is uniquely positioned to provide evidence of ‘hot topics’ (AAAS, 2002) of great relevance in modern society, including evolution and global climate change, and improve students' interest in STEM degrees and careers.

This study worked with teachers who designed integrated STEM lesson plans (see Appendix C) using the context of paleontology and 3D printing to bring the earth's fossil record into the classroom. Many activities involved students in 3D scanning and 3D printing fossils and analysing those scans and prints, while learning important science concepts such as extinction, evolution and climate change. One example was a lesson that spanned five 50-minute class periods and addressed the following guiding question: "What biotic and abiotic factors have changed shark's teeth over time?" The lesson included three main activities: (a) sorting shark teeth to bring out students' initial (mis)conceptions and discover that shark teeth vary, (b) sorting shark teeth like paleontologists to discover that their structure differs greatly based on their function and (c) analysing the 3D printed teeth of Otodus, Mako, Hastalis, Megalodon, Great White and determining when these sharks lived using the geological time scale and what they ate.

Each teacher implemented one lesson on a topic. Most of the lessons were taught in one or two class periods and a few lessons had several more class periods. We intended to include implementation duration in the analysis; however, the duration provided in the lesson plans did not allow consistent coding. For instance, some lesson plans just provided the number of days or weeks without specific class periods information and the time for one class period varied from teacher to teacher. Therefore, we did not include the implementation duration for analysis.

Participants

The participants in this study were a portion of teachers and students who participated in a project that integrated 3D printing technologies in science classrooms within the context of paleontology. The project involved 46 teachers and their students from nine states in the United States. Due to attrition in collecting teachers' lesson plans and students' STEM career interest survey data, we were only able to include 26 teachers and their students' data for this study. After data cleaning and screening of students who completed both the pretest and posttest with the STEM career survey, a total number of $N = 1455$ students were included in the data analysis. Student participants included 187 elementary students, 814 middle school students and 454 high school students. About half of the students identified as male ($n = 681$) and 774 students identified as female. Students' race/ethnicity (Table 1) was diverse, including White, Hispanic, Mixed race or multi-race, Asian, etc.

Amongst the 26 teachers, four identified as male and 22 identified as female (Table 2). There were four elementary teachers, 13 middle school teachers and nine high school teachers. The majority of the teachers were White, with two African American teachers, two Hispanic teachers and two mixed-race teachers. The teachers were across six states including Oklahoma, California, Georgia, Texas, Louisiana and Florida.

Data collection and instrumentation

Teachers' lesson plans were collected after the implementation of 3D printing in their science classrooms to give them the chance to update their lesson plans to reflect the actual implementation of 3D printing. Lesson plan codebooks were developed to analyse teachers' 3D printing integration level and STEM integration level. The codebooks were reviewed by three educational technology experts and revisions were made based on their suggestions to ensure the construct validity. The lesson plans were scored using the codebooks and re-scored a week later by the first author to check the scoring reliability. The percentage of scoring consistency was 92.3%. The minor discrepancies were reviewed and corrected.

TABLE 1 Student demographics

Demographics	Student *N*
Gender	Male (681); Female (774)
School level	Elementary (187); Middle (814); High (454)
Race/Ethnicity	White (704); Hispanic (188); Mixed race or multi-race (141); Asian (99); Black or African American (92); American Indian or Alaska Native (64); Native Hawaiian or other Pacific Islander: (19); Other (115); Do not wish to answer (33)

TABLE 2 Teacher demographics

Demographics category	Teacher *N*
Gender	Male (4); Female (22)
School level	Elementary (4); Middle (13); High (9)
Race/Ethnicity	White (20); African American (2); Hispanic (2); Mixed race (2).
State	Oklahoma (4); California (9); Georgia (3); Texas (1); Louisiana (1); Florida (8)

3D printing integration codebook

Because the current study focused on the integration of a specific technology—3D printing—and in a particular content area—science, level of 3D printing integration were assessed using a custom instrument adapted from general technology integration assessment instruments (Britten & Cassady, 2005; Harris et al., 2010; Pringle et al., 2015) to focus on the integration of 3D printing technology in science classes. Codebook design was also guided by the Technology Integration Matrix (TIM) (Welsh et al., 2011) which illustrates the level of technology integration and meaningful learning environments.

The level of 3D printing integration included entry, adoption, adaptation, infusion and transformation (Harmes et al., 2016). Specifically, the level was determined by how 3D printing was used and how the integration engaged students in a meaningful learning environment and facilitated higher-order learning activities such as apply, analyse, evaluate and create (Krathwohl, 2002). The level of 3D printing integration was scored on a scale from one to five. The codebook (see Appendix A) developed in Cheng et al. (2020) provides level definitions and the coding and scoring criteria.

STEM integration codebook

A codebook with scoring criteria was used to evaluate teachers' STEM integration level. In their lesson plans, all teachers indicated how they designed learning activities to facilitate inquiry-based learning and collaboration. According to the systematic review and meta-analyses on STEM integration (eg, Mustafa et al., 2016; Thibaut et al., 2018), a host of instructional strategies can be used to promote STEM integration, but there is no evidence on which instructional strategies are most effective and whether STEM integration with more instructional strategies would be necessarily more effective than STEM integration with fewer strategies. Therefore, this study focused exclusively on the integration of STEM content. Based on the initial analysis of the lesson plans, the codebook (see Appendix B) included four criteria and STEM integration level was scored from one to four based on the number of subject areas integrated into the lesson (Cheng et al., 2020).

Interest in STEM careers

Students' interest in STEM careers was assessed using the STEM career interest subscale of the previously validated S-STEM survey (Unfried et al., 2015). A pretest and a posttest of the online version of the S-STEM survey were administered before the first 3D printing integration class and upon the completion of the last class in each classroom. The STEM career scale consists of 12-items for different STEM career pathways. Each item provides a description of a specific STEM subject area and corresponding job connected to the subject area. The 12 STEM-related career pathways include physics, environment, biology, veterinary medicine, math, medicine, earth, computer science, medical science, chemistry, energy and engineering. The STEM career interest items in the subscale use a 4-point Likert scale, including ‘Not at all Interested’, ‘Not so Interested’, ‘Interested’ and ‘Very Interested’, with one indicating ‘Not at all Interested’ and four indicating ‘Very Interested’.

Data analysis

Cluster analysis

A cluster analysis was conducted to examine how the 12 STEM career pathways cluster, that is, whether there are subgroups of career pathways that are more closely related to each other. The VARCLUS procedure in SAS v. 9.4 was used, which is a type of oblique component analysis, as the first principal components of each cluster might be correlated. The variables in each cluster are associated with a linear combination using the first principal component, which is a weighted average of the variables that explain as much variance as possible (SAS Institute, 2014). Cluster analysis starts with just one cluster and continues splitting the data into more clusters. If the second eigenvalue of each cluster is just a little greater than one, it is not worth continuing splitting (Pasta & Suhr, 2004). The average score of items in each cluster was calculated to create a cluster score for each students' interest in STEM careers.

Multiple regression

This study attempted multilevel modelling analysis (Heck & Thomas, 2015; Raudenbush & Bryk, 2002) due to the nested structure of the data in which students were nested within each teacher. However, performing a multilevel model resulted in the teacher-level intercept variance at zero, indicating that there is no need to cluster students within teachers and multilevel modelling analysis is not necessary (Peugh, 2010). In this case, a multiple regression analysis could be conducted at either the student level or the teacher level (Raudenbush & Bryk, 2002). A multiple regression analysis at the teacher level would have to aggregate all the student data of each teacher and would not be able to account for the student variables. As this study focuses on both student and teacher variables, a multiple regression analysis was conducted at the student level to include both student and teacher variables at the same level without nesting to evaluate how these variables predicted students' interest in STEM careers.

In the multiple regression analysis, the outcome variable was the mean score of students' interest in STEM careers posttest for each cluster. The predictor variables were (a) student gender, (b) pretest scores of students' interest in STEM careers, (c) teachers' 3D printing integration level and (d) STEM integration level. Except for student gender, all other variables were centred with their grand mean. The assumptions of multiple regression analysis were examined, including the normality assumption of the outcome variable, multicollinearity, normal distribution of residuals and autocorrelation in the residuals. None of the assumptions were violated. SAS v.9.4 was used to perform multiple regression analysis.

RESULTS

3D printing and STEM integration levels

Teachers' 3D printing integration level ranged from 2 to 5, with a mean of 3.61. Teachers' STEM integration level ranged from 2 to 4, with a mean of 3.24 (Table 3).

Cluster analysis results

The cluster analysis for both the pretest and posttest of students' interest in STEM careers indicated there were two clusters. According to Pasta and Suhr (2004), clusters are not worth splitting if the second eigenvalue is a little greater than one. The second eigenvalues of the two clusters in this study were 0.77 and 1.28. Therefore, the analysis stopped at a two-cluster solution. For both the pretest and posttest, Cluster 1 consisted of interest in physics, math, computer science, chemistry, energy and engineering. Cluster 2 included the rest of the career pathways, that is, environmental science, earth science, biology, veterinary medicine, medicine, medical science (Table 4). Based on how the disciplines clustered, Cluster 1 was labelled as Analytic (ie, focus on computation and design to solve problems) and Cluster 2 was labelled as Empathetic (ie, focus on protecting the environment and helping others).

Multiple regression results

Before building the multiple regression model, normality assumption of the outcome variables was checked and the skewness and kurtosis were trivial (between −0.5 and 0.3). The skewness and kurtosis of the residuals were between −1 and 1, and −3 and 3, respectively. Therefore, the residual normality assumption was met. Multicollinearity of the predictor variables was evaluated to determine whether all the variables could be included in the model. In this study, all the variables had a Tolerance of higher than 0.1 and a Variance Inflation Factor (VIF) of less than 10. The autocorrelation in the residuals was evaluated with the Durbin-Watson test. A value of 2 of the Durbin-Watson test indicates no autocorrelation. For the multiple regression model for both clusters, the Durbin-Watson statistic was 2.04,

TABLE 3 3D printing and STEM integration level

Variable	*N*	*M*	*SD*	Min	Max
Printing_Level	26	3.6136	1.0411	2.0000	5.0000
STEM_Level	26	3.2352	0.6831	2.0000	4.0000

TABLE 4 Cluster membership

Cluster	Membership
1 (Analytic)	Physics, math, computer science, chemistry, energy and engineering
2 (Empathetic)	Environmental science, earth science, biology, veterinary medicine, medicine, medical science

TABLE 5 Multiple regression results for Cluster 1 (Analytic STEM Careers)

Variable	Parameter estimate	Standard error	*t* value	*p*
Intercept	2.43329	0.01794	135.64	<0.0001
Pre_Career	0.68669	0.01920	35.76	<0.0001
Gender_Student	−0.13045	0.02520	−5.18	<0.0001
Printing_Level	−0.02196	0.01424	−1.54	0.1233
STEM_Level	0.04511	0.02161	2.09	0.0370

suggesting no autocorrelation in the residuals. Therefore, all the variables were included in the model for further analysis.

Predicting interest in cluster 1 analytic STEM careers

The main regression model for Cluster 1 (Analytic) was significant, $F(4, 1450) = 399.06$, $p < 0.0001$, with an R^2 of 0.5240, indicating that about 52.40% of the total variance in student interest in Analytic STEM careers was associated with the student and teacher level predictors (Table 5). Teachers' 3D printing integration level did not predict students' interest in Analytic careers, $\beta = -0.02$, $t(1450) = -1.54$, $p = 0.12$. However, teachers' STEM integration level positively predicted interest in Analytic STEM careers, $\beta = 0.05$, $t(1450) = 2.09$, $p = 0.04$, when controlling for other variables. Additionally, students' pretest scores of interest in Analytic STEM careers were a positive and significant predictor for students' posttest scores of interest in Analytic STEM careers, $\beta = 0.69$, $t(1450) = 35.76$, $p < 0.0001$. Student gender was also a significant predictor, $\beta = -0.13$, $t(1450) = -5.18$, $p < 0.0001$, indicating that boys had significantly higher interest in Analytic STEM careers than girls.

Predicting interest in cluster 2 empathetic STEM careers

The main regression model was significant, $F(4, 1450) = 272.83$, $p < 0.0001$, with an R^2 of 0.4294, indicating that about 42.94% of the total variance in student interest in Empathetic STEM careers was associated with student and teacher predictor variables (Table 6). Teachers' 3D printing integration level was not a significant predictor, $\beta = -0.02$, $t(1450) = -1.61$, $p = 0.11$. However, teachers' STEM integration level positively predicted student interest in Empathetic STEM careers, $\beta = 0.04$, $t(1450) = 2.06$, $p = 0.04$, when controlling for other variables. Additionally, students' pretest scores of interest in Empathetic STEM careers were a positive and significant predictor for students' posttest scores of interest in Empathetic STEM careers, $\beta = 0.63$, $t(1450) = 30.30$, $p < 0.0001$. Student gender was also a significant predictor $\beta = 0.11$, $t(1450) = 4.45$, $p < 0.0001$, indicating that girls had significantly higher interest in Empathetic STEM careers than boys.

TABLE 6 Multiple regression results for Cluster 2 (Empathetic STEM Careers)

Variable	Parameter estimate	Standard error	*t* value	*p*
Intercept	2.42444	0.01784	135.92	<0.0001
Pre_Career	0.62581	0.02065	30.30	<0.0001
Gender_Student	0.11059	0.02487	4.45	<0.0001
Printing_Level	−0.02299	0.01425	−1.61	0.1069
STEM_Level	0.04458	0.02169	2.06	0.0401

DISCUSSION

Despite the promise of 3D printing to improve students' interest in STEM careers, this study revealed that the 3D printing integration level did not predict students' STEM career interest. Although there is little empirical research regarding the influence of 3D printing integration on students' interest in STEM careers, Xie and Reider (2014) found the integration of innovative technologies can enhance students' motivation for science careers, which is an important component of STEM. The non-significant findings regarding the role of 3D printing integration level in this study suggest that higher use of 3D printing may not necessarily be better for students, at least when it comes to interest in STEM careers. As a previous study revealed, 3D printing is difficult to integrate into schools and it presents a number of technical challenges for both teachers and students such as obstructions in the printer extruder, maintaining consistent platform temperature and so on (Nemorin & Selwyn, 2017). Additionally, teachers do not always make specific connections between the 3D printing integration and STEM career pathways, so students may not link what they learn in the 3D printing integrated classes with possible future STEM careers.

As Honey et al. (2014) suggested, integrated STEM education can facilitate students' interest development. This study confirmed this proposition, specifically demonstrating that STEM integration level positively predicted students' interest in STEM careers. This finding suggests that higher STEM integration level contributes to enhanced interest in joining the STEM workforce. Although we could not identify prior studies that investigated how different STEM integration levels may impact students' interest in STEM careers, a number of previous studies demonstrated that, in general, integrated curriculum or instruction can enhance students' learning motivation (Bragow et al., 1995; Gutherie et al., 2000). More specifically, prior empirical work has revealed that integrated STEM education can increase students' interest in STEM disciplines (Mustafa et al., 2016; Riskowski et al., 2009) and STEM learning motivation (Laboy-Rush, 2011; Wang et al., 2011), which may influence students' interest in STEM careers. Higher level of STEM integration makes learning more connected within and across different disciplines of STEM and students can learn knowledge and skills in one subject within a relevant context of another subject or subjects. Through STEM integration, students can be meaningfully exposed to different areas of STEM, which, as this study shows, may stimulate their interest in STEM careers.

Finally, this study confirmed that student gender mediates student interest in careers, specifically in careers in STEM. Here, we found that boys tended to express interest in STEM career pathways that have been described as analytic (Burns et al., 2016), that is, physics, math, computer science, chemistry, energy and engineering. Unlike boys, girls in our sample of primary and secondary students indicated more interest in STEM careers that involve empathy. These career pathways frequently focus on helping animals, helping people and helping the environment. Specifically, careers that girls in this study's sample preferred included environmental science, earth science, biology, veterinary medicine, medicine, medical science. This finding confirms the results of a recent line of research in STEM and educational technology research showing that girls tend to be drawn to jobs with significant social value (Burns et al., 2016; Godwin & Potvin, 2015). Because STEM educators often do not provide explicit scaffolding to link STEM subjects and social problems involving care and social change (Strobel et al., 2013), it is important that educators transform their instructional practices to include this important aspect making STEM education more explicit and relevant to social value.

CONCLUSIONS AND IMPLICATIONS

This study explored the role of 3D printing and STEM integration in science classrooms and examined the relationship between teachers' 3D printing integration level, STEM integration level, gender and students' interest in STEM careers. We found that while teachers' 3D printing integration was not a significant predictor of student's STEM career interest, teachers' STEM integration level positively predicted students' interest in STEM career pathways. STEM integration is a promising strategy to increase students' interest in STEM careers, which may lead to improved persistence in STEM degree programmes in college and a stronger future STEM workforce. Additionally, gender played an important role in this investigation. Specifically, our analyses revealed that boys tended to express more interest in analytical STEM careers, whereas girls were significantly more interested in empathetic STEM careers that focus on helping others and protecting the environment, that is, jobs with clear potential for social value.

This study provides implications for transforming future teaching practice and research endeavours. The findings of this study demonstrate that integrated STEM learning is a more useful strategy for enhancing student interest in STEM careers compared to the increased infusion of 3D printing in science classrooms. Many teachers are excited about the potential of 3D printing to improve their instructional practices (eg, Maloy et al., 2017; Novak & Wisdom, 2018). Teachers may take the challenge to design and integrate 3D printing in STEM learning to provide opportunities for students to learn STEM using this exciting digital manufacturing technology but unless they also meaningfully integrate STEM disciplines during instruction, such efforts may not result in enhanced student interest in STEM careers. Given our study's findings regarding the role of gender in mediating student interest in STEM careers, it is expedient to recommend that if educators would like to engage girls more fully in STEM activities and show them the relevance of STEM in their lives, they should explicitly emphasise and connect the STEM problems they explore in the classroom to the local and global problems related to social value and social change such as devising new strategies and tools to protect the environment, and provide better care and support for people and animals. When doing this, it is important to minimise the potential for gender bias and stereotyping (eg, Forgasz et al., 2004, 2009) because each learner is a unique individual and may benefit from an emphasis on both the analytical and empathetic aspects of STEM education and STEM problems in our society. Because empathy is often not discussed in STEM classes (Strobel et al., 2013), it is critical that we start addressing the empathetic aspects of STEM more deliberately in our classrooms.

Future research is necessary to address the limitations and delimitations of this study. Because the results of this study cannot imply causal relationships, experimental or quasi-experimental studies are necessary to examine the effects of different levels of 3D printing infused STEM integration on students' interest in STEM careers. Furthermore, due to its quantitative research design, this study cannot discuss nuances regarding the specific reasons why STEM integration level may impact students' interest in STEM careers. Future research is needed to further examine how and why students' interest in STEM careers could be impacted by different levels of STEM integration and why 3D printing infused instruction does not predict enhanced interest in STEM careers. Researchers may include qualitative data from classroom observations and teacher and student interviews to obtain specific and detailed evidence that can explain such quantitative findings. Last, this study was not able to include implementation duration in the analysis. Future studies may examine how implementation duration may moderate the influence of 3D printing integration.

As this study was conducted in the context of learning paleontology, a unique and charismatic area that is inherently interesting and attractive to many students, the findings of this study may only relate to this specific context. Future studies may explore what other STEM contexts could facilitate meaningful STEM integration and how STEM integration in a different context may influence students' interest in STEM careers. Finally, meaningful STEM integration is an intricate and sophisticated process that involves different STEM disciplines and instructional strategies. Future studies may further define a holistic and systematic way to evaluate the quality and level of STEM integration by including more aspects that matter for STEM integration, for example, student-centred instructional strategies and adaptivity to students' differences in prior knowledge, aptitude, self-efficacy, interest, motivation and attitudes.

ETHICS STATEMENT

Our research has been approved by the University of Florida IRB and by the participating school districts.

ACKNOWLEDGEMENT

This material is based upon work supported by the U.S. National Science Foundation under Grant No. 1510410. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

CONFLICT OF INTEREST

The authors declare they have no conflict of interest.

DATA AVAILABILITY STATEMENT

De-identified data are available to others per data management guidelines of the U.S. National Science Foundation.

ORCID

Li Cheng https://orcid.org/0000-0001-7648-6965

REFERENCES

Ali, N., Areepattamannil, S., Santos, I. M., & Khine, M. (2019). Examining the links between affect toward 3D printing technology and interest in STEM careers among female elementary students. In P. H. Bull & J. Keengwe (Eds.), *Handbook of research on innovative digital practices to engage learners* (pp. 138–157). IGI Global.

American Association for the Advancement of Science (AAAS). (2002). *Project 2061*. http://www.project2061.org

Bicer, A., Nite, S. B., Capraro, R. M., Barroso, L. R., Capraro, M. M., & Lee, Y. (2017, October). Moving from STEM to STEAM: The effects of informal STEM learning on students' creativity and problem solving skills with 3D printing. In *2017 IEEE Frontiers in Education Conference (FIE)* (pp. 1–6). IEEE.

Bragow, D., Gragow, K. A., & Smith, E. (1995). Back to the future: Toward curriculum integration. *Middle School Journal*, *27*, 39–46.

Britten, J. S., & Cassady, J. C. (2005). The technology integration assessment instrument: Understanding planned use of technology by classroom teachers. *Computers in the Schools*, *22*(3), 49–61.

Burns, H. D., Lesseig, K., & Staus, N. (2016, October). Girls' interest in STEM. In *Proceedings of 2016 IEEE frontiers in education conference (FIE)* (pp. 1–5). IEEE. https://doi.org/10.1109/FIE.2016.7757645

Ceci, S. J., & Williams, W. M. (2010). Sex differences in math-intensive fields. *Current Directions in Psychological Science*, *19*(5), 275–279.

Cheng, L., Antonenko, P., Ritzhaupt, A. D., Dawson, K., Miller, D., MacFadden, B., Grant, C., Sheppard, T. D., & Ziegler, M. (2020). Exploring the influence of teachers' beliefs and 3D printing integrated STEM instruction on students' STEM motivation. *Computers & Education*, *158*, 103983.

Chien, Y. H. (2017). Developing a pre-engineering curriculum for 3D printing skills for high school technology education. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(7), 2941–2958.

Chien, Y. H., & Chu, P. Y. (2018). The different learning outcomes of high school and college students on a 3D-printing STEAM engineering design curriculum. *International Journal of Science and Mathematics Education*, *16*(6), 1047–1064.

Christensen, R., & Knezek, G. (2017). Relationship of middle school student STEM interest to career intent. *Journal of Education in Science, Environment and Health*, *3*(1), 1–13.

Corbett, C., & Hill, C. (2015). *Solving the equation: The variables for women's success in engineering and computing*. AAUW.

Cunningham, B. C., Hoyer, K. M., & Sparks, D. (2015). *Gender differences in science, technology, engineering, and mathematics (STEM) interest, credits earned, and NAEP performance in the 12th grade. Stats in brief. NCES 2015-075*. National Center for Education Statistics.

Dewey, J. (1913). *Interest and effort in education*. Houghton Mifflin Company. https://doi.org/10.1037/14633-000

DeWitt, J., Osborne, J., Archer, L., Dillon, J., Willis, B., & Wong, B. (2013). Young children's aspirations in science: The unequivocal, the uncertain and the unthinkable. *International Journal of Science Education*, *35*(6), 1037–1063.

Forgasz, H. J., Leder, G. C., & Kloosterman, P. (2004). New perspectives on the gender stereotyping of mathematics. *Mathematical Thinking and Learning*, *6*(4), 389–420.

Forgasz, H. J., Vale, C., & Ursini, S. (2009). Technology for mathematics education: Equity, access and agency. In C. Hoyles & J.-B. Lagrange (Eds.), *Mathematics education and technology-Rethinking the terrain. New ICMI Study Series* (Vol. *13*, pp. 385–403). Springer.

Frenzel, A. C., Goetz, T., Pekrun, R., & Watt, H. M. G. (2010). Development of mathematics interest in adolescence: Influences of gender, family, and school context. *Journal of Research on Adolescence*, *20*(2), 507–537. https://doi.org/10.1111/j.1532-7795.2010.00645.x

George, R. (2006). A cross-domain analysis of change in students' attitudes toward science and attitudes about the utility of science. *International Journal of Science Education*, *28*(6), 571–589.

Godwin, A., & Potvin, G. (2015). Fostering female belongingness in engineering through the lens of critical engineering agency. *The International Journal of Engineering Education*, *31*(4), 938–952.

Gonzalez, S. R., & Bennett, D. B. (2016). *3D printing: A practical guide for librarians* (Vol. *22*). Rowman & Littlefield.

Grant, C. A., MacFadden, B. J., Antonenko, P., & Perez, V. J. (2017). 3-D fossils for k–12 education: A case example using the giant extinct shark Carcharocles Megalodon. *The Paleontological Society Papers*, *22*, 197–209.

Gutherie, J. T., Wigfield, A., & VonSecker, C. (2000). Effects of integrated instruction on motivation and strategy use in reading. *Journal of Educational Psychology*, *92*, 331–341. https://doi.org/10.1037/0022-0663.92.2.331

Harmes, J. C., Welsh, J. L., & Winkelman, R. J. (2016). A framework for defining and evaluating technology integration in the instruction of real-world skills. In R. Yigal, F. Steve, & M. Maryam (Eds.), *Handbook of research on technology tools for real-world skill development* (pp. 137–162). IGI Global.

Harris, J., Grandgenett, N., & Hofer, M. (2010). Testing a TPACK-based technology integration assessment instrument. In C. D. Maddux, D. Gibson, & B. Dodge (Eds.), *Research highlights in technology and teacher education 2010* (pp. 323–331). Society for Information Technology and Teacher Education (SITE).

Heck, R. H., & Thomas, S. L. (2015). *An introduction to multilevel modeling techniques: MLM and SEM approaches using Mplus*. Routledge.

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*, *41*(2), 111–127.

Honey, M., Pearson, G., & Schweingruber, H. (Eds.). (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research*. National Academies Press.

Hsiao, H. S., Chen, J. C., Lin, C. Y., Zhuo, P. W., & Lin, K. Y. (2019). Using 3D printing technology with experiential learning strategies to improve preengineering students' comprehension of abstract scientific concepts and hands-on ability. *Journal of Computer Assisted Learning*, *35*(2), 178–187.

Koehler, K. E. (2017). *Examining the conceptual understandings of geoscience concepts of students with visual impairments: Implications of 3-D printing (Order No. 10702675)* (Doctoral dissertation). Retrieved from ProQuest Dissertations & Theses Global. (1999311016). The Ohio State University.

Krapp, A. (2002). Structural and dynamic aspects of interest development: Theoretical considerations from an ontogenetic perspective. *Learning and Instruction*, *12*(4), 383–409.

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into Practice*, *41*(4), 212–218.

Kwon, H. (2017). Effects of 3d printing and design software on students' interests, motivation, mathematical and technical skills. *Journal of STEM Education*, *18*(4), 37–42.

Laboy-Rush, D. (2011). *Integrated STEM education through project-based learning*. https://www.rondout.k12.ny.us/common/pages/DisplayFile.aspx?itemId=16466975

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.

Maloy, R., Trust, T., Kommers, S., Malinowski, A., & LaRoche, I. (2017). 3D modeling and printing in history/social studies classrooms: Initial lessons and insights. *Contemporary Issues in Technology and Teacher Education*, *17*(2), 229–249.

Maltese, A. V., Melki, C. S., & Wiebke, H. L. (2014). The nature of experiences responsible for the generation and maintenance of interest in STEM. *Science Education*, *98*(6), 937–962.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education*, *95*(5), 877–907.

Mitchell, M. (1993). Situational interest: Its multifaceted structure in the secondary school mathematics classroom. *Journal of Educational Psychology*, *85*(3), 424–436.

Moore, T., Stohlmann, M., Wang, H., Tank, K., Glancy, A., & Roehrig, G. (2014). Implementation and integration of engineering in K-12 STEM education. In S. Purzer, J. Strobel, & M. Cardella (Eds.), *Engineering in pre-college settings: Synthesizing research, policy, and practices* (pp. 35–60). Purdue University Press.

Mustafa, N., Ismail, Z., Tasir, Z., Said, M., & Haruzuan, M. N. (2016). A meta-analysis on effective strategies for integrated STEM education. *Advanced Science Letters*, *22*(12), 4225–4228.

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8*. The National Academies Press.

National Research Council. (2011). *Successful K-12 STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*. National Academies Press.

Nemorin, S., & Selwyn, N. (2017). Making the best of it? Exploring the realities of 3D printing in school. *Research Papers in Education*, *32*(5), 578–595.

Ng, O. L. (2017). Exploring the use of 3D computer-aided design and 3D printing for STEAM learning in mathematics. *Digital Experiences in Mathematics Education*, *3*(3), 257–263.

Novak, E., & Wisdom, S. (2018). Effects of 3D printing project-based learning on preservice elementary teachers' science attitudes, science content knowledge, and anxiety about teaching science. *Journal of Science Education and Technology*, *27*(5), 412–432.

Pasta, D. J., & Suhr, D. (2004). Creating scales from questionnaires: PROC VARCLUS vs. Factor analysis. In *Proceedings of the twenty-ninth annual SASR users group international conference (Paper 205-29)*. SAS Institute Inc.

Peugh, J. L. (2010). A practical guide to multilevel modeling. *Journal of School Psychology*, *48*(1), 85–112.

Pringle, R. M., Dawson, K., & Ritzhaupt, A. D. (2015). Integrating science and technology: Using technological pedagogical content knowledge as a framework to study the practices of science teachers. *Journal of Science Education and Technology*, *24*(5), 648–662.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). Sage.

Renninger, K. A. (1992). Individual interest and development: Implications for theory and practice. In K. A. Renninger, S. Hidi & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 361–395). Erlbaum.

Renninger, K. A., & Hidi, S. (2002). Student interest and achievement: Developmental issues raised by a case study. In A. Wigfield & J. S. Eccles (Eds.), *Development of achievement motivation* (pp. 173–195). Academic Press.

Riskowski, J. L., Todd, C. D., Wee, B., Dark, M., & Harbor, J. (2009). Exploring the effectiveness of an interdisciplinary water resources engineering module in an eighth grade science course. *International Journal of Engineering Education*, *25*(1), 181–195.

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.

SAS Institute. (2014). *SAS/STAT®13.2 user's guide: The VARCLUS procedure*. Author.

Schiefele, U. (2009). Situational and individual interest. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of motivation in school* (pp. 197–223). Taylor Francis.

Schmidt, J. A., Rosenberg, J. M., & Beymer, P. N. (2018). A person-in-context approach to student engagement in science: Examining learning activities and choice. *Journal of Research in Science Teaching*, *55*(1), 19–43.

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research*, *2*(1), 28–34.

Strobel, J., Hess, J., Pan, R., & Morris, C. A. (2013). Empathy and care within engineering: Qualitative perspectives from engineering faculty and practicing engineers. *Engineering Studies*, *5*(2), 137–159.

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*(6), 859–884.

Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Life Science*, *312*(5777), 1143–1144.

Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., Boeve-de Pauw, J., Dehaene, W., Deprez, J., De Cock, M., Hellinckx, L., Knipprath, H., Langie, G., Struyven, K., Van de Velde, D., Van Petegem, P., & Depaepe, F. (2018). Integrated STEM Education: A Systematic Review of Instructional Practices in Secondary Education. *European Journal of STEM Education*, *3*(1), 02. https://doi.org/10.20897/ejsteme/85525

Thornburg, D., Thornburg, N., & Armstrong, S. (2014). *The invent to learn guide to 3D printing in the classroom: Recipes for success*. Constructing Modern Knowledge Press.

Unfried, A., Faber, M., Stanhope, D. S., & Wiebe, E. (2015). The development and validation of a measure of student attitudes toward science, technology, engineering, and math (S-STEM). *Journal of Psychoeducational Assessment*, *33*(7), 622–639.

Urban, M. J., & Favlo, D. A. (Eds.). (2016). *Improving K-12 STEM education outcomes through technological integration*. IGI Global.

Varma, R. (2010). Why so few women enroll in computing? Gender and ethnic differences in students' perception. *Computer Science Education*, *20*(4), 301–316.

Wang, H. H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research*, *1*(2), 1–13. https://doi.org/10.5703/1288284314636

Weber, J., Kotsopoulos, D., & Senger, N. (2017). Visual-spatial reasoning, design engineering, and 3D printing. In E. Galindo & J. Newton (Eds.), *Proceedings of the 39th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 1373–1376). Hoosier Association of Mathematics Teacher Educators.

Welsh, J., Harmes, J. C., & Winkelman, R. (2011). Florida's technology integration matrix. *Principal Leadership*, *12*(2), 69–71.

Whalen, D. F., & Shelley, M. C. (2010). Academic success for STEM and non-STEM majors. *Journal of STEM Education: Innovations and Research*, *11*(1), 45–60.

Xie, Y., & Reider, D. (2014). Integration of innovative technologies for enhancing students' motivation for science learning and career. *Journal of Science Education and Technology*, *23*(3), 370–380.

How to cite this article: Cheng, L., Antonenko, P. P., Ritzhaupt, A. D., & MacFadden, B. (2021). Exploring the role of 3D printing and STEM integration levels in students' STEM career interest. *British Journal of Educational Technology*, 52, 1262–1278. https://doi.org/10.1111/bjet.13077

APPENDIX A.

Codebook for 3D printing integration levels (Cheng et al., 2020)

Category	Criteria	Score
3D printing integration levels	Entry: The teacher just introduced 3D printing technology or brought in 3D printed objects, students had no access to 3D printing technology and had minimal access to 3D printed objects, 3D printing technology did not contribute to the learning environment or student learning	1
	Adoption: Students had access to 3D printing technology or 3D printed objects, but the technologies were not used during the learning activity. The use of 3D printing technology or 3D printed objects minimally contributed to a meaningful learning environment and student learning.	2
	Adaptation: Students used 3D printed objects for some part of the learning activity but there was no deep interaction. The use of 3D printing technology or 3D printed objects contributed to a meaningful learning environment and student learning but not strong	3
	Infusion: Students used 3D printed objects throughout or for the most part of the learning activity. The use of 3D printing technology or 3D printed objects strongly contributed to a meaningful learning environment, but the 3D printing technology was not used to facilitate higher-order learning activities such as apply, analyse, evaluate, and create	4
	Transformation: Students participated in the 3D printing process, printed 3D models, and used 3D printed objects throughout or for the most part of the learning activity. The use of 3D printing technology and 3D printed objects strongly contributed to a meaningful learning environment and the 3D printing technology was used to facilitate higher-order learning activities such as apply, analyse, evaluate, and create	5

APPENDIX B.

Codebook STEM integration levels (Cheng et al., 2020).

Criteria		Score
Integration of STEM content	Science	1
	Science + 3D Printing Technology	2
	Science + 3D Printing Technology + Math	3
	Science + 3D Printing Technology + Math + Engineering	4

APPENDIX C.

All the lesson plans in the project are available through http://www.idigfossils.org/lessons/.