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Cultural Representations of Gender and STEM: Portrayals of Female STEM Characters in Popular Films 2002–2014

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ABSTRACT

Images of science, technology, engineering, and mathematics (STEM) professionals in popular films influence public perceptions of the participation, status, role, and contributions of women in STEM. This study used content analysis and textual analysis to examine the prevalence and portrayals of female STEM characters in 42 popular films in the United States from 2002 to 2014. Findings revealed that female STEM characters were outnumbered by male STEM characters in speaking roles by 2 to 1. Female STEM characters appearing in lead, co-lead, and secondary roles (N=62) typically were cast in co-lead or secondary roles in the films, and the typical female STEM character was a Caucasian scientist employed as a biologist or astronaut who worked as a member of a research team, was attractive, was equally as likely to be in either a romantic relationship or single, and was not a mother. Social learning theory and possible selves theory suggest that presenting a greater number and more diverse portrayals of female STEM characters may be important for girls' and young women's identification with STEM characters and future interest in STEM careers. These findings call for an increase in the overall presence of female STEM characters in popular films, including women from traditionally underrepresented racial and ethnic groups, and a greater focus on more diverse portrayals of female STEM characters to replace overt and subtle gender stereotypes of STEM professionals.

KEYWORDS

gender and STEM; cultural representations of gender; gender stereotypes; popular films; possible selves; media images

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INTRODUCTION

Research has noted that stereotypes of STEM professionals are likely to affect girls' and young women's interest in future STEM careers (Cheryan, Master, & Meltzoff, 2015; Lips, 1995, 2004; Steinke, 2003, 2005). Children, adolescents, and young adults for decades have reported stereotypical images of scientists, typically describing them as middle-aged or older white males with unkempt hair who are socially awkward, wear lab coats and glasses, and work alone conducting dangerous experiments in laboratories (Beardslee & O'Dowd, 1961; Buck, Clark, Leslie-Pelecky, Lu, & Cerda-Lizarraga, 2008; Chambers, 1983; Cheryan, Plaut, Handron, & Hudson, 2013; Hillman, Bloodsworth, Tilburg, Zeeman, & List, 2014; Huber & Burton, 1995; Maoldomhnaigh & Hunt, 1988; Mead & Metraux, 1957; Steinke et al., 2007; Tan, Jocz, & Zhai, 2015). However, little research has determined how exposure to specific stereotypes of STEM professionals affect girls' and young women's perceptions or views of themselves as future scientists, technologists, engineers, and mathematicians. Analyzing and documenting the portrayals of STEM professionals in popular media is a necessary first step before assessing the specific effects of these images on attitudes and behavior. Therefore, the present study examined the prevalence of female STEM characters in speaking roles and the portrayals of female STEM characters in lead, co-lead, and secondary roles in popular films released from 2002 to 2014 in the United States.

Despite recent gains in participation in some STEM fields, women remain underrepresented in the fields of engineering, computing, physics, and mathematics (American Association of University Women, 2015; National Science Foundation, 2017). A number of factors collectively contribute to this underrepresentation, including factors in homes, schools, and society (Clewell & Campbell, 2002; Rosser, 2012). Studies have shown that children's exposure to images of scientists in the media may be one factor that influences their perceptions of scientists (Steinke et al., 2007; Tan et al., 2015) and that exposure to stereotyped media images of STEM professionals and may affect their interest in STEM (Lee, 1998) as well as self-identification with STEM careers (Steinke et al., 2007; Steinke, Lapinski et al., 2009; Tan & Barton, 2008).

Historically, media portrayals of women scientists and engineers in popular movies in the United States have reinforced traditional gender stereotypes of STEM and STEM professionals. Typically, these gender stereotypes have been perpetuated through the overall limited number of women shown on screen as STEM professionals and the gender-stereotyped portrayals of women as scientists and engineers portrayed in popular movies (Elena, 1997; Flicker, 2003; Steinke, 2005). A number of studies (Elena, 1993, 1997; Smith, Choueiti, & Pieper, 2014; Steinke, 2005) have found fewer female than male scientist and engineer characters represented in popular films. Also, stereotyped portrayals of female scientists and engineers in such films have conveyed mixed messages about the status, role, and

contributions of women in STEM fields by focusing on their attractiveness and romantic relationships, and by showing them in subordinate roles as research assistants (Elena, 1993, 1997; Flicker, 2003; Steinke & Long, 1996).

While fictitious representations of female STEM professionals do not represent reality, the "vicarious contact" (Fujioka, 1999, p. 54) afforded by exposure to media depictions of female STEM characters may be an important source of information and influence when direct contact with real-life female STEM professionals is lacking. Films, in particular, may potentially be important vehicles for providing accurate and inspirational portrayals of female STEM professionals because adolescents aged 12–17 report viewing an average of 10.8 movies each year, on portable devices and in theaters, showing preferences for comedy, action/adventure, and science-fiction/fantasy movie genres (Nielsen, June 2009). Research indicates, however, that portrayals of female STEM professionals in popular films in the United States often fall short in providing positive, inspirational portrayals of female STEM professionals in one of two ways: by featuring fewer female than male STEM professionals overall, and particularly in lead or primary roles; and by presenting mixed messages about the contributions of female STEM professionals through portrayals that reinforce traditional gender stereotypes.

Symbolic Annihilation: The Prevalence of Female STEM Professionals in Popular Films

In American society, films perform a function similar to television, which has been described as "an agency of the established order, and as such serves primarily to extend and maintain rather than to alter, threaten, or weaken conventional conceptions, beliefs, and behaviors" (Gerbner & Gross, 1976, p. 175). Gerbner and Gross (1976) explained the societal implications of representation and absence in popular media as follows: "Representation in the fictional world signifies social existence; absence means symbolic annihilation" (p. 182). While some progress has been made related to greater representation of women in popular media, research has noted an absence or "symbolic annihilation" of women in popular media for a variety of formats and genres (Tuchman, Daniels, & Benet, 1978).

Popular films have contributed to this "symbolic annihilation" of women through depictions of STEM professionals. An examination of 122 film biographies of scientists found that only 19 of these focused on female scientists, and 11 of these focused on female nurses (Elena, 1993, 1997). Similarly, a study of popular films from 1991 to 2001 found that out of 74 films featuring scientists and engineers as primary characters, only 25 featured females as primary or lead characters (Steinke, 2005). An analysis of films across 11 countries showed approximately 105 (3.5%) of 3,000 characters as STEM professionals, but only 11.6 per cent of these were female, revealing a ratio of 7.6 STEM males to every 1 STEM female (Smith, Choueiti, & Pieper, 2014). In addition, female STEM characters were outnumbered by male STEM characters for every character role and type of STEM occupation, with only five female characters shown working in the computer science and technology fields and male characters outnumbering female characters as engineers by a ratio of 10 to 1 (Smith et al., 2014). A recent study reported an overall lack of female protagonists in science-fiction films (Simis et al., 2016).

Mixed Messages: The Characterization of Female STEM Professionals in Popular Films

When shown on the Big Screen as scientists, technologists, engineers, and mathematicians, women often have been portrayed in limited roles that reinforce traditional gender stereotypes. An analysis of the 1943 film *Madame Curie* noted that images of Marie Curie emphasized the "awkward duality required for a female scientist" (Elena, 1997, p. 276) and focused on her domestic and personal life, highlighting her romantic relationship with her husband, Pierre (Elena, 1997). Her professional aspirations were shown as secondary to those of her husband, reinforcing a stereotype that depicted female scientists as research assistants subordinate to male scientists (Elena, 1997). A study of female scientists appearing in 60 feature films released between 1929 and 1997 noted six different stereotyped depictions of female scientists: old maid (*Spellbound*, USA, 1945), male woman (*The Andromeda Strain*, USA, 1971), naïve expert (*The Lost World: Jurassic Park*, USA, 1997), evil plotter (*Indiana Jones and the Last Crusade*, USA, 1989), daughter or assistant (*Torn Curtain*, USA, 1966), and lonely heroine (*Contact*, USA, 1997) (Flicker, 2003). A study of portrayals of female scientists and engineers shown as primary characters in 23 popular films from 1991 to 2001 found that feminine attributes such as glamour, attractiveness, popularity, youth, and romance were dominant themes (Steinke, 2005). Relatively few counter-stereotyped portrayals of female scientists have been found in film analyses (Elena 1997; Steinke, 1999).

Theory and research suggest media portrayals of female STEM professionals have potential effects on public attitudes and behaviors. However, a better understanding of how cultural representations of gender and STEM are presented in popular films is needed in order to determine *how* to break down gendered stereotypes of STEM that may keep girls from pursuing STEM careers (see Steinke, 2017). Research shows that girls are less interested in STEM careers than boys (Farkas & Leaper, 2016; Riegle-Crumb, Moore, & Ramos-Wada, 2011) and their occupational interest is relatively fixed or unchanged from early adolescence into adulthood (Low, Yoon, Roberts, & Rounds, 2005). While it is beyond the scope of the present study to assess specific effects of film portrayals of female STEM professionals on girls' interest in pursuing STEM careers, this study draws from two theories, social cognitive (learning) theory and possible selves theory, to describe the potential effects of these portrayals or *how* these portrayals might affect girls' perceptions.

THEORETICAL FRAMEWORKS

Social cognitive (learning) theory explains how stereotypes reflected by media portrayals of characters may influence attitudes and behaviors. According to this theory, repeated observation of symbolic models, such as those found in media environments, teaches cultural patterns of behaviors (Bandura, 1969, 1986). Social learning theory posits that through the process of "identificatory learning" (Bandura, Ross, & Ross, 1963, p. 533), viewers learn to imitate behaviors from media characters they observe. A 1957 study by Maccoby and Wilson provided evidence of identificatory learning, showing that viewers identified with film characters of the same sex and more accurately remembered the words and actions

of characters with whom they identified. This study also found that women were more likely than men to remember female characters whom they perceived as important as well as the actions of female characters shown in romantic scenes (Maccoby & Wilson, 1957). Other research noted a link between the specific attributes or traits of scientist characters in popular media and adolescent girls' identification with scientist characters viewed in television clips (Steinke, Applegate, Lapinski, Ryan, & Long, 2012).

Possible selves theory offers an explanation of how stereotyped images in the media might influence adolescent girls and young women as they consider both their current and future conceptions of self as well as potential future occupations for themselves. Possible selves represent both current representations of who one is and future representations of who one might become that are shaped by perceptions of past, current, and future possible selves (Markus & Nurius, 1986). Research shows that adolescents' conceptions of possible selves motivate behavior related to life goals (Markus & Nurius, 1986; Markus and Ruvolo, 1989; Strahan & Wilson, 2006), career aspirations (Markus & Nurius, 1986), and future career selection (Lips, 2007).

Collectively, these two theories underscore the importance of investigating portrayals of female STEM professionals in popular films and point to some of the potential effects of these portrayals on attitudes and behaviors related to STEM interest and participation. Social cognitive theory suggests that girls and young women may learn about female STEM professionals through exposure to media images of female STEM professionals and may be more likely to imitate or model the behavior of STEM characters in the media when those characters exhibit certain physical characteristics and display specific actions with which they identify. Possible selves theory, meanwhile, explains that media images of female STEM professionals may shape girls' and young women's conceptions about women in STEM that may influence how they envision their future possible selves as STEM professionals. Both of these theoretical perspectives were used to inform the research questions stated below.

OVERVIEW OF RESEARCH AND RESEARCH QUESTIONS

This study takes an important first step in examining portrayals of female STEM professionals in recent popular films in order to understand better the potential effects of these portrayals on adolescent girls' and young women's perceptions of and identification with STEM professionals and careers. The purpose of the study was to examine popular films released between 2002 and 2014 in the United States to determine the prevalence of female STEM professionals in speaking roles, compared to male STEM professionals, and to analyze portrayals of female STEM professionals in lead, co-lead, and secondary roles. Specifically, a content analysis was conducted to document the number of female and male STEM characters in speaking roles, and both content analysis and textual analysis were used to examine portrayals of female STEM characters in lead, co-lead, and secondary roles in popular films that featured STEM characters. The textual analysis provided more descriptive data on portrayals of female STEM characters. This study fills gaps in the literature by providing an update on how recent popular films have represented

and portrayed women scientists and engineers, and by examining female characters for all STEM professions, including the fields of engineering and computing, where women are most underrepresented. The following research questions were posed based on the literature cited above:

RQ1: What is the number of female STEM professionals compared to the number of male STEM professionals in speaking roles in recent popular films that feature female STEM professionals?

RQ2: How are female STEM professionals in lead, co-lead, and secondary roles portrayed in recent popular films that feature female STEM professionals?

Findings from this study will allow for comparisons with those from previous research (Smith, Choueiti, & Pieper, 2014; Steinke, 2005) in order to assess changes in portrayals over time. While it is beyond the scope of the present study to assess media effects (e.g. specific effects of portrayals of female STEM characters on viewers), the implications for future research in this area will be discussed.

METHODS

Selection of Films

Internet Movie Database (IMDb) and Google searches were conducted to identify popular films from the United States released from 2002 to 2014 that featured female STEM professionals as lead, co-lead, or secondary characters. Films were identified using the following combinations of keywords: *movie and scientist, film and scientist, movie and woman scientist, film and woman scientist, movie and physicist, movie and space scientist, movie and biologist, movie and chemist, movie and geologist, and movie and researcher, women scientist, women engineer, women researcher, woman and female computer/programmer/programmer/ engineer/ computer scientist.* In addition, popular films listed on a "women in science and entertainment" blog (Chambers, 2015) were selected in order to generate as comprehensive a list as possible. A total of 48 films were identified.

Female STEM professionals cast in lead, co-lead, or secondary roles were identified by reviewing the "Full Cast and Crew" lists and plot summaries in IMDb and "Cast" lists in Wikipedia. Female STEM characters shown in lead roles were defined as protagonists in the films; those shown in co-lead roles were defined as protagonists who shared that role with another character; those shown in secondary roles were defined as those who appeared in some scenes in the films but were not central characters. Non-speaking female characters who appeared infrequently on screen or in group shots of characters were not included in the analysis. The films were watched by the first author to verify that the female characters met the selection criteria for identification as a STEM character (Appendix A). Six films were removed from the sample, five because the female characters did not meet these selection criteria and another because the film was not available for viewing in a traditional format. Forty-two (42) films were identified as featuring female STEM characters in lead, co-lead, or secondary roles (Appendix B).

Analysis of Films and STEM Characters

Descriptive information from the IMDb listings was recorded for each film related to its year of release, genre (first listed), Motion Picture Association of America (MPAA) rating, and film-maker gender. STEM characters (male and female) who spoke on screen and were identified as STEM professionals (Appendix B) were counted while viewing the films. The cast list and actors' bios in IMDb, preliminary viewing of the films, and the context/setting of the films were considered in order to determine the racial/ethnic backgrounds of the STEM characters.

This study used a mixed-methods approach to document portrayals of the 62 female STEM characters shown in lead, co-lead, and secondary roles in the 42 selected films. A content analysis (Krippendorff, 2013) and a textual analysis (Bainbridge, 2011; Frey, Botan, & Kreps, 1999) were conducted for the following codes (Krippendorff, 2013) or signs (Bainbridge, 2011): *race/ethnicity, role in film*, *STEM discipline/profession*, *professional status*, *romantic relationship status*, *parental status*, *physical appearance*, *hypersexualization*, and *primary characterization.* These codes or signs were selected based on prior studies of portrayals of female scientists and engineers in popular films (Smith, Choueiti, & Pieper, 2014; Steinke, 2005) and studies of female characters in popular films (Smith, Choueiti, & Gall, 2013; Smith, Choueiti, & Pieper, 2013; Smith, Choueiti, & Pieper, 2014). A codebook with definitions was created to assist in identifying codes or signs. The second author was trained by the first author in using the codebook for films not included in this study. Discrepancies in coding were resolved through re-viewing and discussing scenes from these films, and refinements were subsequently made to the codebook and coding procedures. Codes were determined based on viewing of the films and studying reviews of plot and character descriptions in IMDb. Coders independently coded a random selection of a subset of approximately 10 per cent of the selected films. Inter-coder reliabilities were calculated for Scott's pi (Scott, 1955) using ReCal (Freelon, 2010). The average inter-coder reliability score for seven of the nine codes was .86 with scores ranging from .72 to 1.00. Scott's pi values were undefined for two codes (physical appearance and characterization) because of invariant values, although the per cent agreement for both codes was 100 per cent. The first author then coded the frequency of appearance of each code or sign and recorded specific descriptive examples of codes or signs for all selected films.

RESULTS

Film Ratings and Filmmaker Gender

Motion Picture Association of America (MPAA) ratings of appropriateness for certain audiences for the 42 selected films were as follows: two were rated PG, 24 were rated PG-13, 12 were rated R, three were rated TV-PG, and two were given no rating. Two of the films (*Kettle of Fish* and *Teknolust*) were written by female filmmakers.

Number of STEM Characters in Speaking Roles by Gender and Race/Ethnicity

Overall, 72 female and 145 male STEM characters were shown in the selected films, producing a ratio of 1 female for every 2 male STEM characters in speaking roles (Table 1). Few depictions of STEM characters from underrepresented racial and

ethnic minority groups were found in speaking roles in the selected films. The majority (slightly over 80 per cent) of all male and female STEM characters appearing in speaking roles were White/Caucasian (Table 1). Approximately 7 per cent were Black or African American, 9 per cent were Asian/Indian American, 1 per cent were Hispanic or Latino/a, 2 per cent were multiracial, and for less than 1 per cent race/ethnicity could not be determined.

Table 1: Male and Female STEM Characters in Speaking Roles by Race/Ethnicity

Gender	*White/ Caucasian*	*Black or African American*	*Asian/ Indian American*	*Hispanic or Latino/a*	*Multiracial*	*Undetermined*	***Total***
Female	55 (25%)	3 (1%)	7 (3%)	3 (1%)	4 (2%)	0 (0%)	**72 (33)**
Male	120 (55%)	11 (5%)	12 (6%)	0 (0%)	0 (0%)	2 (0.9%)	**145 (66%)**
Total	**175 (81%)**	**14 (7%)**	**19 (9%)**	**3 (1%)**	**4 (2%)**	**2 (<1%)**	**217 (100%)**

Representation of Lead, Co-Lead, or Secondary Role Female STEM Characters by Race and Ethnicity

Female STEM professionals in lead, co-lead, or secondary roles were mostly (approximately 82 per cent) White/Caucasian in the selected films. Few of the female STEM characters in primary and secondary roles were from underrepresented racial and ethnic minority groups, with approximately 2 per cent being Black/African American, 6 per cent Asian/Indian American, 3 per cent Hispanic or Latina (Table 2), and 6 per cent multiracial. Some of the characters from minority groups included Alice Thibadeau (*Virtuality*), an African American astrobiologist; Lieutenant Uhura (*Star Trek* and *Star Trek: Into Darkness*), a Latina communications officer and space scientist; Dr. Amanda Waller (*Green Lantern*), an African American biologist; and Diondra (*Debug*), an Asian computer scientist.

Table 2: Female STEM Characters in Lead, Co-Lead, and Secondary Roles by Race/Ethnicity and Genre

Genre	*White/ Caucasian*	*Black or African American*	*Asian/Indian American*	*Hispanic or Latino/a*	*Multiracial*	***Total***
Action/Adventure	25	0	2	2	3	**32 (52%)**
Drama/Crime	17	1	0	0	0	**18 (29%)**
Comedy	4	0	1	0	0	**5 (8%)**
Science Fiction	1	0	0	0	0	**1 (2%)**
Horror	4	0	1	0	1	**6 (10%)**
Total	**51 (82%)**	**1 (2%)**	**4 (6%)**	**2 (3%)**	**4 (6%)**	**62 (100%)**

Portrayals of Lead, Co-Lead, or Secondary Role Female STEM Characters
Of the 62 female STEM characters in lead, co-lead, or secondary roles in the selected films, the majority of characters were shown in co-lead roles and more were shown in secondary than lead roles. Approximately 24 per cent were shown in lead roles or as protagonists, 43 per cent were shown in co-lead roles (often with male co-leads), and 32 per cent were shown in secondary roles across all genres (Table 3).

Table 3: Female STEM Characters by Movie Role and Genre

Role	*Action/ Adventure*	*Drama/Crime*	*Comedy*	*Science Fiction*	*Horror*	***Total***
Lead	7	5	1	1	1	**15 (24%)**
Co-lead	11	7	4	0	5	**27 (43%)**
Secondary	14	6	0	0	0	**20 (32%)**
Total	**32**	**18**	**5**	**1**	**6**	**62 (100%)**

STEM Discipline and Professional Status
A little over one-third (36 per cent) of the female STEM characters in lead, co-lead, or secondary roles were shown working in the biological sciences fields, while almost one-fourth (23 per cent) were shown working in astronomy. Approximately one-tenth (11 per cent) of female STEM characters in these roles worked in robotics/technology, and another one-tenth (10 per cent) in computer science. Few female scientists were found working in other STEM disciplines or fields (Table 4). A complete list of all female STEM characters in these roles by their STEM discipline or field is given in Appendix B.

Table 4: Female STEM Characters by STEM field and Genre

STEM Field	*Action/Adventure*	*Drama/Crime*	*Comedy*	*Science Fiction*	*Horror*	***Total***
Engineering	0	3	0	0	1	**4 (7%)**
Computer Science	0	3	0	0	3	**6 (10%)**
Biology	9	8	3	0	2	**22 (36%)**
Chemistry	0	0	0	0	0	**0 (0%)**
Astronomy	11	2	0	1	0	**14 (23%)**
Mathematics	1	1	0	0	0	**2 (0%)**
Physics	1	0	0	0	0	**1 (2%)**
Psychology	2	0	2	0	0	**4 (7%)**
Robotics/	7	0	0	0	0	**7 (11%)**

Technology						
Anthropology	0	1	0	0	0	**1 (2%)**
Geology	1	0	0	0	0	**1 (2%)**
Archeology	0	0	0	0	0	**0 (0%)**
Total	**32**	**18**	**5**	**1**	**6**	**62 (100%)**

Across all genres, half (50 per cent) of all female STEM characters in lead, co-lead, or secondary roles were shown working as a member of a research team and almost one-quarter (23 per cent) were shown as a lead researcher or director of a lab. Nine per cent were depicted as research assistants and 3 per cent filled other roles (Table 5). Professional status was determined by viewing the role of female STEM professionals depicted in the film, whereby a lead researcher or director of the lab was defined as being the primary STEM professional in charge of a lab or field research project, while an equal member of a research team was shown working with at least one other or a team of other STEM professionals. A research assistant – a category also including graduate students and postdoctoral research assistants – was defined as one who was subordinate to another scientist.

Table 5: Female STEM Characters by Professional Status and Genre

Professional Status	*Action/ Adventure*	*Drama/ Crime*	*Comedy*	*Science Fiction*	*Horror*	***Total***
Lead Researcher	7	4	2	0	1	**14 (23%)**
Member of Research Team	14	11	0	1	5	**31 (50%)**
Research Assistant	6	0	3	0	0	**9 (15%)**
Student	3	3	0	0	0	**6 (9%)**
Other	2	0	0	0	0	**2 (3%)**
Total	**32 (51%)**	**18 (29%)**	**5 (8%)**	**1 (2%)**	**6 (10%)**	**62 (100%)**

In the selected films, most of the female STEM characters worked as equal contributing members of research teams. Female STEM characters in films such as *Contagion*, *Debug*, *The Bourne Legacy*, and *Virtuality* worked with diverse research teams that included male and female STEM characters as well as STEM characters from diverse racial and ethnic groups. Some female STEM characters like Susan "Sue" Storm, a technology expert in *Fantastic Four* and *Fantastic Four: Rise of the Silver Surfer*, worked with an all-male research team. Several of the female STEM characters worked with one other male or female STEM professional, such as Dr. Madeline Madsen, a molecular biologist in *Finn on the Fly*, and Tiffany, a genetic engineer in *The Curse of the Komodo*.

A few of the portrayals of female STEM characters shown working on a research team depicted them as secondary to a research project or lab director. This

depiction was most pronounced for Violet Barnes, a graduate student in psychology in *The Five-Year Engagement,* who worked in the lab of a psychology professor and dissertation advisor who promoted her work because of his romantic attraction to her rather than his interest in her scientific contributions.

Some of the female STEM characters in lead roles were shown working as a project or lab director or sole researcher on science or engineering projects. These characters – such as Dr Susan Calvin in *I, Robot*, Dr Grace Augustine in *Avatar*, Ginger in *Kettle of Fish*, Temple Grandin in *Temple Grandin*, Sam Walczak in *Walled In,* and Dr Madeline Madsen in *Finn on the Fly* – typically were portrayed as competent, knowledgeable, and skilled STEM professionals. For example, Dr Marie Clare King, a geneticist working on breast cancer research in *Decoding Annie Parker*, is portrayed as professional, knowledgeable, resourceful, and competent, and is often shown leading discussions with her research team, interacting with other scientists and administrators, and giving public presentations about her research. However, other portrayals emphasized challenges some of the women faced as STEM professionals – for example, Dr Grace Augustine, an anthropologist in *Avatar*, is clearly in charge when she first appears and as she directs the research project and project activities of other researcher team members. However, Dr Augustine's genetic engineering research project is undermined by an ambitious and ruthless manager of a mining project, and Augustine is killed when trying to protect her work and the Na'vi people. And in the comedy *Finn on the Fly*, Dr Madeline Madsen's research assistant, Bob, takes credit for her scientific breakthrough and advances himself professionally by presenting the findings from her research to a funding agency. Madsen, a middle-aged single mother and chemist who works in the basement of her home researching a transformation serum to change humans to animals, is portrayed as a self-absorbed, single-minded, attention-seeking, dominant, eccentric chemist, even though she is the one who makes an unusual scientific discovery.

Roles in Film

Portrayals of female STEM characters in lead, co-lead, and secondary roles across all genres were most likely to portray them as professionals (87 per cent). Only a few portrayals showed female STEM professionals in stereotyped roles as mad or maniacal (6 per cent), loners or socially awkward (5 per cent), or as nerdy or geeky (2 per cent) scientists (Table 6). The female STEM characters' professionalism was reinforced in a number of different ways such as showing them in professional attire (typically a white lab coat or space suit) and professional workplaces; conducting scientific experiments, collecting specimens, explaining or reviewing scientific or technical data; posing questions or providing hypotheses based on research findings; supervising students or research team members; or discussing scientific or technical concepts with other STEM professionals or a public audience. Traditional STEM stereotypes were found for a few portrayals such as Dr Madeline Madsen (*Finn on the Fly*), who was portrayed as a mad and eccentric chemist; Dr Rosetta Stone (*Teknolust*), who was portrayed as a nerdy and geeky biogeneticist; and astronomy student Rhonda Williams (*Another Earth*), who was portrayed as a loner.

Table 6: Female STEM Characters by Characterization and Genre

Characterization	*Action/ Adventure*	*Drama/ Crime*	*Comedy*	*Science Fiction*	*Horror*	*Total*
Professional	32	15	3	1	3	**54 (87%)**
Mad/maniacal	0	0	1	0	3	**4 (6%)**
Clumsy/absentminded	0	0	0	0	0	**0 (0%)**
Nerdy/geeky	0	0	1	0	0	**1 (2%)**
Loner, antisocial, socially awkward	0	3	0	0	0	**3 (5%)**
Total	**32 (52%)**	**18 (29%)**	**5 (8%)**	**1 (2%)**	**6 (10%)**	**62 (100%)**

Physical Appearance and Hypersexualization

The majority (95 per cent) of female STEM characters in lead, co-lead, and secondary roles across all genres were portrayed as attractive, with only 5 per cent portrayed as not attractive – a trait found mostly in portrayals of female STEM characters in comedies (Table 7). Attractive or glamorous characters were those who did not show any overt physical signs often associated with a lack of beauty (messy or unstylish hair, unstylish or out-of-date clothing or attire).

Table 7: Female STEM Characters by Appearance and Genre

Appearance	*Action/Adventure*	*Drama/Crime*	*Comedy*	*Science Fiction*	*Horror*	***Total***
Attractive	32	17	3	1	6	**59 (95%)**
Glamorous/Sexy	0	0	0	0	0	**0 (0%)**
Unattractive/geeky /nerdy	0	1	2	0	0	**3 (5%)**
Unattractive to attractive/ glamorous/sexy	0	0	0	0	0	**0 (0%)**
Total	**32 (52%)**	**18 (29%)**	**5 (5%)**	**1 (2%)**	**6 (10%)**	**62 (100%)**

Many of the featured female STEM professionals were portrayed by attractive and popular Hollywood actresses such as Sandra Bullock (Ryan Stone in *Gravity*), Rachel Weisz (Hypatia in *Agora* and Dr Martha Shearing in *The Bourne Legacy*), Emma Stone (Gwen Stacy in *The Amazing Spider-Man* and *The Amazing Spiderman 2*), Natalie Portman (Jane Foster in *Thor* and *Thor: The Dark World*) and Keira Knightley (Joan Clarke in *The Imitation Game*). Although many wore a white lab coat or a spacesuit while working, these characters were shown at other times wearing stylish clothes and trendy styles. In fact, only three characters in all the films were classified in the unattractive/ nerdy/geeky category, and these characters appeared in comedy and drama/crime films – for example, in *The Girl*

with the Dragon Tattoo, Lisbeth Salander, a computer hacker, wears black clothes, tattoos, and heavy piercings, and is also pale and very thin, while Tilda Swinton, as Dr Rosetta Stone in *Teknolust* (2002), wears big eyeglasses, is pale and has unstylish hair.

In some of the films, 31 per cent of female STEM characters were hypersexualized and shown as partially naked or with cleavage showing (Table 8), most likely in horror films. In one scene in the film *Star Trek: Into Darkness*, a female quantum physicist suddenly disrobes for no apparent reason, asking a male colleague to turn his back while she changes clothes.

Table 8: Female STEM Characters by Hypersexualization and Genre

Hypersexualization	*Action/ Adventure*	*Drama/ Crime*	*Comedy*	*Science Fiction*	*Horror*	***Total***
Sexualized attire or partially naked	8	4	2	0	5	**19 (31%)**
Regular/modest attire	24	14	3	1	1	**43 (69%)**
Total	**32 (51%)**	**18 (29%)**	**5 (8%)**	**1 (2%)**	**6 (10%)**	**62 (100%)**

Romantic Relationships

In the films studied for this research, there was almost the same proportion of female STEM characters portrayed who were not in a relationship (39 per cent) as those who were in a dating relationship (34 per cent), although relatively few (10 per cent) were shown as being married (Table 9). Some of the female STEM characters were considering a relationship (8 per cent) and others were the focus of romantic interest that they did not reciprocate (8 per cent) (Table 9). Those who were most likely to be in a relationship appeared in science-fiction and horror films, while those who were least likely to be in a relationship appeared in drama/crime films.

Table 9: Female STEM Characters by Romantic Status and Genre

Romantic Interest	*Action/ Adventure*	*Drama/Crime*	*Comedy*	*Science Fiction*	*Horror*	***Total***
Married	3	3	0	0	*0*	**6 (10%)**
In a relationship	10	4	3	0	4	**21 (34%)**
Considering relationship	5	0	0	0	0	**5 (8%)**
Focus of romantic interest/Not reciprocated	4	0	0	1	0	**5 (8%)**
Not in a relationship	9	11	2	0	2	**24 (39%)**
Cannot determine	1	0	0	0	0	**1 (2%)**
Total	**32 (51%)**	**18 (29%)**	**5 (8%)**	**1 (2%)**	**6 (10%)**	**62 (100%)**

Almost 40 per cent of portrayals of female STEM characters focus exclusively on their professional work rather than their romantic lives – for example, the portrayal of geneticist Dr Marie Clare King in *Decoding Annie Parker* includes only scenes that showed her in professional settings as she conducts research focused on the discovery of the breast cancer gene. However, romance is still a recurring theme in other portrayals of female STEM characters, such as in the film *The Five-Year Engagement*, which focuses more on Violet Barnes' romantic relationships than her professional work as a psychology postdoc, showing her romantic relationships as conflicting with her scientific aspirations. In this film, Violet is initially romantically involved with a non-scientist who leaves his career as a chef and moves from England to Michigan with her so that she can pursue a postdoctoral position at the University of Michigan. Violet later becomes romantically involved with the professor who supervises her research before she realizes she wants to marry her first partner, who gave up his career for her.

A few films focus on female scientists falling in love with other male colleagues. After starting work on a federal project, cryptanalyst Joan Clarke in *The Imitation Game* falls in love with a male colleague, mathematician Alan Turing, while in *I Origins* biology research assistant Karen becomes romantically involved and later marries the project director of the lab who initially was condescending towards her when she first started work in his lab. Other characters, such as Hypatia in *Agora*, demonstrate a lack of interest in a romantic relationship because of a focus on their work.

Parental Status

In all film genres included in the study, few female STEM characters were depicted as being parents; a total of 86 per cent of these characters were shown as not having children (Table 10). In most films, the female STEM characters were single or married without children.

Table 10: Female STEM Characters by Parental Role and Genre

Parental Role	*Action/ Adventure*	*Drama/ Crime*	*Comedy*	*Science Fiction*	*Horror*	***Total***
Parent/guardian	1	3	1	0	0	**5 (8%)**
Former parent/guardian	2	0	0	1	1	**4 (6%)**
No children	29	15	4	0	5	**53 (86%)**
Total	**32 (51%)**	**18 (29%)**	**5 (8%)**	**1 (2%)**	**6 (10%)**	**62 (100%)**

Several films showing female STEM characters as mothers emphasized the incompatibility of a STEM career and motherhood. In *The Day the Earth Stood Still*, widowed female scientist Dr Helen Benson, faces challenges as her late husband's son's legal guardian. Her professional work as a scientist even places the boy's life at risk. In *The Jensen Project*, Claire Thompson, who works as a technology expert

with a top-secret group of scientists, places her son Brody's life at risk when she returns to join a research team focused on stopping a malicious, power-seeking scientist who later implants a nanobot in Brody's body.

Some female STEM characters were shown describing experiences of having lost a child, such as astronaut Ryan Stone in *Gravity* and marine biologist Skylar Shane in *Amphibious Creature of the Deep* whose work in remote tribal villages led to the disappearance and death of her daughter. In *Splice*, genetic engineer Elsa Kast loses the half-child, half-creature daughter she engineered using her own DNA and who dies tragically as a result of Elsa's questionable ethical and scientific choices.

In *Polytechnique*, the challenges women face balancing STEM work and family is directly addressed by Valérie Dompiere, a mechanical engineering student, in this film about the real-life shooting that targeted female students at the École Polytechnique in Montreal, Quebec. Following an interview for an internship position, Valérie expresses her frustration about a comment from a male interviewer who said that her choice of mechanical engineering was unusual and that civil engineering was easier for women raising a family.

DISCUSSION

This study provided an update on research on portrayals of female scientists and engineer characters in popular films from over a decade ago (Steinke, 2005) and extended previous research by providing an analysis of female characters in all STEM fields, such as computing, where the underrepresentation of women has been particularly pronounced (AAUW, 2015; National Science Foundation, 2017) Portrayals of women STEM professionals in popular films are likely to be important sources of information about STEM professionals because of the increasing focus on science found in popular films and the realism of the medium (Kirby, 2011). One researcher explains: "Hollywood cinema, with its perceptually realistic images and linear narrative structures, contextualizes science in a manner that can establish our primary cultural meanings of science more than any other media" (Kirby, 2011, pp. 39–40).

Findings from this study that focused on STEM characters in speaking roles indicated that male STEM professionals outnumbered female STEM professionals by a ratio of 2 to 1. (It is important to note that this finding relates specifically to films intentionally selected because they featured female STEM professionals in lead, co-lead, or secondary roles.) This ratio is similar to those from other research that found male speaking or named characters outnumbered female speaking or named characters by 2.66 to 1 for "Best Picture" Academy Award films from 1977–2006 (Smith, Choueiti, Granados, & Erickson, 2008), 2.1 to 1 for "Best Picture" Academy Award films from 1977–2010 (Smith, Choueiti, & Gall, 2013), 2.51 to 1 for popular top-grossing films from 2012 (Smith, Choueiti, Scofield et al., 2013), and 2 to 1 for popular films appearing in 11 different countries from 2010–2013 (Smith, Choueiti, & Pieper, 2014). Studies focused specifically on *STEM* characters in films have found even fewer female characters. For example, a study of popular films released from 1991 and 2001 found that, of 74 films featuring scientists and engineers as primary characters, only 25 depicted females as primary or lead characters,

revealing a ratio of 3 males to 1 female (Steinke, 2005). A study of films across 11 countries released between January 1, 2010 and May 1, 2013 with an MPAA rating of G, PG, or PG-13 or equivalent found that only 11.6 per cent of 3,000 characters portrayed as STEM professionals were female, revealing a ratio of 7.6 STEM males to every 1 STEM female (Smith, Choueiti, & Pieper, 2014). The increase in number of female STEM professionals in speaking roles noted in the present study may be related to the method used for film selection or may indicate an overall slight increase in these roles for female STEM characters in popular films in the United States.

Findings from the present study show underrepresentation of female STEM professionals from traditionally underrepresented racial and ethnic groups in speaking roles. Fewer than 20 per cent of all STEM scientists (female and male), and 7 per cent of all female STEM professionals in speaking roles were from underrepresented racial and ethnic groups. These findings mirror the historical, industry-wide trend related to a dearth of racial and ethnic diversity characters in popular films in the United States (Smith, Choueiti, & Pieper, 2016) and point to a larger cultural issue related to inclusion and diversity in film portrayals.

The present study found more female STEM professionals in co-lead (N=27) and secondary roles (N=20) than primary roles (N=15) in comparison to previous studies. This study revealed few female STEM professionals in lead roles (N=15) during the selected 12-year period (2002–2014) similar to the number of female scientists and engineers (N=11) found in a prior study for a ten-year period (1991–2001) (Steinke, 2005). This decreased prevalence of female STEM characters in lead roles is even more pronounced considering that the present study included films that featured female characters from all STEM professions while the previous study (Steinke, 2005) included films that featured only female scientists and engineers. A comparison of female characters in co-lead and secondary roles from prior research was not possible because only female characters in lead roles were included in that previous analysis (Steinke, 2005).

Overall, findings related to the number of female STEM professionals appearing in popular films suggest "symbolic annihilation" of women as STEM professionals. Presenting more males as STEM professionals in popular media conveys gendered stereotypes that reinforce the masculine image of STEM (Blickenstaff, 2005; Kelly, 1985). Research shows that cultural stereotypes of successful scientists are more likely associated with males who are perceived as having agentic traits, which are often also associated with scientists, than with females who are perceived as having communal traits (Carli, Alawa, Lee, Zhao, & Kim, 2016). Research also suggests that cultural stereotypes of gender and STEM perpetuated by popular media send messages that may lead children and adolescents to develop gendered assumptions about the composition of the STEM workforce (Steinke, 2005). While the percentage of males in some STEM fields in the United States is greater than the percentage of females (National Science Foundation, 2015), creating more equal representation of female STEM characters in lead roles in popular media may be an important strategy for broadening the participation of women in STEM, particularly for the engineering and computer science fields, where women are most

underrepresented. Additional research has found that positive experiences with female role models serve as "sources of resilience" (Richman, van Dellen, & Wood, 2011, p. 493) that have helped women in engineering cope with threats to their social identity from being a numerical minority in a traditionally masculine field (Richman, van Dellen, & Wood, 2011), while other research has noted the importance of female role models in changing adolescent girls' self-efficacy related to science (Hughes, Nzekwe, & Molyneaux, 2013). Thus, increasing the prevalence of women STEM professionals in popular media may be important for providing vicarious role models for girls and young women when direct interaction with real-life role models is not possible.

Creators of popular films need to be mindful of the potential implications of this "symbolic annihilation" (Tuchman, 1981) of female STEM professionals. Presenting fewer female STEM professionals as characters in speaking roles not only promotes a masculine image of STEM fields but also reinforces the gendered organization of STEM fields (Smith-Doerr, Vardi, & Croissant, 2016). Social learning theory (Bandura, 1969, 1986) and possible selves theory (Markus & Nurius, 1986) suggest that a greater number of female STEM professionals, including a greater number in important lead roles, may encourage adolescent girls to identify with these STEM characters and, in turn, may help them to envision a future possible self as a STEM professional. A review of current theoretical models related to developing a STEM identity suggests that media producers need to consider a range of STEM identity relevant variables including gender as well as race and ethnicity when creating media content (Steinke, 2017)

Findings related to the specific professions of the female STEM characters in the selected films found that most were depicted as biologists or astronomers/astronauts. Few were shown as engineers (7 per cent) or computer scientists (10 per cent), reflecting the actual low numbers of women in these STEM fields (AAUW, 2015; National Science Foundation, 2015). These findings indicate that popular films show few female characters as engineers and computer scientists as vicarious role models that could encourage girls' and young women's increased participation in these STEM fields, where women are most underrepresented.

Recently, the US television industry launched an initiative to feature more female protagonists as engineers on television. The National Academy of Engineering, USC Viterbi School of Engineering, the MacGyver Foundation, the Paley Center for Media, and Lee Zlotoff sponsored a competition and selected finalists to create a television series about "that next female hero that will inspire a generation of young women to see themselves as engineers" ("The Next MacGyver," 2015). The Alfred P. Sloan Foundation, meanwhile, sponsors a program to encourage the next generation of filmmakers to create films about science and scientists (Alfred P. Sloan Foundation, 2016). Initiatives like these may be important vehicles for changing gender-stereotyped images of engineers and computer scientists. Films like *Ghostbusters* (2016) and *Hidden Figures* (2017), released since this study was conducted, indicate positive changes in cinematic representation and portrayals of female engineers and computer scientists.

This analysis found several differences in portrayals of female STEM professionals in comparison to previous research. Specifically, it found that they were typically depicted as equal members of a research team rather than as a project director or lead researcher, while overall there were fewer portrayals of female STEM characters in lead roles depicting them as the primary researcher or director of a laboratory when compared to findings from the previous decade (Steinke, 2005). Approximately half of the female STEM professionals in the selected films were portrayed as equal members of research teams. These findings suggest an overall increase in portrayals as equal members of research teams as well as a slight increase in portrayals in subordinate roles for female STEM characters featured in recent popular films.

Findings from this study also showed changes in the typical characterization of female STEM professionals over time, with an overall decrease in portrayals that depicted them according to scientist stereotypes (mad/maniacal, geeky/nerdy, clumsy/absentminded, loner/antisocial) in comparison to findings from a study of female scientists and engineers from over a decade ago (Steinke, 2005). The present study found that most of the female STEM characters were portrayed as professionals and in a realistic manner. Indeed, other studies of portrayals of scientists in both television and films from the past decade have also noted an overall decrease in stereotypical depictions of scientists (Dudo et al., 2011; Kirby, 2011). These findings suggest that popular media, and in particular films, have made progress in presenting more positive and realistic images of STEM professionals in recent years.

Similar to findings from prior research on film portrayals of female scientists and engineers from over a decade ago (Steinke, 2005), this study also showed a focus on the attractiveness of the female STEM characters. Almost all (95 per cent) of the 62 female STEM characters were attractive, popular and glamorous Hollywood actresses who filled these roles. Overall, these findings indicate that the film industry is more likely to portray female STEM professionals as attractive women. The image of attractiveness used in these depictions of female STEM professionals was based on conceptions of beauty created through Hollywood portrayals. Films often portray attractiveness as a desirable trait for women, and subsequently viewers often perceive media conceptions of beauty or attractiveness as social standards (Bazzini, Curtin, Joslin, Regan, & Martz, 2010).

The implications of the effects of mediated portrayals focused on the attractiveness of STEM professionals are unclear. One study that used print media to evoke middle-school girls' cognitive images of STEM professionals found that magazine interviews describing university students who displayed feminine characteristics and success in STEM had negative impacts on middle-school girls who did not identify with STEM (Betz & Sekaquaptewa, 2012). The middle-school girls were demotivated rather than inspired by feminine STEM role models and less likely to report interest in a STEM subject, specifically mathematics (Betz & Sekaquaptewa, 2012). Another study found that when shown photographs of real female and male scientists without knowledge of the actual occupations of those featured in the photographs,

adults were less likely to judge female scientists with feminine appearances to be scientists (Banchefsky, Westfall, Park & Judd, 2016).

Other studies, however, suggest that presenting female STEM professionals as attractive may be important for some adolescent girls' and young women's identification with STEM professionals. Research has shown that middle-school girls' wishful identification with female scientist characters on popular television shows varies by character attribute as well as program genre (Steinke et al., 2012). A study of female protagonists in a major Hollywood motion picture found that viewing attractive female protagonists was found to be a predictor of the appropriateness of the characters as a role model for women (Taylor & Setters, 2011). Research on children aged 6-12 found that they showed a preference for peers they perceived to be attractive in appearance whether or not they experienced prior exposure to Disney films focused on attractive characters (Bazzini et al., 2010).

Portrayals that depict female STEM professionals as attractive may also be important because they counter some of the traditional, unflattering stereotypes that have historically been associated with scientists (mad, geeky, nerdy, clumsy,absentminded, lonely,antisocial). Research has suggested that cultural stereotypes of the types of people (e.g. nerdy and antisocial) in the STEM professions in which women have been underrepresented, combined with the work they are involved in and the values they hold, send signals to girls that these fields are not appropriate for them and may limit and prevent their participation (Cheryan et al., 2015). Film depictions of female STEM professionals as attractive and feminine rather than geeky or nerdy also may help adolescent girls and young women to see that they do not have to "do masculinity" (Smith-Doerr et al., 2016, p. 65) to be a successful scientist, technologist, engineer, or mathematician. Indeed, one recent study indicated the incompatibility that exists between public perceptions of femininity and STEM (Banchefsky et al., 2016).

However, focusing on the attractiveness of female STEM characters runs the risk of depictions that overlook women's competence and credibility as scientists, especially when female STEM characters are shown as hypersexualized. This present study found that almost one-third of the female STEM characters were shown as hypersexualized – findings similar to research on 100 popular films from 2012 that found one-third of White, Black and Hispanic females (more than from any other racial/ethnic background) were portrayed as hypersexualized, or depicted in tight or revealing attire (Smith, Choueiti, & Pieper, 2013). Hypersexualized portrayals objectify female STEM professionals and "repeated viewing of these types of portrayals may teach younger males and females that women are valued for how their bodies look rather than who they are" (Smith, Choueiti, & Pieper, 2013, p. 6).

Findings from this research noted a significant focus on the romantic relationships of female STEM characters, similar to findings from a previous study of portrayals of female scientists and engineers in films from 1991 to 2001 (Steinke, 2005). Such a focus may promote adolescent girls' and young women's identification with the

female STEM characters, according to research has found that females are more likely to remember the actions of female characters shown in romantic scenes (Maccoby & Wilson, 1957). However, research has also found that women who associated possible romantic partners with chivalry and heroism showed less interest in high-status occupations, noting that "implicit romantic beliefs" (Rudman & Heppen, 2003, p. 1369) may limit women's potential: "Romance idealizes femininity and places women on a pedestal. But it also may teach women (e.g. through romantic fairy tales) to depend on men for economic and social rewards" (Rudman & Heppen, 2003, p. 1358).

Findings from this study revealed a dearth of portrayals of women STEM characters as working mothers. Additionally, the portrayals of working mothers that highlighted the risks their jobs posed to their children may reinforce the image of STEM being a traditionally masculine domain (Blickenstaff, 2005; Kelly, 1985) and stereotyped assumptions about women's inabilities to balance work and family. This finding was similar to research on the television program *CSI*, which found depictions of one of the female STEM characters, Catherine, as a working single mother who is ineffective in balancing work and childcare (Warren, Goodman, Horton, & Bynum, 2016). Research shows that females who perceive STEM occupations as being incompatible with motherhood may experience identity conflict (Settles, Jellison, & Pratt-Hyatt, 2009) when trying to integrate a parent or family identity with a science identity or STEM identity (Carlone & Johnson, 2007; Herrera et al., 2012). The lack of portrayals of female STEM professionals successfully balancing family and scientific careers may also affect some adolescent girls' and young women's identification with future STEM careers.

LIMITATIONS OF THE RESEARCH AND DIRECTIONS FOR FUTURE RESEARCH

Findings from this study documented cultural representations of gender and STEM through an analysis of portrayals of female STEM characters in popular films from 2002–2014 in the United States. Examining the prevalence and depictions of female STEM characters in popular media is an important first step in understanding how these images may influence public perceptions of women in STEM fields and provide insights that may partly explain why adolescent girls and young women turn away from these disciplines. While female STEM professionals have become more common on the Big Screen, they are still underrepresented in popular films. In addition, Hollywood continues to produce gender-stereotyped portrayals of female STEM characters.

One of the limitations of this study was that it examined images of female STEM characters in only one popular medium: films. Future research needs to examine the many images of female STEM characters who appear in books, magazines, television, online videos, websites, and social media sites. Additionally, future research needs to determine which media are most important for girls and young women at various stages of development, and longitudinal studies need to investigate the cumulative effect of these mediated images over time. Future research also needs to consider the collective effects of exposure to images of female STEM professionals from various media.

The present study focused on examining recent images of female STEM professionals in popular films in the United States from 2002–2014. Other film industries such as Bollywood and Nollywood and films from countries in Latin America, Europe, and Asia were not considered. Bollywood and Hollywood, followed by Nollywood, are some of the most important films industries to date (Rivera, 2010; Elena, 2012). Future research should address films from other industries and other countries to provide a broader analysis of cultural representations of women STEM professionals in films. A cross-cultural comparison would fill a gap in the literature and advance research on media representations of STEM professionals across cultures. This comparison would also provide insights on how STEM professionals are portrayed and perceived by different cultures.

The exclusive focus of this study on analyzing images and the use of a content analysis and textual analysis to document depictions of female STEM professionals did not provide information about the specific effects of these images on the audience. Additional research providing evidence related to adolescents' viewing and preferences for these films would advance understanding of potential effects on adolescents' perceptions of STEM professionals and in promoting STEM possible selves. While this was beyond the scope of the present study, this research is critical for assessing the potential effects of these images on specific attitudes toward STEM professionals and fields. For example, research on the effects of "vicarious contact" (Fujioka, 1999; Tan, Fujioka, & Lucht, 1997) afforded by attention to media images of female STEM characters would provide useful information about how these images might influence adolescent girls' attitudes and behaviors toward STEM. Prior research focusing on print media found that undergraduate women were more likely to consider computer science as a major after reading a newspaper article describing more diverse and less stereotyped images of computer scientists than undergraduate women who read a newspaper article describing computer scientists as "stereotypical techno-nerds, with their short-sleeve shirts and pencil protectors in their pockets" and a "pasty, willowy student in a dorky shirt, face hidden behind bangs and glasses" (Cheryan et al., 2013, p. 68). Future research replicating this study using images from digital media would advance understanding related to the potential effects of viewing stereotypical images of STEM in popular films.

Of even greater importance, additional research focusing on how images in the popular media influence girls' and young women's exploration of "possible selves" (Markus & Nurius, 1986) is needed to assess specific effects of these images on attitudes and future behaviors, specifically STEM career decision-making. Understanding how adolescent girls' and young women's perceptions of STEM professionals are shaped by enduring media images, and how these images affect visions of their own STEM "possible selves", may be a critical first step toward the development of a science identity (Carlone & Johnson, 2007; Herrera, Hurtado, Garcia, & Gasiewski, 2012) and pursuit of a future career in STEM.

The findings from this study underscore the need for empirical research on the influence of popular media and vicarious media role models on girls' interest and participation in STEM fields. A gap remains in the research on broadening STEM

participation that provides empirical evidence that explains *how* and *when* girls' and women's lack of interest and participation in STEM has been influenced through various forms of media (books, magazines, television, films, video games, websites, social media) and years of exposure to cultural stereotypes of gender and STEM. In addition, this research must carefully consider a wide range of attributes of mediated female STEM characters and the diverse viewing environments that may affect girls' and young women's identification (see Steinke et al., 2012 and Steinke, 2017). For example, future research in this area needs to examine differences in media effects that are likely to result from individual differences in viewer responses to differentiated film content, including differentiated portrayals such as those examined in this study. Research has shown that stereotypes are malleable and their influence can be minimized through counter-stereotypes or alternative images (Blair, Ma, & Lenton, 2001). However, other research has found that exposure to counter-stereotypical occupational role models leads women to show a decrease interest in male-dominated careers, possibly through fear of backlash (Rudman & Phelan, 2008) if they follow nontraditional career paths (Rudman & Phelan, 2010). Additional research in this area is needed to advance understanding of the types of portrayals and the specific effects of these portrayals.

CONCLUSION

This study provided a comparison of the prevalence of female to male STEM professionals in speaking roles and a description of portrayals of female STEM professionals in lead, co-lead, and secondary roles in recent popular films in the United States. This study provided evidence of "symbolic annihilation" as well as overt and subtle gender stereotyping of female STEM professionals in popular films. Social cognitive theory and possible selves theory collectively suggest that limited and stereotyped portrayals like those found in this study may influence public perceptions of STEM professionals and affect public attitudes and behaviors toward women in STEM. While it was beyond the scope of this study to assess viewers' attitudes towards female STEM professionals and STEM careers or to assess girls' and young women's identification with the female STEM professionals featured in them, both of these theories suggest potential effects for girls and young women. Bandura's (1986) social cognitive theory suggests that viewers are likely to model the behavior of media characters, particularly those perceived to have similar and/or desirable traits or characteristics. Markus and Nurius's possible selves theory (1986) suggests that viewers may be affected by media images when thinking about who they are and who they expect or hope to become.

Future research focused on assessing how popular portrayals of female STEM professionals in films influence the attitudes and behaviors of girls and young women would be useful in determining ways to encourage their interest in STEM. It is also important to note that the specific effects of these portrayals on girls' and young women's attitudes and behaviors are likely to vary based on viewers' individual differences related to an array of differences in their personal backgrounds and experiences, differences in their perceptions of salience and relevance of the portrayals, as well as differences in the specific characteristics and attributes of the female STEM professionals featured in these portrayals (see Steinke, 2017). Future research also should examine if girls and young women

actively seek out and watch these films. Additionally, future research focused on assessing how popular portrayals of female STEM professionals in films influence the attitudes and behaviors of boys and young men would be useful in order to determine ways to encourage greater inclusiveness in STEM.

Producers of American mass media are "important contributors to the construction and maintenance of gender stereotypes" (Lauzen, Dozier, & Horan, 2008, p. 201). The present study revealed that gender stereotypes of female STEM professionals are evident in recent popular films in the United States. These gender stereotypes are a concern because years of research indicate that the prevailing public image is that scientists and engineers typically are male (Barman, 1999; Beardslee & O'Dowd, 1961; Buck, Clark, Leslie-Pelecky, Lu, & Cerda-Lizarraga, 2008; Chambers, 1983; Flick, 1990; Fort & Varney, 1989; Huber & Burton, 1995; Maoldomhnaigh & Hunt, 1988; Mead & Metraux, 1957; Parsons, 1997; Steinke et al., 2007; Tan, Jocz, & Zhai, 2015; Thomas & Hairston, 2003). In addition to this gender stereotype of STEM professionals, the public often perceives STEM professionals to exhibit other negative stereotypes, such as being absent-minded, socially inept, untrustworthy, evil, and self-centered (Congressional Commission on the Advancement of Women and Minorities in Science Engineering and Technology Development, 2000; Hagerty, 1964; Kirby, 2011). Understanding the potential influence of gender-stereotyped and negative stereotyped portrayals of STEM characters in media on adolescent girls' and young women's cognitive processing of information during the career decision-making stage is critical for identifying strategies to best promote their interest and participation in STEM.

Hollywood has the potential to be an important change agent in altering cultural representations of gender and STEM and shifting popular beliefs of gender and STEM. The findings from this research suggest that in order to counteract gender stereotypes prevalent in the US film industry, writers and producers of popular films could increase the overall presence of female STEM professionals, and particularly those shown in lead roles, and eliminate gender stereotypes in film portrayals of female STEM professionals. Providing a greater number of female STEM characters from a greater variety of STEM fields and presenting more diverse and fewer gender-stereotyped portrayals of female STEM characters affords adolescent girls and young women vicarious contact with positive female STEM role models who are more like them. As long as girls continue to grow up in a culture permeated by contextual cues and images that associate males with STEM professions and marginalizes the contributions of female STEM professionals, the underrepresentation of women in all STEM fields is likely to continue.

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Appendix A

STEM Character Definition and Selection Criteria

A STEM (science, technology, engineering, mathematics) character is defined here as a general scientist, specific kind of scientist (marine biologist, chemist, astronaut), engineer, technology professional, computer scientist/programmer, mathematician, and anyone using scientific equipment or computers in a work/research setting

The STEM character must meet one or more of the following criteria:

1. Character is listed as scientist or STEM professional in cast lists on IMDb or Wikipedia

2. Character is mentioned by other characters in the film as a scientist or STEM professional

3. Character describes him/herself or self-identifies as a scientist or STEM professional in the film

4. Character is shown in a white lab coat or other professional attire that indicates affiliation with science and/or technology

5. Character is shown working as a scientist or STEM professional (doing science experiments, programming or operating computers, mixing chemicals, gathering scientific samples) in a STEM workplace such as a scientific laboratory, computer station, space station or spaceship, or scientific research field-work station (archeology dig site, geology site, oceanography lab on beach or boat)

Appendix B
Films and Characters Selected

Films Featuring Female STEM Professionals Lead, Co-Lead, and Secondary Characters, 2002 to 2014 (*n* = 42)		
Film	**Female Character(s)**	**STEM Profession**
Agora (2009, Adventure, PG-13)	Hypatia (Rachel Weisz)	Mathematician
Amazing Spider-Man, The (2012, Action, PG)	Gwen Stacey (Emma Stone)	Biologist (Geneticist)
Amazing Spider-Man 2, The (2014, Action, PG)	Gwen Stacey (Emma Stone)	Biologist (Geneticist)
Amphibious Creature of the Deep (2010, Action, R)	Skylar Shane (Janna Fassaert)	Biologist (Marine Biologist)
Another Earth (2011, Drama, PG-13)	Rhoda Williams (Brit Marling)	Astronomer
Avatar (2009, Action, PG-13)	Dr Grace Augustine (Sigourney Weaver)	Anthropologist
Bourne Legacy, The (2012, Action, PG-13)	Dr Martha Shearing (Rachel Weisz) Dr Connie Dowd (Elizabeth Marvel)	Biologist Psychologist
Contagion (2011, Drama, PG-13)	Dr Leonora Orantes (Marion Cotillard) Dr Erin Mears (Kate Winslet) Dr Ally Hextal (Jennifer Ehle)	Mathematician (Epidemiological Statistician) Biologist (Epidemiologist) Biologist (Microbiologist/Geneticist)
Curse of the Komodo, The (2004, Horror, R)	Tiffany (Melissa Brasselle)	Biologist (Genetic Engineer)
Dawn of the Planet of Apes (2014, Action, PG-13)	Keri Russell (Ellie)	Biologist
Day the Earth Stood Still, The (2008, Drama, PG-13)	Helen Benson (Jennifer Connelly)	Astronomer/Astrobiologist
Debug (2014, Horror, R)	Lara (Sidney Leeder) Diondra (Jadyn Wong) Kaida (Jeananne Goosseen)	Computer Scientist (Programmer) Computer Scientist (Programmer) Computer Scientist (Programmer)

Decoding Annie Parker (2013, Drama, R)	Marie Clare King (Helen Hunt)	Biologist (Geneticist)
Fantastic Four (2005, Action, PG-13)	Susan "Sue" Storm (Jessica Alba)	Technologist
Fantastic Four: Rise of the Silver Surfer (2007, Action, PG-13)	Susan "Sue" Storm (Jessica Alba)	Technologist
Finn on the Fly (2008, Comedy, PG)	Dr Madsen (Ana Gasteyer)	Biology (Molecular Biologist)
Five-Year Engagement, The (2012, Comedy, R)	Violet Barnes (Emily Blunt) Vaneetha (Mindy Kaling)	Psychologist Psychologist
Fountain, The (2006, Drama, PG-13)	Dr Lillian Guzetti (Ellen Burstyn)	Biologist
Girl with the Dragon Tattoo, The (2009, Drama, R)	Lisbeth Salander (Rooney Mara)	Computer Scientist (Computer Hacker)
Gravity (2013, Sci-fi, PG-13)	Ryan Stone (Sandra Bullock)	Astronaut (Space physicist)
I Origins (2014, Drama, R)	Karen (Brit Marling)	Biologist
I, Robot (2004, Action, PG-13)	Dr Susan Calvin (Bridget Moynahan)	Psychology (Psychology and Advanced Robotics)
Green Lantern (2011, Action, PG)	Carol Ferris (Blake Lively) Dr Amanda Waller (Angela Bassett)	Engineer Biologist
Imitation Game, The (2014, Drama, PG-13)	Joan Clarke (Keira Knightley)	Computer Scientist
Interstellar (2014, Adventure, PG-13)	Brand (Anne Hathaway) Murph (Jessica Chastain)	Astronomer Astronomer
Jensen Project, The (2010, TV Movie, G)	Claire Thompson (Kellie Martin)	Technologist
Kettle of Fish (2006, Comedy, R)	Ginger (Gina Gershon)	Biologist (Animal Behaviorist)
Polytechnique (2009, Drama, PG-NR)	Valérie Dompiere (Karine Vanasse) Stephanie (Evelyne Brochu)	Engineer (Biogenetic Engineer) Engineer
Prometheus (2012, Adventure, PG-13)	Elizabeth Shaw (Noomi Rapace)	Astronaut
Rise of the Planet of the Apes (2011, Action, PG-13)	Dr Caroline Aranha (Freida Pinto)	Biologist (Primatologist)
Splice (2009, Horror, PG-16)	Elsa Kast (Sarah Polley)	Biologist (Genetic Engineer)
Star Trek (2009, Action, PG-13)	Uhura (Zoe Saldana)	Astronaut
Star Trek: Into Darkness	Dr Carol Wallace/Marcus	Physicist (Quantum

(2013, Action, PG-13)	(Alice Eve) Uhura (Zoe Saldana)	Physicist) Astronaut
Sunshine (2007, Adventure, R)	Corazon (Michelle Yeoh) Cassie (Rose Byrne)	Biologist/Botanist Astronaut (Pilot)
Teknolust (2002, Comedy, PG-R)	Dr Rosetta Stone (Tilda Swinton)	Biologist (Biogeneticist)
Temple Grandin (2010, Drama, TV-PG)	Temple Grandin (Claire Danes)	Biologist (Animal Behaviorist)
Thor (2011, Action, PG-13)	Jane Foster (Natalie Portman)	Astronomer (Astrophysicist)
Thor: The Dark World *(2013,* Action, PG-13)	Jane Foster (Natalie Portman)	Astronomer (Astrophysicist)
Transformers: Age of Extinction (2014, Action, PG-13)	Darcy (Sophia Myles)	Geologist
TRON: Legacy (2010, Action, R)	Quorra (Olivia Wilde)	Technologist (Computer Programmer)
Virtuality *(2009,* TV Movie, NR*)*	Rika Goddard (Sienna Guillary) Alice Thibadeau (Joy Bryant) Billie Kashmiri (Kerry Bishe) Sue Parsons (Clea Duvall)	Biologist (Botanist/Microbial Exobiologist) Astrobiologist Computer Scientist (Reality TV Show Host) Flight Systems Engineer
Walled In (2009, Horror, PG-13)	Sam Walczak (Mischa Barton)	Engineer

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