Sciential

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DEAR READER,

Welcome to Issue 7 of *Sciential*! As first-time Editors-in-Chief, we are excited to present this issue to you and we hope you enjoy it. We are, as always, committed to providing undergraduate students with the opportunity to publish their work. In doing so, *Sciential* gives students a platform to present the topics that they are passionate about and feel strongly about. It is more important than ever to foster student lead clubs and organizations while working in an online environment. Though the world is still experiencing isolation, these collaborative initiatives promote a sense of connection among students that we hope is evident throughout this issue.

This issue explores a diverse array of topics: the misdiagnosis of endometriosis public health crisis; the sparse reporting of postpartum depression in Canadian news sources and its contribution to stigmatization; determining associations between the colour and heavy element abundance of global clusters; the importance of implementing science communication in science programs and science communication pedagogy; an interview with Dr. Ayesha Khan about her perspective on the benefits of including equity, diversity, and inclusion principles in academic course content.

This year, the *Sciential* team welcomed many new members, which added new perspectives into the publishing process. We would like to thank our Senior Editors, Dalen Koncz and Lavanya Sinha, for their dedication and incredible work-ethic. Moreover, we want to recognize the diligence and strong commitment of the *Sciential* Editors. We are also grateful for the contributions of our communications coordinator, Cynthia Chung, in organizing our team's correspondence. As always, we appreciate the incredible work of our Creative Director, Angelina Lam, and the rest of *Sciential's* Creative Board. We would finally like to acknowledge the founders of *Sciential*, Aiman Shahid and Alisa Nykolayeva, along with our Senior Advisor Team, Dr. Kimberley Dej, Dr. Veronica Rodriguez Moncalvo, Dr. Katie Moisse, and Science Librarian, Abeer Siddiqui, for their support.

Thank you for reading our letter for *Sciential's* 7th issue and for continuing to support the voices of undergraduate students. Enjoy the rest of Issue 7!

Naomi Suzuki
Editor-in-Chief

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ORIGINAL RESEARCH

Demonstrating the Relationship Between the Colour and Heavy Element Abundance of Globular Clusters

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SUMMARY

Globular clusters are dense collections of the oldest stars in the universe, ranging from 11 to 13 billion years old. The stars that make up the clusters share common characteristics, such as their heavy element abundance (metallicity), as they are formed at the same time from the same dust cloud. Globular clusters outside the Milky Way are only seen as a single point of light, not as individual stars. This study investigates how the metallicity of clusters affects the colour light they emit. Colour-metallicity diagrams were created from 11 theoretical cluster models. Results showed that there was a relationship between the amount of heavy element abundance and the colour of light emitted. This relationship was then placed on the clusters from the real galaxy NGC 6166. The distribution of metallicities this gave was not a simple normal curve. This suggests that NGC 6166 merged with other globular clusters at some point in time, which is consistent with the literature.

ABSTRACT

Extragalactic globular clusters are viewed as single points of light, as the density of their stars make them individually indiscernible. The aim of this study was to find a correlation between the integrated colour of globular star clusters and the metallicity of their individual stars. This was accomplished by using the colour magnitudes and metallicities of individual stars from 11 cluster models based on work from Girardi et al. Integrated colour-metallicity diagrams found the relationship between clusters to be an increasing two-step linear function for each of the six colour ratios examined. To validate these findings, the F475W-F814W relationship was applied to integrated colour data of 5557 clusters from the real galaxy NGC 6166. Histograms taken of the colour and metallicity both showed non-gaussian distributions. Bimodal gaussian fits were applied to both and found that each exhibited the presence of subpopulations: one metal-poor ($\mu = -1.59$), and one metal-rich ($\mu = -0.41$). This suggests the occurrence of galactic mergers with NGC 6166 to create the population structure of clusters that is currently seen.

Keywords: Globular clusters, isochrones, colour-metallicity diagrams

INTRODUCTION

Globular clusters are collections of stars that are gravitationally bound in a distinct spherical shape (Figure 1). The clusters orbit a parent galaxy, residing in the surrounding galactic halo, displaying as much of a spherical symmetry as the galaxy itself does.[1] The vast number of stars they contain in their relatively small system, gives them some of the highest stellar densities in the galactic vicinity. The clusters around the Milky Way galaxy have an average of 200,000 $M_\odot$ (solar masses) and a tidal (boundary) radius of ~ 50 pc, giving them a range of average densities from 0.2 $M_\odot$ pc^{-3} at their boundaries up to 10^4 $M_\odot$ pc^{-3} at their cores.[2] As of 2010, there have been 158 confirmed globular clusters around the Milky Way, with a handful more possibly residing on the other side of the galactic disk, in which infrared imaging might be able to locate them.[3,4] The positioning of the clusters around the galactic core is what the astronomer Harlow Shapley used to dispel the notion that the solar system resided in the center of the galaxy.[5] In addition, the immense age of some clusters (reaching up to 13 billion years (Gyr)) allowed for a fundamental lower limit of the age of the universe to be set, as the universe must be older than the stars it holds.

**Figure 1.** **Hubble image of NGC 7006, one of the globular clusters surrounding the Milky Way.[6]**

There are two major sub-groups of globular clusters. The first contains the older metal-poor clusters, which emit more blue light, and approach an age of 13 Gyr. The second subgroup includes the younger metal-rich clusters, which emit more red light, and sit around 11 Gyr.[7] These ages can only be discerned for the populations that exist in the Milky Way and its surrounding satellites, for reasons that will soon be mentioned. Aging the clusters is achieved through isochrone fitting to their respective stellar sequences. An isochrone is a specific curve or track on the Hertzsprung-Russell (H-R) diagram that consists of stars with the same age (Figure 2). Stellar clusters (both globular and open) are well disposed for this, as the entire population is born out of the same homogenous cloud at relatively the same time.[8] The only varying factor between them is their mass, the stars. As a result, when they are plotted in terms of their luminosity and surface temperatures, it will yield a unique path that at some point deviates from the standard line of hydrogen burning stars, which is deemed the zero-age main sequence.[1]

The most common method of plotting globular cluster stars is on a colour-magnitude diagram, which is created with just the magnitudes of two distinct wavelength filters of each star in the cluster.[8] Predetermined isochrones are fitted to the plot in the hopes of matching the position where the stars begin to deviate, called the main sequence turn-off point. This point, which leads to further evolutionary tracks such as the red giant branch and the horizontal branch, moves downwards towards the smaller, less luminous stars as time progresses, allowing for anticipatory dynamic motions in the tracks.[9] Figure 3 shows an example of how theoretical isochrones can be fitted

to a real population of stars (in this case using a H-R diagram), thereby giving further detail and structure of age and direction to an otherwise chaotic diagram.
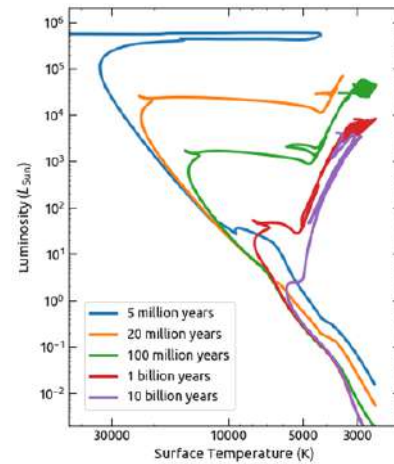
Figure 2. **Theoretical isochrones from the stellar models by Leo Girardi and collaborators (Padova) for near-solar metallicity and a range of ages.[10]**
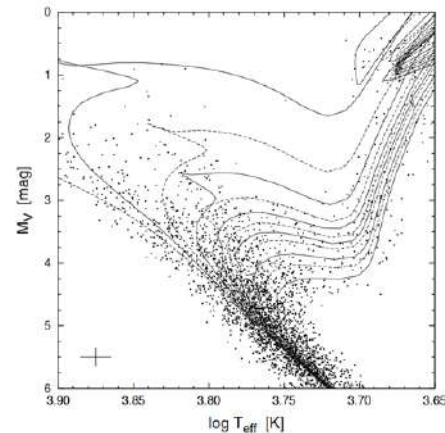
Figure 3. **A Hertzsprung-Russell diagram of 2968 artificial stars overlayed with isochrones that span from 1 Gyr at the top to 15 Gyr at the bottom.[11]**

Globular clusters can be found around any galaxy in the Local Group (which includes the Milky Way, Andromeda, and their respective satellite galaxies) with sufficient mass. The amount of clusters orbiting is also proportional to the dynamical mass of the host galaxy.[12] However, when looking at increasingly distant extra-galactic clusters, the ability to discern their individual stars becomes more and more difficult. Eventually, the light that is collected comes as a singular entity, in which any information that is extracted will be measuring the integrated properties of that cluster.[8] Without the individual star data, colour-magnitude diagrams are ineffective, and isochrone fitting cannot be done. Therefore, we must look to more immediate clusters to extrapolate the trends they would hold if viewed as a single, composite object.

METHODS

The initial work was begun using 11 cluster models computed from Girardi's *CMD* web interface. Each were created using a compilation of research on stellar populations and their tracks.[13–18] The models were created on October 15, 2019, using the *CMD 3.3* configuration. The data extracted from each model and used for this project included the cluster metallicity, the log of the luminosity of each star, the log of the effective temperature of each star, as well as the magnitudes of each star in the light filters of *F435W*, *F475W*, *F555W*, *F606W*, *F814W*, and *F850LP*. Table 1 includes additional information on the scale and metallicity of each cluster.

Table 1. The number of stars and the metallicity of each of the 11 clusters used for the analysis.

Cluster	Number of Stars	Metallicity (Z)
Girardi +0.2	137131	0.02259
Girardi 0.0	139350	0.01471
Girardi -0.2	138601	0.00947
Girardi -0.4	137780	0.00605
Girardi -0.6	136913	0.00385
Girardi -0.8	136407	0.00244
Girardi -1.0	135531	0.00155
Girardi -1.2	135167	0.00098
Girardi -1.5	134844	0.00049
Girardi -1.8	134573	0.00025
Girardi -2.1	127889	0.00012

Initial isochrones were created through Hertzsprung-Russell diagrams, where the log of the effective temperature was plotted against the log of the luminosity for every star in each cluster, as shown in Figure 4. This illustrates the diversity of evolution that each cluster had undergone, through the position of their turn-off points, and the extent of their horizontal branches. A composite of all 11 isochrones with a heatmap of their metallicities was plotted to help further express this notion.

H-R diagrams are useful for intragalactic clusters, however, for extragalactic clusters the use of integrated colour over temperature is more appropriate. Therefore, a Colour-Magnitude diagram (CMD), an alternative isochrone method, was chosen, as it utilizes only the magnitude of two wavelengths. Using the filter lengths mentioned previously, each cluster was plotted as six different CMDs, one for every colour ratio that was used. The standard filter ratios were F435W-F555W, F435W-F606W, F475W-F814W, F475W-F850LP, F555W-F814W, and F606W-F814W. Figure 5 shows a sample of the cluster CMDs using the F475W-F814W ratio, along with an additional composite image of the two clusters with the minimum and maximum metallicity value.

The next step was to integrate each cluster down to a singular point, as if to simulate what they would look like if viewed from a long distance. To do this, the magnitudes needed to be converted into luminosities, as magnitude is a unitless metric, while luminosity was measured in watts. The conversion function is represented by Equation 1, where L is the luminosity, M is the magnitude, and k is a conversion constant.

(1)
$$L = 10^{-0.4(M-k)}$$

A constant of 20 was used for k as it gave values that were of a reasonable magnitude to work with. Each star magnitude was converted to luminosity for all six wavelengths. They were then summated and converted back into an integrated magnitude. This was accomplished by using Equation 2.

(2)
$$M = k - 2.5(\log_{10} L)$$

The integrated colour was calculated by subtracting the specific integrated magnitudes denoted by the colour ratios. By plotting the known metallicity values from Table 1 against the integrated colour of the cluster, Colour-Metallicity diagrams (CMetD) were created, as shown in Figure 6. Multi-step linear trendlines were fitted to each CMetD, as shown in Figure 7, with Table 2 indicating the formula associated for each step of each diagram.

To check the viability of these trends, further tests were conducted using real data. A supergiant cD type galaxy called NGC 6166 was utilised for this. Using photometric data obtained from the HST ACS/WFC and WFC3 cameras within the F475W and F814W filters, integrated colours were calculated for the 5557 clusters surrounding the galaxy.[19] With each point already exhibiting integrated properties, a CMetD could be directly created, as is shown in Figure 9. By inverting the formulas found for the F475W-F814W colour ratio of the modelled clusters, it was possible to apply them to the integrated colours of the NGC 6166 clusters and yield their metallicity.

A notable difference in cluster density on either side of the pivot point (as seen in Figure 10), suggested the distribution should be further explored. Figures 11 and 12 show frequency histograms of the integrated colour of the clusters, and the metallicities of the clusters, respectively. The optimal bin width for each was calculated using Scott's normal reference rule, which comes in the form of Equation 3, where σ is the standard deviation and n is the number of data points.[20]

(3)
$$h = \frac{3.49\sigma}{\sqrt[3]{n}}$$

The optimal number of bins was calculated using a function in the form of Equation 4, where k is the number of bins, x is the data set, and h is the bin width.

(4)
$$k = \left\lceil \frac{\max x - \min x}{h} \right\rceil$$

The optimal number of bins for colour was 28, and 30 for metallicity. The non-gaussian distribution they both presented, with their pairs of distinct peaks, suggested the presence of subpopulations. To confirm this, a bimodal gaussian fit was applied to each, using the *curve_fit* routine from the *SciPy* library to optimize them, with the subsequent curves being seen in Figures 13 and 14.

RESULTS

Panels *a* through *k* of Figure 4 have plotted the log of the effective temperature against the log of the luminosity for every star in each cluster. Unlike those shown in Figure 2 and 3, each cluster follows only a single isochrone, as all the stars are the same age. As each cluster represents a theoretical model, their stars match the trend that would be given by an idealized isochrone. Each cluster initially follows a main-sequence path (with each sequentially increasing in temperature in a range of 3.35-3.50) until the stars have exceeded 1 $L_\odot$ (solar luminosity). There, each cluster has a sharp turn-off point where the stars begin to cool yet retain their present luminosity, until suddenly their luminosity begins to increase rapidly. This transition occurs when the stars have entered the Red Giant branch, a period when hydrogen fusion in the core has been completed, and fusion from the hydrogen shell surrounding the new helium core causes the star's envelope to expand.[21] This continues until the internal pressure and temperatures of the star grow to where helium fusion is enabled.[22] This can be seen in panels a through *k* of Figure 4 where the stars begin to increase in temperature again but decrease in luminosity. The clusters with the lowest metallicities (panels *i, j*, and *k* of Figure 4) also exhibit the beginnings of the horizontal branch, a stable period where both helium and hydrogen fusion occur. Panel *l* of Figure 4 is a composite image of all eleven clusters. It also illustrates each cluster's metallicity in a heatmap, with metallicities decreasing as the stars become cooler and redder (to a minimum of $\log(Z/Z_{Sun})$ = -2.091), and increasing with the stars becoming hotter and bluer (to a maximum of $\log(Z/Z_{Sun})$ = 0.171). The use of $\log(Z/Z_{Sun})$ normalized for solar metallicity values, with values of 0 matching that of the Sun.
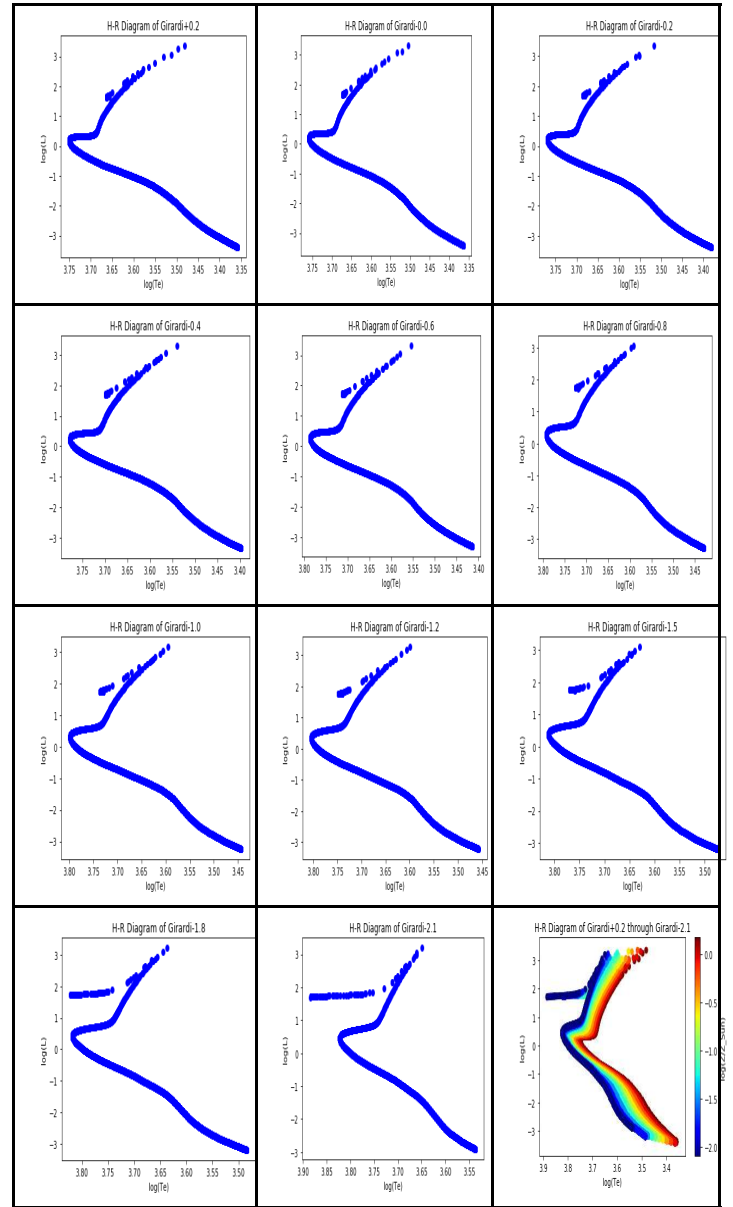

Figure 4. **Panels a − k. Hertzsprung-Russell diagrams of the 11 Girardi clusters and Panel l. Composite image of Panels a − k with a metallicity heatmap in solar units.**

Panels *a* through *k* of Figure 5 show the CMD isochrones of the same eleven Girardi clusters, with the colour ratio of *F475W-F814W*. They present the same overall structure for each, with the turn-off point, the red giant branch, and the horizontal branch all being visible. Panel *l* of Figure 5 is a composite image of the two clusters with the maximum and minimum metallicity value, with Girardi -2.1 (Z = 0.00012) being in blue, and Girardi +0.2 (Z = 0.02259) being in red, matching the relation seen in panel *l* of Figure 4.
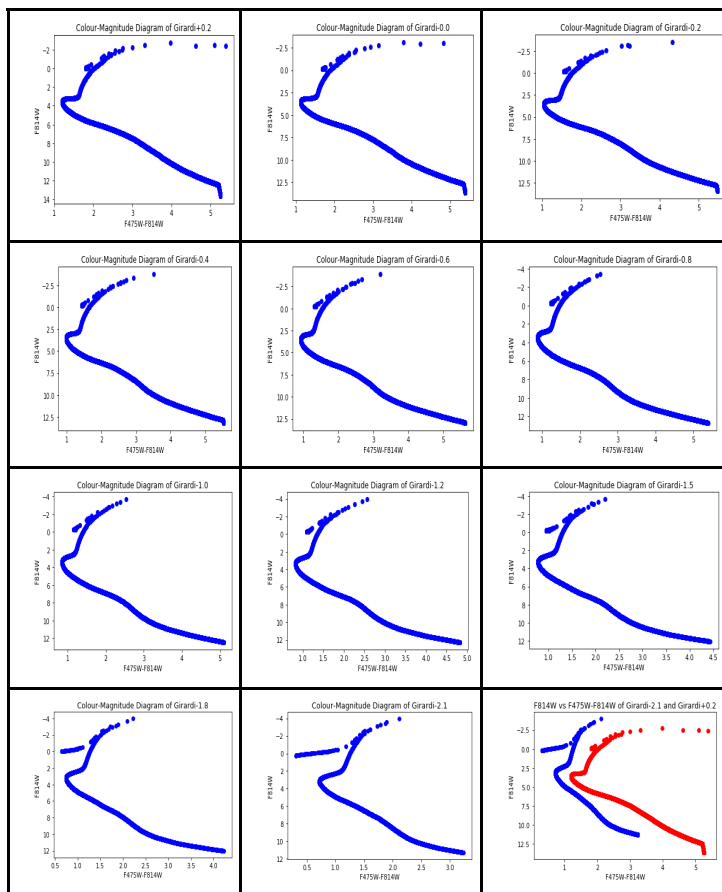
Figure 5. Panels a − k. Colour-Magnitude diagrams of the 11 Girardi clusters. Panel l. Composite image of panels a − k with panel a being coloured red and panel k being coloured blue to represent their relative difference in metallicity.

The panels of Figure 6 depict the CMetDs for all six colour ratios. Each panel has the same positioning on the x-axis as the log of their metallicity remains constant. The range of the integrated colours are only slightly variable, causing a consistent overall relationship between the clusters.
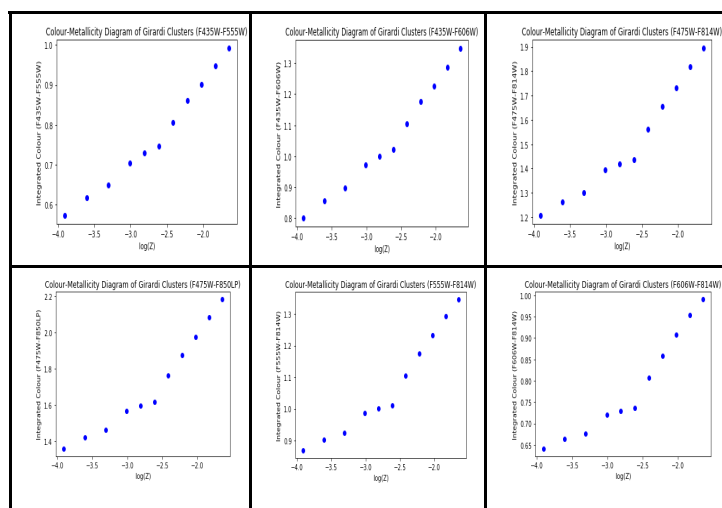
Figure 6. Colour-Metallicity diagrams for the 11 Girardi clusters with colour ratios of F435W-F555W, F435W-F606W, F475W-F814W, F475W-F850LP, F555W-F814W, F606W-F814W, respectively.

The panels of Figure 7 show the panels of Figure 6 with their respective increasing two-step linear trends and equations. Table 2 contains the formulas for the metal-poor trend and the metal-rich trend for each of the diagrams.
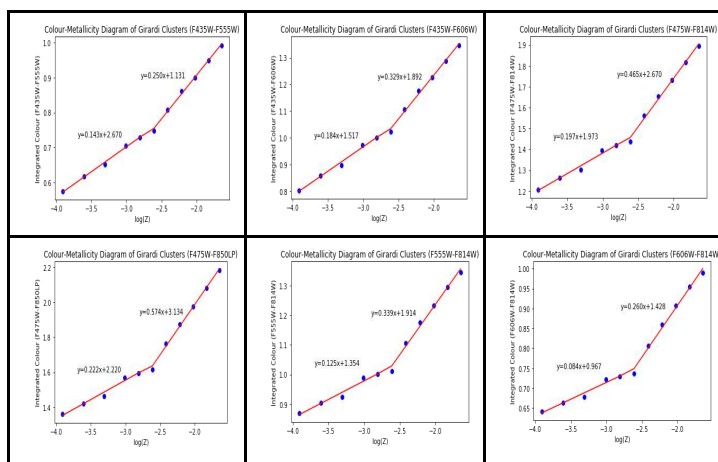

Figure 7. Copies of Figure 6 panels with their respective trendlines and equations for the colour-metallicity relation, for all 11 Girardi clusters, and for each of the six colour ratios.

**Table 2.** Formulas of the metal-poor and metal-rich trends for each of the colour-metallicity

Colour Ratio	Metal-poor	Metal-rich
F435W-F555W	$y = 0.143x + 2.670$	$y = 0.250x + 1.131$
F435W-F606W	$y = 0.184x + 1.517$	$y = 0.329x + 1.892$
F475W-F814W	$y = 0.197x + 1.973$	$y = 0.465x + 2.670$
F475W-F850LP	$y = 0.222x + 2.220$	$y = 0.574x + 3.134$
F555W-F814W	$y = 0.125x + 1.354$	$y = 0.339x + 1.914$
F606W-F814W	$y = 0.084x + 0.967$	$y = 0.260x + 1.428$

Figure 8 shows the CMD of the NGC 6166 clusters, helping to visualise the decrease in cluster concentration as they increase in brightness. The inversion of the F475W-F814W formulas for the metal-poor portion and the metal-rich portion were found to be $y = 5.076x + 10.015$, and $y = 2.151x + 5.742$, respectively. The manual pivot point was chosen to be F475W-F814W = 1.4607, as that is the intersection point of both functions. Figure 9 shows the CMetD that is created when those equations and pivot point are applied to the clusters of NGC 6166. Figure 10 shows a portion of Figure 9 isolated on the pivot point, showing the change in cluster density between the two segments.
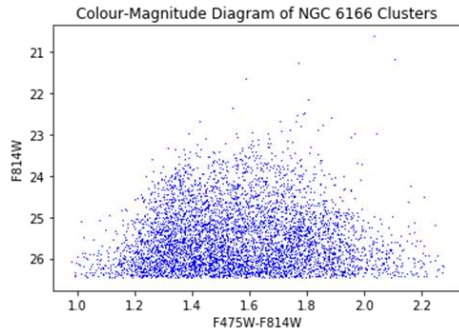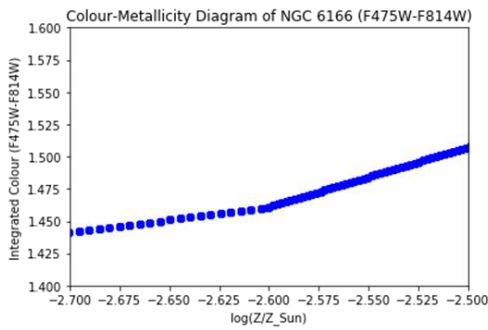
**Figure 8.** A colour-magnitude diagram of the clusters of NGC 6166.
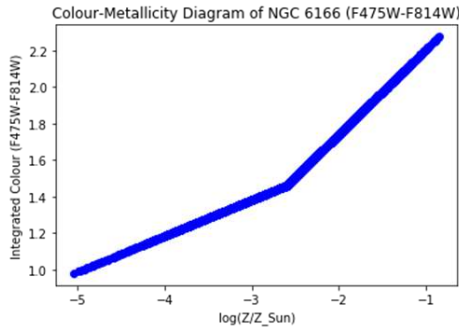
Figure 9. A colour-metallicity diagram of the clusters of NGC 6166 using the inverted formula and pivot point of the trendlines from the colour respective Girardi clusters.


Figure 10. An isolated portion of Figure 9 showing the difference in density between the two metallicity populations.

Figures 11 and 12 show the frequency distribution of the clusters for their colour and metallicity, respectively.
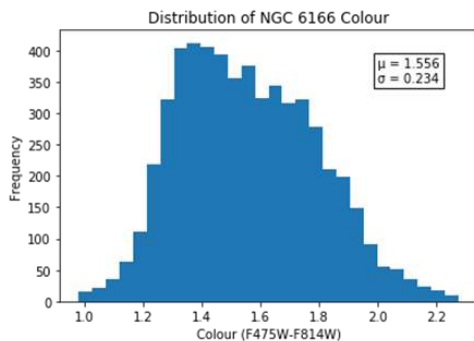

Figure 11. Frequency distribution of the F475W-F814W colour of the NGC 6166 clusters, showing a non-gaussian right-skewed structure.
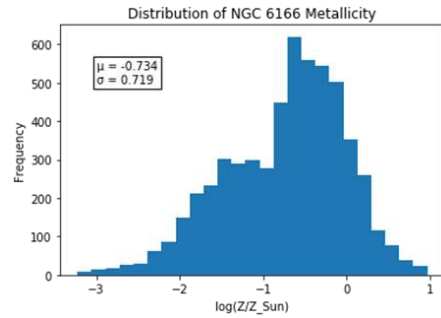
Figure 12. Frequency distribution of the log of the metallicity in solar units of the NGC 6166 clusters, showing a definite non-gaussian left-skewed structure.

Figure 13 shows the fit of the colour distribution, with the metal-poor gaussian curve in blue (with a mean of μ = 1.343), and the metal-rich gaussian curve in red (with a mean of μ = 1.634). The standard deviation of the metal-rich is more than double that of the metal-poor, being σ = 0.220 and σ = 0.101, respectively. Figure 14 shows the fit of the metallicity distribution, again with the metal-poor gaussian curve in blue (μ = -1.587), and the metal-rich gaussian curve in red (μ = -0.734). The standard deviation of the metal-rich is similar to that of the metal-poor, with them being σ = 0.456 and σ = 0.389, respectively.
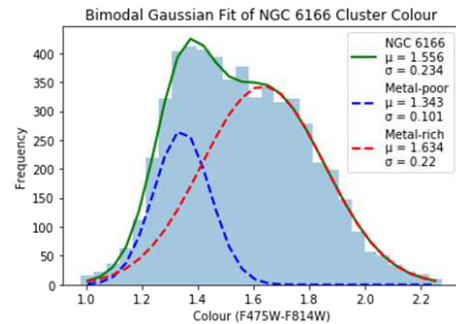
Figure 13. A bimodal gaussian fit applied to the colour distribution of the NGC 6166 clusters.
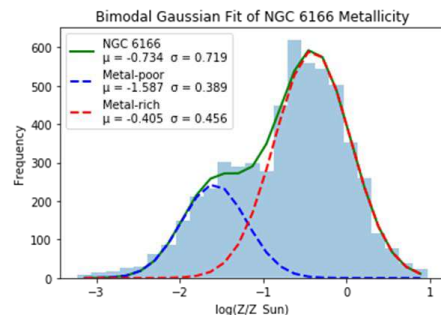
Figure 14. A bimodal gaussian fit applied to the metallicity distribution of the NGC 6166 clusters.

DISCUSSION

By looking at each cluster model through Hertzsprung-Russell diagrams (Figure 4), it was possible to validate the idealized nature of their isochrones. By confirming that the clusters followed the idealized trends, it inferred this project might lead to a relationship between colour and heavy element abundance that yield a result closer to the true theoretical relationship. The CMDs of each cluster followed the general structure of their H-R diagrams as each presented clear turn-off points, red giant branches, and horizontal branches in Figure 5. For this reason, it was possible to continue and find the integrated magnitude of each cluster. CMetDs were created using the integrated colour of the six ratios, shown in Figure 6. The consistency of the trends between all of the ratios simplified the process of creating a useful correlation between the cluster's integrated colour and its metallicity. The trend appeared to be an increasing piecewise linear function, which allowed for simpler methods of calculating the correlation (Figure 7). A linear best fit was applied to the segments separated by a manually chosen pivot point. The point, however, was consistent throughout all the CMetDs, being at the same metallicity condition where the Girardi -0.8 cluster sat (Figure 7).

Although Figure 8 shows a vast, chaotic distribution of the NGC 6166 clusters, when the *F475W-F814W* model equations were applied, it forced the clusters to take on the idealized two-step linear structure shown in Figure 9. This is not interesting by itself, but when isolating in on the pivot point, like in Figure 10, a large difference in density can be seen between the two populations. The population in the metal poor region is much less densely populated than those in the metal rich region . Figures 11 and 12 focus on the distribution of the colour and metallicity. Although both figures show a non-gaussian relationship, the metallicity distribution is much more distinct.

A bimodal gaussian fit was successfully applied to both clusters, as Figures 13 and 14 show. The fits found in the metallicity distribution strongly suggest that the clusters of NGC 6166 are divided into at least two subpopulations, with one containing metal-poor clusters, and the other containing metal-rich clusters. The mean metallicity of each cluster (μ = -1.587 and μ = -0.734, respectively) shows that even the majority of the metal-rich clusters have lower metallicities than our Sun, validating the advanced age of both populations. The presence of these distinct cluster populations also indicates the high probability of galactic mergers within the history of NGC. This fits well with the research stating NGC 6166 is a brightest cluster galaxy, having likely evolved from complex mergers during its assembly.[23] The relative number of clusters in the two populations, as well as a larger standard deviation for the metal-rich (σ = 0.456) and smaller deviation for the metal-poor (σ = 0.389), also suggest the merger of a younger, larger galaxy, with an older, smaller galaxy.

LIMITATIONS

The use of only 11 models to create the integrated colour-metallicity relationship most likely gave an incomplete and simplified version of what the true metallicity function is. The manual placements of pivot points for linear steps was not a sustainable method for calculations, however, it was a necessity for the limited computational skill of the author. Further work should then be completed, with both real and modelled data, in order to create a more realistic function of determining metallicity from integrated colour. The models used in this project increased by log(Z) = 0.2 - 0.3, and if the missing intermediate models were added it could lead to a more complicated or realistic function. It is possible that this more advanced function might find increased levels of cluster subpopulations, helping to broaden the understanding of certain galactic formations through these fingerprints of evolution.

SUMMARY

This project used 11 computational globular cluster models, with a metallicity range of $\log(Z/Z_{Sun})$ = -2.091 to 0.171, to create six mathematical relationships between the integrated colour of clusters and the metallicity of its stars. This was done through the creation of H-R diagrams and CMDs in order to subsequently convert the data to create integrated colour-metallicity diagrams that covered the colour ratios of F435W-F555W, F435W-F606W, F475W-F814W, F475W-F850LP, F555W-F814W, and F606W-F814W. The viability of the calculated F475W-F814W relationship was confirmed through the use of real colour data from 5557 clusters surrounding the supergiant galaxy NGC 6166, through the creation of a corresponding colour-metallicity diagram. A histogram taken of the cluster metallicity suggested a more complicated distribution than a standard gaussian curve. A *curve_fit* routine was applied and it showed a bimodal gaussian fit of metal-poor and metal-rich subpopulations, suggesting at least one merger within the galaxy's formational past, which is consistent with the literature.

ACKNOWLEDGEMENTS

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ACADEMIC REVIEW

Postpartum Depression Reporting Within Canadian News Sources (2010-2019)

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SUMMARY

Postpartum depression (PPD) is a serious mental health disorder that may occur soon after childbirth in mothers and/or fathers. Despite its high prevalence in Canada, PPD is often stigmatized and not discussed. The representation of PPD in Canadian media has not been evaluated in literature to date. It is important to understand the societal perception of PPD given its debilitating nature in the lives of new parents. In this study, we investigated the prevalence and common themes (i.e., use of personal anecdotes and scientific information) of PPD related articles published in three popular Canadian news outlets (*The Globe and Mail, National Post* and *Toronto Star)* in 2010, 2015 and 2019. A total of 27 articles that had at least two mentions of PPD were published, however, of these only eight articles from 2010 and 2019 had PPD as their main focus. Overall, 62.5% of articles included accounts of mothers' personal experiences with PPD, while only 25% included a description of fathers' experiences. In 2010, 85.71% of articles presented various forms of scientific information. Our findings suggest that more diverse reporting and awareness of PPD among the general population is needed, however further research is required.

ABSTRACT

Postpartum depression (PPD) is often stigmatized and there appears to be a significant lack of representation of PPD in Canadian media outlets. This showcases the necessity for diverse reporting in the media and an increase in awareness of PPD among the general population. The extent to which PPD is underrepresented in Canadian news sources over the past decade has not been evaluated to date. In this study, we investigated the prevalence of articles about PPD published in three popular Canadian newspapers (*The Globe and Mail, National Post and Toronto Star*) in 2010, 2015 and 2019 using Factiva. We scored the publications based on relevancy, approach to communicating PPD and discussion of resources. In 2010, 58.3% (*n=7*) of articles retrieved covered PPD, compared to 0% (*n=0*) and 16.7% (*n=1*) of articles in 2015 and 2019, respectively. Only articles that discussed PPD as their main focus were included in further analysis. Anecdotes of mothers' personal experiences with PPD were present in 62.5% of articles (*n=5*), while only 25% (*n=2*) included descriptions of fathers' experiences with PPD. Scientific information about PPD was mentioned in 85.71% of the articles (*n=6*). There was no discussion surrounding providing support or resources for mothers or fathers experiencing PPD in any of the analyzed articles. Evidently, the number of articles mentioning or discussing PPD has decreased in the last decade. In 2010, there was greater discussion of PPD in media sources, emphasizing relevant science and personal experiences of parents. Articles published in 2010 also included a greater representation of males' perspectives on PPD. Overall, the analysis suggests a plausible trend in the reporting of PPD and PPD stigmatization, however more research needs to be conducted in order to understand whether or not PPD has become more stigmatized in the last decade.

Keywords: Postpartum depression, maternal health, Canadian news media, science communication

INTRODUCTION

Postpartum depression (PPD) is a mental health disorder that typically occurs within the first month of childbirth.[1] PPD is similar to clinical depression with respect to the diagnosis, symptoms and treatments. The main difference, however, is that PPD affects new mothers and/or fathers primarily after childbirth. In Canada alone, greater than 20% of new mothers report emotions associated with PPD.[2]

One difficulty associated with the diagnosis of PPD is that the signs of mental illness are also consistent with natural changes that occur within mothers after childbirth and are difficult to differentiate. For instance, symptoms of PPD include weight changes, fluctuations in appetite, disruptions in sleep patterns, anhedonia

(i.e., inability to feel pleasure), feelings of worthlessness, depression, poor concentration and similar cognitive deficits/declines.[1] There are many factors that increase the risk of PPD prevalence, such as an individual and family history of depression, issues with prior pregnancies, and hormonal and emotional factors.[1]

People diagnosed with PPD are usually prescribed various treatment options that meet specific individual needs. The most common treatment options for PPD are support groups/counseling, psychotherapy, hormonal therapies, and massage therapies.[1] Most of these treatments take place in conjunction with the administration of antidepressants.[1]

PPD has often been stigmatized and the extent of how often it is discussed in the media is not well-known. To this day, there is still a high degree of stigma attached to the diagnosis of PPD, which plays a key role in the experiences of those affected.[3] This stigma leads to the belief that motherhood should be a time of joy and puts pressure on pregnant persons to meet these societal expectations.[3] Such a societal norm is problematic because pregnant persons and their families may fail to recognize symptoms of PPD and be unaware of how to get the help they need.[3] Those affected by PPD may also be afraid to discuss their feelings openly out of fear that others may undermine their experiences.

Within the healthcare sector, PPD is considered a public health issue that demands an increase in awareness among the public in efforts to destigmatize the disorder.[4] Increasing awareness and reducing the stigma associated with PPD are both necessary for pregnant persons and their support groups.[4] Doing so helps to reduce the prevalence of PPD, and provides appropriate resources and social support to those affected.[4]

Additionally, we are in a time where society is more open to having conversations about mental illnesses and the importance of mental health. This is being reflected through celebrities opening up about their experiences with PPD, the formation of support groups and discussions around fathers' experiences with PPD being more prevalent.[5-7] A societal shift in the way we view mental illnesses should be encouraged. We should also bring more awareness to mental illnesses, such as PPD, that are less prevalent among entire populations. Analyzing how PPD is communicated in our media can help destigmatize the experiences of postpartum persons and increase awareness of PPD in scientific and non-scientific communities.

Current research regarding the representation of PPD in North American media outlets emphasizes some common themes. Dubriwny highlights that American televised news medicalizes PPD, and raises problematic questions of what good motherhood should look like and whether or not PPD is a natural phenomenon to motherhood.[8] Cummings and Konkle demonstrated that Canadian newspapers promote awareness of depression and use research findings as evidence for their statements.[9] However, Canadian news sources rarely incorporate personal stories from those affected by a mental illness.[9] Additionally, Schanie and colleagues found that popular American press magazine articles often publish inaccurate and incomplete information about PPD.[10]

Evidently, it appears that a qualitative analysis of how PPD is represented in Canadian news sources, specifically, over the past decade (i.e., 2010 to 2020) has not been completed. This research topic is of interest because it allows for the identification of trends in the way PPD is communicated in Canada. It can also highlight and emphasize the need for diverse reporting and awareness of PPD and other mental health disorders as suggested in the existing literature.

This research investigation particularly focused on examining how Canadian media outlets have portrayed PPD and whether there was a shift in reporting within the past decade. The researchers identified and compiled relevant Canadian news reports published during the years 2010, 2015 and 2019. Articles were evaluated on their mentions of scientific studies or quotes from scientists, people's experiences with PPD, and support resources for individuals affected by PPD. After careful analysis, the selected news reports were scored and categorized based on their content.

We hypothesize that there has been a shift in PPD reporting within Canadian media over a 10-year span. More specifically, we believe that the discussion of PPD in the media has shifted from a scientific to an experiential lens, where there is an increase in accessibility and availability of resources to those affected. The identification of a potential shift of PPD in Canadian media outlets may reflect a change in public opinion and can demonstrate the significance of the media's roles and responsibilities regarding the translation of knowledge to society.

METHODS

Data Collection

Data was collected using Factiva, which is a search database that contains current and archived content from major global media publications. Through this database, we searched the most popular Canadian newspapers for their coverage of PPD in 2010, 2015 and 2019. We opted to search for news articles in 2019 rather than in 2020, since the extensive media coverage of the COVID-19 pandemic in 2020 led to a decrease in reporting of PPD in the news. *The Globe and*

Mail, The National Post and *The Toronto Star* were selected as they are the three most circulated English Canadian newspapers.[11]

Search Criteria

We conducted three searches on Factiva using the exact phrase "at least 2 postpartum depression." We completed the search in three newspapers: "The Globe and Mail - All sources" OR "National Post (Canada)" OR "The Toronto Star." The searches retrieved articles from January 1st to December 31st in the years 2010, 2015 and 2019. We included articles only published in English and excluded duplicate articles from the search.

Scoring System

First, a preliminary analysis was completed by reading through all the retrieved news articles to determine if the main theme of the article was PPD and, thus, relevant to the study. If the news articles solely just mentioned PPD, they were considered to be irrelevant and were excluded from further analysis. Relevant articles were then further analyzed and scored using the following criteria by two reviewers.

Approach

The language and content of each article was assessed in this category. Articles that discussed a scientific study or used a quote from a scientist received a 'y' for yes. The number of experts, scientific studies, and statistics used in the article were captured as numerical values. Articles that did not report a scientific study, statistic, or quote from a scientist received an 'n' for no.

This section further assessed whether personal experiences of PPD in mothers or fathers were mentioned in the article. This was separated into two subsections: mothers and fathers. Both subsections were evaluated on the same criteria. Articles that discussed a person's experience with PPD in a few sentences or throughout the article received a 'y.' The number of personal experiences mentioned in the article was captured as a numerical value. Articles that did not report a person's experience with PPD received an 'n'.

Discussion of Resources

This section assessed whether support or resources for postpartum persons were mentioned in the article. This was separated into two subsections: mothers and fathers. Both subsections were evaluated on the same criteria. Articles that discussed resources received a 'y.' The number of resources mentioned was also reported as a numerical value. Articles that did not report any sources of support or resources for postpartum persons received an 'n.'

FIGURES

The findings from the scoring system were used to compare how the articles within and between years scored in each aforementioned category. Graphs of key results were created using *Microsoft Excel for Mac 2021 (version 16.46)*.

RESULTS

A total of 27 news articles were found across 2010, 2015 and 2019 upon the initial search criteria. The search retrieved a total of 13 articles in 2010, 3 of which were from *The Globe and Mail*, 6 from *The National Post* and 4 from *The Toronto Star*. The 2015 search retrieved a total of 8 headlines. 2 articles were from *The Globe and Mail*, 2 from *The National Post* and 4 from *The Toronto Star*. A total of 6 articles were retrieved from 2019. 1 article was published by *The Globe and Mail*, 3 by *The National Post* and 2 by *The Toronto Star* (Tables 1-3, Appendix A).

Preliminary analysis was completed on all 13 articles in 2010, 8 articles in 2015 and 6 articles in 2019 to determine whether they were relevant to the nature of this study. Through this, one headline from 2010 was excluded from the analysis as it was a letter rather than a news article. From the 2015 articles, two were excluded as one was an advice column and the other was a duplicate article.

Articles that Mention PPD or are About PPD

Further analysis was conducted on all remaining articles (i.e., reading the article in-depth and determining whether the main focus was PPD). In 2010, 58.3% *(n=7)* were about PPD, while 41.7% *(n=5)* articles only made mention of PPD. In 2015, 100% *(n=6)* of articles only made mention of PPD. In 2019, 16.7% *(n=1)* of articles were about PPD and 83.3% *(n=5)* just made mention of PPD (Figure 1). This yielded a total of 8 relevant articles from 2010 and 2019, which were scored further on their approach to discussing PPD and inclusion of support resources.
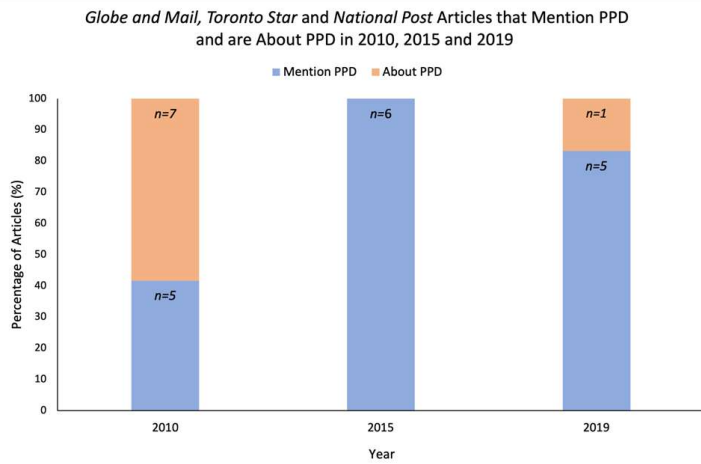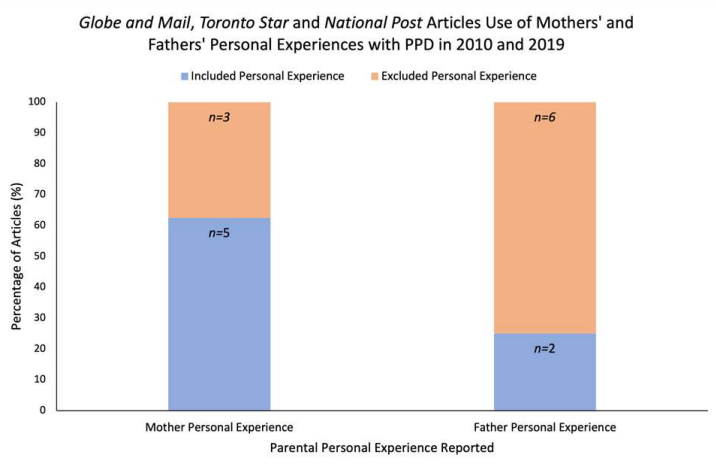
Figure 1. **Percentage of articles that only made mention of PPD (blue) versus articles that focused on PPD (orange) in 2010 (*n=12*), 2015 (*n=6*) and 2019 (*n=6*).** One headline from 2010 was excluded from the analysis due it being a letter rather than a news article. Two articles were excluded from 2015 as one was an advice column, and the other was a duplicate article. All articles were included from 2019.

Discussion of PPD Personal Experiences of Mothers and Fathers

A recurring theme in the content of some of the articles was mentioning personal experiences of PPD, particularly those of mothers. In 2010 *(n=4)* and 2019 *(n=1),* 62.5% of articles included accounts of mothers' personal experiences with PPD (Figure 2). In contrast, only 25% of all articles included a description of fathers' experiences with PPD. Data from only 2010 and 2019 was included in this figure due to there being no data pertaining to the use of mothers' and fathers' personal experiences with PPD for 2015.
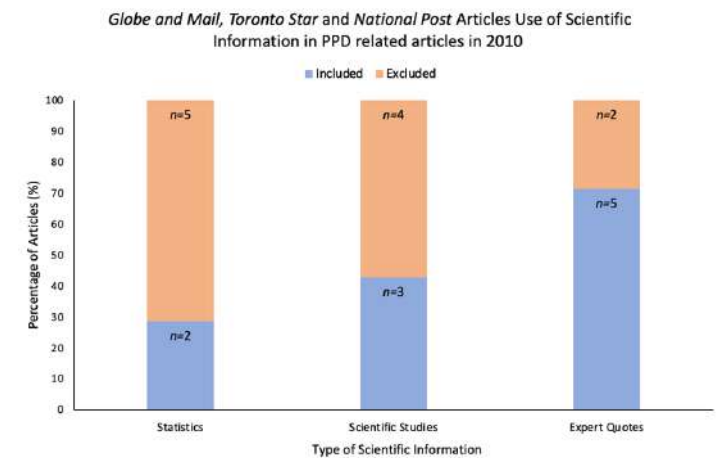

Figure 2. **Percentage of articles that included (blue) and excluded (orange) mothers' and fathers' personal experiences with PPD in 2010**

and 2019. All articles except for 1 were published in 2010 (*n=8).*

Discussion of Scientific Information Regarding PPD

From the articles that met the inclusion criteria, scientific information was mentioned in 85.71% of the articles in 2010, which was all articles except for one (n=6). Scientific information was presented in the form of statistics, reference to scientific studies and quotes from experts in the field. Expert quotes were included the most with 71.43% articles incorporating at least one comment from a scientist (Figure 3). Findings from scientific studies were described in 42.86% of articles, while statistics about PPD were included in just 28.57% of articles. Only data from 2010 was included in this figure due to there being no data pertaining to the use of scientific information in PPD for 2015 and 2019.

Figure 3. **Percentage of articles that included (blue) and excluded (orange) statistics, scientific studies, and quotes from experts about PPD in 2010 (n=7).**

Discussion of Resources

None of the articles that were analyzed included any sort of discussion about support or resources for mothers or fathers experiencing PPD.

Themes

Various themes emerged in the articles (n=27), some of which included infanticide in relation to crime and law, the majority of which were found in 2010. Another theme was biographies or personal accounts. Mothers' experiences were recounted most frequently, although discussion of fathers' experiences was also a recurring theme (Figure 2).

DISCUSSION

Our research study explored how PPD has been represented in Canadian news outlets in the years 2010, 2015, and 2019. We focused on assessing how news articles have discussed PPD through the use of scientific information, personal experiences, and resources available for individuals affected by PPD. We embarked on this study in order to examine whether discussions regarding PPD in the media have shifted to reduce stigmatization and increase the accessibility and availability of resources.

Our findings suggest that in the last decade, there has been a decrease in the number of articles that are about or mention PPD. Specifically, there has been a reduction in the number of articles about PPD from 2010 onwards. Articles retrieved from 2010 focused primarily on scientific studies and the personal experiences of new parents affected by PPD. These articles discussed the incidence of PPD by including statistics on prevalence, symptoms, and experiences from both the maternal and paternal perspectives. Articles published in 2015 and 2019 had simple mentions of PPD in relation to other topics, such as crime, but there was no increase in the reporting of scientific findings or personal experiences of PPD during these years. These findings may suggest that news outlets are now discussing PPD more in terms of how it may impact one's actions (e.g., lead to crime), instead of focusing on the prevalence of PPD. Additionally, there was a decrease in reporting personal stories and scientific studies about PPD throughout the years. The articles that were published in 2010 had greater mentions of scientific studies, expert opinions, and personal experiences from both the mothers' and fathers' perspective. It is plausible to suggest that news outlets are shifting their reporting style, however the sample size in this study is too low to generalize.

Previous studies have suggested that stigma is linked with familiarity and stereotypes.[12] According to Thorsteinsson and colleagues, familiarity is the degree of awareness and knowledge about a subject matter and can be acquired in a variety of ways, including, but not limited to, media.[12] Higher familiarity has been shown to reduce stigma and stereotypes.[12] Stereotypes, on the other hand, are built upon knowledge structures that are shared by the public. Stereotypes can lead to the misconception that people with a particular mental illness, or in this case PPD, can be dangerous. This type of thinking can lead to the formation of prejudice followed by the act of discrimination.[12] In our study, familiarity of PPD in the articles was assessed by looking at the level of knowledge, experiences and resources shared in each article, along with the context of the articles. Two of the 13 articles published in 2010 shared a stereotype that those suffering from PPD may be dangerous and commit crime. The remaining articles published in 2010 discussed statistics, science,

and expert opinions about PPD, which contributed to the increased level of familiarity. Whereas articles published in 2015 and 2019 had less information regarding PPD. This may suggest a possible trend in how PPD is reported in the media, but more research is needed to confirm this trend.

LIMITATIONS AND NEXT STEPS

There are some important limitations to this study that are worth mentioning. First, the relevant articles were not scored by the same reviewer. Articles from 2010, 2015 and 2019 were split between four reviewers. This introduces the possibility for bias, which would then reflect differences in the outcomes of scores. In the future, the same reviewer(s) should be responsible for scoring all relevant articles utilized within the study.

Initially, the reviewers intended to examine articles over a 10-year period. However, there was a significant lack of PPD related publications in the year 2020 due to the COVID-19 pandemic. The years 2010, 2015, and 2019 were analyzed to reflect this 10-year period. Future studies should present findings that are based over a longer time frame. Due to a lack of data found in 2010, 2015 and 2019, additional years would increase the accuracy regarding potential shifts in media coverage.

A final limitation is that only three media outlets were analyzed, resulting in a low sample size that may not be representative of all sources of information in Canada. Going forward, research should investigate news articles from more media outlets in order to better assess the trends that can be generalized across Canada. Furthermore, studies should be conducted utilizing social media, blogs, and additional platforms of social communication, enabling a more in-depth understanding of how PPD is communicated on a national scale. These study limitations can also be considered as future steps.

CONCLUSION

In conclusion, our findings reveal that there has been a decrease in the number of articles regarding PPD in Canada's top three news media sources since the year 2010. Specifically, the reporting of relevant scientific findings, personal experiences of mothers and fathers, and resources for those affected by PPD has decreased over the last decade. This may suggest a shift in reporting and, thus, reduced familiarity associated with PPD, which may mean that stigmatization of PPD has not decreased over the past decade. However, further research with a greater sample of news articles is needed in order to determine whether PPD reporting has led to a change in the illness' stigmatization and social understanding.

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APPENDIX A

Table 1. Titles and sources of articles retrieved in Factiva from 2010.

Source	Article	Source	Article	Source	Article
	2010				
Globe and Mail	Did you hear the one about the Mormon comedian? In her new memoir, I Love Your Laugh, Jessica Holmes chronicles her journey from Latter-day Saints to stand-up and TV through postpartum depression	National Post	I would never have hurt my baby	Toronto Star	Mom with breast cancer denied EI; Women who become ill on maternity leave are losing out on sickness benefits, critics say
	Baby killing: infanticide or murder?; Depression Defence; A 'middle ground' punishment for mothers who kill		Hearing tests postpartum depression defence; Appeals court to decide on murder vs. infanticide		10% of new dads suffer postpartum depression; According to a new study, postpartum depression is common in fathers. And a big barrier to treatment is that it is still widely seen as a woman's illness
	Saving women and children from postpartum psychosis		Health; A Toronto doctor hopes his findings will help prevent postpartum depression		Postpartum depression: Her hidden secret Early Problems; Signs and symptoms can often be dismissed as the baby blues or trials of motherhood
			Winnipeg mom charged with stabbing her children		Mysterious fall of a rising star; What prompted a Toronto-raised, NYU professor to leap to his death?
			Postpartum depression risk for dads, too		
			Even Dad gets the blues: Postpartum depression can also affect fathers, who often suffer in silence, Dakshana Bascaramurty reports		

Table 2. Titles and sources of articles retrieved in Factiva from 2015.

Source	Article	Source	Article	Source	Article
	2015				
Globe and Mail	Mother charged in toddler's death; Police trying to determine if she had postpartum depression	National Post	I'm pregnant and I have an eating disorder; Shame often prevents people from seeking help, but even when they take that brave step, the right services can be hard to access	Toronto Star	Listen for clues about how friend is doing: Ellie
	Scotiabank pulls more cultural funding		Be a good listener for friend in crisis		How bias hurts women, from the lab to the medicine cabinet
					I do not believe she was suffering from mental illness
					Lisa Raitt's latest comeback: Adroit transport minister returns after health scare and picks up right where she started - 'full steam ahead'

Table 3. Titles and sources of articles retrieved in Factiva from 2019.

Source	Article	Source	Article	Source	Article
	2019				
Globe and Mail	Ontario program treats perinatal anxiety	National Post	Singer Battles Anxiety Following Birth of Third Child	Toronto Star	A Blow in the Face takes audiences through the 'cave' of postpartum depression
			Five Canadian things to know about		A graphic (novel) look at postpartum depression; Author Talks
			How do you solve a problem like DeMar?; A Qualified tribute to past raptors teams		

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Endometriosis Misdiagnosis

What is Endometriosis?

Endometriosis is a disease defined by the presence of endometrial tissue implanted in extrauterine locations.[1-4] This results in inflammation in the affected areas.[1-4, 7]
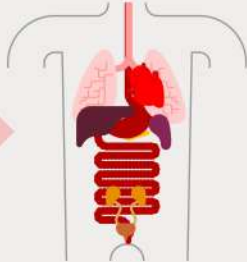
Approximately 10% of reproductive-aged females have endometriosis.[1,3,4,5,6] The frequent misdiagnosis of the disease have become a serious public health crisis that necessitates a reevaluation of diagnosis criteria.[7]

60% of cases go undiagnosed[7]

The pathogenesis of the disease is not well understood due to its involvement with many organ systems.[1,4]

Up to 50%[4] of individuals with endometriosis experience pelvic pain and infertility[5,6,7]

50%

- results in decreased quality of life
- e.g. increased likelihood of depression, difficulty with activities of daily living, adverse effects on sexual intimacy[7]

Despite the overwhelming evidence that endometriosis can greatly affect one's health, there remains an issue of misdiagnosis and delays in diagnosis, leaving individuals untreated for a significant portion of their life.[7]

Difficulties with Diagnosis

First Symptom

Successful Diagnosis

The misdiagnosis of endometriosis is extremely common, with delays from first symptom onset to diagnosis typically ranging from 4 to 11 years.[7]

Why do practitioners experience difficulties with diagnosing endometriosis?

- Endometriosis has no specific biomarkers[1]
- Symptoms can be attributed to many other conditions[1]

Symptoms of endometriosis and their association with other diseases:

- Dysmenorrhea (severe cramping in lower abdomen during or before menses) [8] is associated with ectopic pregnancy, adenomyosis, etc. [9]
- Dyspareunia (genital pain before, during, or after intercourse) [10] is associated with vaginismus [9]

The current gold standard for diagnosis is a laparoscopy [1,7,11] with or without histological examination - microscopic examination of tissue [2,7,11]

A laparoscopy is the surgical examination of abdominal organs. The surgery is invasive and often inaccessible. For endometriosis diagnosis, physicians search for the visible extrauterine lesions. [12]

Laparoscopies can be unreliable:
- Poor correlation between pathology and symptom severity [1,7,11]
- Lesions can have poor visibility [7]
- Interobserver variability [7]

Improved System of Diagnosis

Use a clinical definition over a histological definition for diagnosis.
- Endometriosis is more than its physical lesions [7]
- Better defined as a menstrual cycle-dependent, chronic, inflammatory, systemic disease that commonly presents as pelvic pain [7]
- Reduces need for diagnostic surgery [7]

Specified criteria for positive diagnosis - symptom analysis.
- Cyclic, chronic, and progressive pelvic pain [7]
- Dysmenorrhea unresponsive to nonsteroidal anti-inflammatory drugs (NSAIDs) may indicate endometriosis [7,11]
  - NSAIDs can treat primary dysmenorrhea (pain unrelated to a pelvic disease) but not secondary dysmenorrhea (pain related to a pelvic disease) [7]

Physical examination. [7,11]
- Bimanual pelvic examination has a diagnostic accuracy of 86%-99% [7]
- Criteria for a positive result include:
  - Palpable nodularity
  - Thickened pelvic anatomy [7]
- Less accurate for diagnosing deep endometriosis [7]
- Accuracy improves if examination is performed during menses [7]

Imaging.
- Transvaginal ultrasound can be a useful tool for diagnosis (when combined with previous techniques)
  - Particularly for deep endometriosis [7]
- Inexpensive and easy to perform [11]

Accuracy of diagnosis will be maximized if all four methods of improvement are used in conjunction with each other! [7]

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Interview with Dr. Ayesha Khan: Equity, Diversity, and Inclusion in Education

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BIOGRAPHY

Dr. Ayesha Khan is an associate professor with a cross-appointment at the School of Interdisciplinary Science and the Department of Psychology, Neuroscience & Behaviour at McMaster University. She has taught in the Life Sciences program since 2013. Over this time, she has received McMaster's Student Union Award for her work in community-engaged education and McMaster President's Award for Outstanding Contributions to Teaching and Learning.

Dr. Khan believes in incorporating equity, diversity and inclusion (EDI) principles into her course content. By applying a critical lens to the material she delivers, she thinks about how her course content relates to broader social issues. Dr. Khan cultivates her teaching philosophy by facilitating student empowerment. One way she allows students to showcase this skill is through the delivery of community-engaged education projects. In LIFESCI 40X3, The Biopsychology of Sex, students mobilize their knowledge into an end-of-term project aimed at informing students in LIFESCI 3E03, Reproductive Endocrinology, about topics surrounding reproductive issues and EDI. She believes that integrating these EDI principles is essential in empowering students to honour their voices and experiences. In her seminar and tutorial-style classes, students are exposed to several perspectives through the facilitation of peer conversations. Dr. Khan values the conversations she has with students about EDI. She uses these discussions as a learning tool to further her knowledge about the subject. By encouraging this dialogue, she strives to create an environment where students can openly express themselves.

Dr. Ayesha Khan, PhD

ABSTRACT

Equity, diversity and inclusion, (EDI) is emerging as a central topic in science today. EDI refers to an approach where individuals are encouraged to participate and given opportunities to succeed (1). In this approach, barriers and advantages are recognized and further, dissimilarities between individuals are respected and celebrated (1).

In this interview, Dr. Ayesha Khan shares what EDI means to her as a professor at McMaster University. She speaks about her relationship with EDI as an ongoing learning process that she is navigating with the help and guidance of students as well as academic resources. Her experience with EDI indicated to her that she should actively create a learning environment that is inclusive by allowing her students to have open conversations with one another. By indicating the value of EDI in an academic context, students are encouraged to be considerate of the effects of inequality in society. In this interview, Dr. Khan explains how consideration of EDI principles has made her an advocate for student empowerment and critical thinking.

Keywords: Equity, diversity, inclusion, academia

Equity, diversity and inclusion have been at the forefront of many discussions concerning the workplace, media, and education. What does EDI mean to you as an educator?

Equity, diversity, and inclusion is relevant to all of us. Right now, I would say that I'm working towards understanding the different ways in which people define this rather complex issue. The definitions of EDI might vary. Additionally, I spend a lot of time thinking about how to discuss EDI issues with students and what the best ways of presenting them are. In no way do I consider myself as an expert in such matters, so I co-share my learning with my students to better understand the definition and the lived experiences of everyone. To do that, I have to be very vulnerable to my students and let them know I don't have all the answers, and in particular, I am a student just like them when it comes to this topic. The importance of including EDI in education allows me to partner with my students in a more authentic way so that we can co-learn together and explore how we can put EDI principles into practice.

Was there a moment where you decided to include EDI principles in your classroom?

One basic principle around my teaching philosophy is student empowerment. I'm constantly looking for ways to empower my students to voice their thoughts and question the content they are learning in their courses. The purpose of university education is to gain a lot of discipline knowledge around a particular topic. But ultimately, students are citizens of a community. They should be people who think deeply about issues relevant to themselves and those around them. They should consider EDI issues to consider varied perspectives better. Further, connecting EDI to their academics can empower them to have a well-rounded perspective. Relating my empowerment philosophy to EDI made complete sense because many global issues are happening right now, especially within the context of reproductive endocrinology and reproductive health.

"Hopefully, our students are empowered enough to provide a meaningful perspective where it counts."

One of the seminars you lead, LIFESCI 4X03: the Biopsychology of Sex, has a high demographic of people who identify as women over any other gender identity. Do you think this poses a challenge of representing different perspectives?

I hope to get students engaged and excited about the content they are learning in the classroom. One consequence of cultivating their passion is that they are keen to openly and respectfully discuss their unique lived experiences with others.

"As a result, the message spreads even if the classroom has a particular demographic because students feel like these issues are worth talking about with others."

There are other courses where subjects of sex and gender are not a part of the course content. Do you feel that efforts should be made in these other classes to include EDI principles?

It is possible. For instance, recently, the Nobel Peace Prize recipients were announced. Instructors could discuss the number of women in a particular field versus the number of Nobel Peace prizes awarded to women.

That's not to say that those professors who are not talking about EDI issues in their classrooms are not interested in such matters. If you are going to include EDI as a topic of conversation, you need to have enough time to address student questions and provide many opportunities for ongoing discussions. There also needs to be enough time to share resources to gain varied perspectives so that there is time to go beyond superficial analysis. There are logistical constraints for why that can't happen in all courses.

Another challenge is that most of us in the Faculty of Science are experts in subject matters outside of EDI as an academic discipline. Including material that you are passionate about while still learning about it can pose a challenge because you don't want to present

information in a way that could be misinterpreted or deliver inaccurate information. When you're trying to help your students learn something that you are also learning with them, there are many risks.

What is your personal goal with EDI in the classroom?

If there is awareness around EDI issues, then as students transition into the next phase of their academic and professional journeys, we've planted a seed that EDI is a significant part of our lives. Equity, diversity and inclusion is about empowerment, to see things differently.

> "I also feel that there is strength in numbers. Just one student alone can go on and bring awareness to many others."

Co-learning EDI with my students and sharing this information makes me feel like I have done something noteworthy with my platform.

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ARTICLE INFORMATION

Science Communication: A Basic Skill That Needs To Be Developed In Undergraduate and Graduate Programs

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ABSTRACT

Communication skills are one of the most widely recognized learning outcomes for numerous programs in higher education. However, proper training in science communication (SciComm) skills are consistently falling short of requirements. This highlights the need to examine the curriculum as a whole as opposed to a course level view. In this piece, I present arguments expressing the need for proper incorporation of formal communication training in undergraduate and graduate programs to enhance the quality of discourse between scientists and the lay public. Specifically, this opinion piece briefly describes the current state of SciComm training and the lack of core skills in existing courses, the essence of science communication and teaching, and its impact in the workplace.

Keywords: Science, communication, skill, training, program, teaching

INTRODUCTION

Communication skills are a largely recognized learning outcome across undergraduate science programs.[1] The responsibility of communicating a multitude of science research, breakthroughs, and discoveries to various individuals with differing levels of education has been linked to science practitioners.[1] Today, there is a global push to improve scientists' ability to communicate research to avoid the translation of misinformation, inadequacy, and poorly executed knowledge that prevents proper diffusion of science and sustainability of practises.[2,3]

Today, the COVID-19 pandemic has proven the importance of science communication in an age of misinformation as new knowledge is abundant, evolving, and controversial.[3] For example, the misinformation of science and the lack of proper public communication surrounding the pandemic can hinder population health and protocol by leading to negative outcomes.[3] The continued outbreaks, the uncertainty in receiving the vaccine, and the controversy over wearing a face mask are unfortunate examples of how disorganized science communication can confuse non-scientific audiences.[3] A lesson that has become clear during this pandemic is that not properly disseminating information towards the public makes it a challenge to counter misinformation as it leads to confusion.[3] Numerous amounts of scientific evidence are presented each day, often times contradicting one another and making opposing claims about the reality and seriousness of an issue.[4] This results in public hesitation stemming from their inability to distinguish and understand the information presented to them.[3] Upon reading the information, skepticism enters the public's perception of scientists and the entirety of the of science field, followed by distrust.[4] This leads to distrust of scientific evidence and casts doubt about the justification for health protocols and alterations in personal behaviour as new information surfaces.[3]

The ineffective communication the public receives is not due to a lack of science literacy, but failure for scientists to acquire formal training in science communication during their undergraduate and graduate science programs, which acts as a barrier.[5] Currently, scientists are encouraged to learn and are trained in analytical skills, research methodologies, problem-solving, critical thinking, and scientific writing between other scientists. These skills are at the basis of being an effective scientist in order to conduct exceptional research. However, the same scientists do not learn the fundamentals required to communicate their research to a layperson audience, as their oral, interpersonal, and written communication skills are not challenged in their program.[2] In order to meet this requirement, increasing the inclusion of communication training as a mandatory or a 'generic' learning outcome of science programs will ensure graduates possess relevant skills required to live productive professional lives in various careers.[2] The current state of scientific training seems to lack the inclusion of conveying information effectively among various audiences outside the academic

discipline.[6] This presents a call for examination into current science programs to assess and map the effectiveness of science communication training at both an undergraduate and graduate level.

DISCUSSION

What is Science Communication?

The field of Science Communication (SciComm) is continuously evolving and a developing discipline of research and practise.[7] Science communication entails using a variety of skills to translate scientific philosophies, knowledge, research, and critiques, to a non-science audience in an accessible, engaging, and useful manner. To make a piece of work accessible, means an audience with varying communication needs can understand the information presented to them. The purpose of SciComm is to introduce narratives to non-scientists. Furthermore, science communication is an interdisciplinary field that includes a broad range of areas, incorporating science, communication, education, pedagogy, psychology, philosophy, and sociology of learning.[5] Effective practise of SciComm skills will produce a response in individuals, such as Awareness, Enjoyment, Interest, Forming an Opinion, and Understanding (AEIOU).[7] It is important to understand that this area of academia is not meant to encourage scientists to discuss more about their work, but to make sense of their science and explain it in a digestible fashion to inform and inspire the intended audience.[5] Given the interdisciplinary nature of the field and varying definitions and opinions, the purpose of this piece is to explain to readers what science communication entails.[5]

Science communication training: the current state and the lack of core skills

The skill 'Communication' has been introduced as a learning outcome for science degrees in many countries, including Canada.[5] Recognizing that the communication of science needs to be better taught, has resulted in an increased number of courses designed to teach and train students about effective communication techniques.[5] Although this acknowledgment is a positive step in better educating early scientists, their efforts to learn are hindered as there is little evidence to support what content should comprise the core element(s) taught in science communication courses and/or the depth with which each element should be taught.[5] The 12 core science communication skills are: identifying and understanding a suitable target audience, using appropriate language for the target audience, identifying the purpose of the intended communication, proper consideration of target audiences' prior knowledge, identifying vital information from non-

important content, choosing the best platform to communicate with the targeted audience, properly considering the social/political/cultural content of scientific information being presented, identifying appropriate modes of communication (i.e. humour, analogies, diagrams), understanding the underlying theories leading to science communication, ensuring audience engagement, storytelling and narrative techniques, and two-way dialogue between the presenter and the audience.[5]

The absence of undergraduate and graduate students' possession of "generic" communication skills is the result of the limited opportunities in the science curriculum due to the lack of courses offered, the access to such course(s), the encouragement for students to enrol in SciComm directed courses, and how important a student perceives SciComm.[1,2,5,6] Elective science communication courses tend to attract scientists who actively seek communication opportunities to learn or pique their interest in specific careers in SciComm.[5] The inclusion of science communication content in other science courses (non-SciComm based) is dictated and at the discretion of the scientists in charge of lecturing.[5] This is a challenge as these professors often times take part in and practise traditional science communication between individuals in the same field, which involves scientific jargon and language.[5] Although professors are experts in discipline-specific content, they may be unaware what pedagogy is the most effective to learn material. In general, professors encounter challenges in communicating science effectively to a range of audiences, due to their in ability to limit the use of the academic discipline-specific content they pose when explaining science.[5] As scientists progress through undergraduate studies to post-graduate and then doctorate, they inevitably become more specialized in their field of study. This poses a challenge to also become a master in science communication. This calls into question a scientist's/professor's level and ability to demonstrate a desired skill like 'communication', as they may also find it challenging to perform communication practises. Since educators play an integral part in training and preparation of students in their specialized field of study, the lack of professors possessing a background or knowledge in SciComm suggests a deficiency of prospective students obtaining these skills, too.

One key research paper has presented results giving reason to assess the effectiveness of current SciComm training across respected universities. Researchers Mercer-Mapstone and Kuchel examined which science communication skills were being taught and assessed directly, indirectly, or were altogether absent in undergraduate science courses across four research intensive universities.[1] The researchers found that 10 of the 12 core science communication skills were absent in more than 50% of assignments, with a little over 20% of assignments containing more than five skills.[1] Specifically, the 2 core communication skills that were

directly taught were audience engagement and modes of communication.[1] Furthermore, 77% of all assessments administered by professors in these courses taught less than five core communication skills and 22% taught five or more directly.[1] An important result to mention is the significant difference in how openly the communication skills were taught across different science majors/disciplines.[1] This is a critical finding, as based on the field of science that one is in, there is a lack of explicitness and diversity in the way communication skills are being taught.[1] An encouraging trend identified was that communication assignments geared towards non-scientific audiences were taught more directly than assessments targeted at scientific audiences.[1] However, the failure to develop the necessary core science communication skills challenges the ability of early scientists to communicate to a non-scientific audience. One such example is the ability to determine whether a word is considered jargon.

This study provides motivation to encourage similar studies across all universities worldwide that are known for their respected science programs to understand the current state of science communication training and their efforts/motivate to ensure its necessary incorporation into the curriculum.

Communicating to the public, the essence of SciComm: a challenge

The significance of writing for a lay person audience is essential, as there is a need to increase health and science literacy in a variety of topics.[8] Therefore, it is important to understand the definition of 'public' with regards to science communication. The 'lay public' is everyone in society; hence it is a heterogenous group encompassing a mixture of individuals of varying age, professions, cultures, socio-economic circumstances and levels of knowledge.[7,8] Furthermore, the 'lay public' also includes other scientists who are non-experts in the field of science that is being presented to them.[7]

It is no secret that science journalism is the gateway for spreading scientific material and news to the public. Science journalists that obtained the skills necessary for transmitting science information are able to make complex topics accessible to a lay audience, while ensuring accuracy. However, informing the public on matters related to science has become increasingly difficult for graduates of science degrees due to lack of proper teaching of science communication, explicitness, and diversity in the way communication skills are being taught to students, such as communicating to non-scientists.[1,9] The reason for the detachment between the science community and the public is that SciComm is not typically a part of formal training for scientists at any academic level.[9] In the United States, only 3 of the 10 top neuroscience PhD programs have elective courses or seminars; however,

none have required courses.[9] Since material can become oversimplified and generalized, this can lead to basic information being obscured.[8] This spread of misinformation and communicating research effectively presents as a challenge in science journalism.[8] Scientists are trained to publish papers and discuss findings with their peers, hence making it challenging for them to understand how lay audiences think and interpret.[8] Communicating scientific findings and analysis of results becomes difficult, due to discipline-specific jargon and language.[8] This problem often arises as scientists fear being misunderstood and presenting inaccurate information, resulting in using extensive specialized language.[8] Lay audiences oftentimes find jargon challenging to comprehend, confusing, and overwhelming.[8] A lack of SciComm training makes it difficult for practising scientists to determine whether a word is jargon or a typical term making communication of scientific concepts to the public a challenge.[8] A simple word, such as 'significant', can be considered as jargon, as not every individual accurately understands its meaning. Furthermore, phrases such as 'positive correlation' may be inferred as something confident; however, it can actually represent a negative link between two things. Although practising scientists may not acknowledge the importance of writing to a lay audience, the ability to write for a wide range of individuals becomes increasingly important with regards to continuing their research. For example, in order to obtain funding for research, scientists must be able to clearly communicate to peers, reviewers, and other public bodies about how their ideas and discoveries are valuable and applicable to society. Scientists are an essential link between policy makers, taxpayers, stakeholders, and governments. The ensure evidence-based decision making occurs through these individuals based on their research explanation and its implications.[6,10]

Therefore, the gaps between what scientists believe the public knows and what the general public truly understands can be bridged by incorporating formal communication skills when training scientists during their undergraduate and graduate programs. This will provide the quality of discourse needed between scientists and the general public.

Science Communication Training and the Workplace

Today, the science community has been identified as the least trained group of professionals with regards to public communication.[11] Communication is one skill that is consistently highlighted by a variety of professionals, including educators, employers, and government officials, as it is a requirement for science graduates to possess.[5] However, employers in the United Kingdom, United States, and Canada found that the

training received by graduate students does not reflect the reality of the modern day workplace requirements needed to be successful.[1] Specifically, successful graduates of science program are well-rounded, meaning they are able to successfully demonstrate analytical, technical, problem-solving, and communication skills.[5] However, their communication skills are consistently falling short as they fail to meet the needs of write in contexts beyond academic.[5] Therefore, they also fail to meet the needs of what is required of a science career in real world settings.[5]

Every year, a set of learning outcomes are established that act as a threshold for acquiring knowledge that can help to guide curriculum development.[2] This, in turn, promotes graduate employability.[2] Learning outcomes describe the knowledge, skill, and fundamentals one should acquire upon completion of an evaluation, course, or program.[12] Within an undergraduate or graduate program, the learning outcomes stated that one should acquire upon completion of their degree is comprised of the learning outcomes stated within the classes offered throughout the program.[12] Although professors have the freedom to design courses, the ministry of education has introduced 'communication' as a learning outcome for science degrees, which should aid in curriculum development.[5] Specifically, in higher education, professors/scientists/lecturers within science programs are responsible for the development of course design.[5] Therefore, they are also responsible for forming and designing the learning outcomes.[5] However, since these individuals are typically experts in one primary field of study, they select priorities, skills, and applicable knowledge based on the course's topic from a large set of learning goals.[13] As a result, they often omitting or failing to make science communication a key outcome.[13] Today, science professionals hardly have the time, resources, or formal training to communicate their own research to non-scientific audiences, let alone helping students find resources, developing assessments that help students build the necessary skills; or developing the components of courses(s) needed to accurately reach communication.[5] This results in failed SciComm education and a lack of training.[5]

Therefore, the reservations expressed by workplace professionals calls to question the science communication training in both undergraduate and graduate programs. There are various complaints from journalists, industries, government officials, and the public stating that scientists are not equipped with the proper communication skills needed to convey information effectively to non-experts.[1] This demonstrates that there is a discrepancy between what universities say science graduates should be able to do and the quality of skills they actually possess upon completion, including the need for improved training and courses.[1] Therefore, it is imperative to improve communication training in

higher education to create a solid foundation for graduates of a science program and employability.

Integrating SciComm training into the current curriculum

In an effort to provide suggestions to address this serious issue in training scientists, I strongly believe each science course, regardless of the discipline (i.e. chemistry, biology, physics), should include an assignment dedicated to writing towards a lay audience. Although integrating these resolutions into the curriculum would be complex, requiring money and time, this is nonetheless valuable in helping solidify a student's acquisition of science communication skills. When one is in their desired program of choice, they tend to place energy/take more seriously the courses directed towards that discipline. However, in general, elective courses tend to not receive the same level of effort as program specific courses; hence, this results in a lack of assertiveness to learn its content. Often times, science communication courses are offered as elective classes, which does not motivate students to enroll in them as they tend to place moderate or limited importance on SciComm skills.[14,15] Therefore, I strongly believe during each academic year, it should be mandatory to have science students take one course directed at learning science communication skills, ensuring that they are developing these fundamentals throughout their program and building on existing competences in this field of practise. This means within science programs, SciComm courses should not be elective, rather, required as a significant portion of literature on this topic has stated that students in undergraduate and graduate BSc. programs fail to acquire these skills as discussed in this opinion piece.

CONCLUSION

This opinion piece brings forth the importance of science communication training in undergraduate and graduate science programs by briefly describing the current state of SciComm training and the lack of core skills, the essence of science communication and teaching, and its impact in the workplace. There is a growing body of research on the 'science' of science communication and how it impacts practising scientists throughout their career, including the benefits they gain from their ability to communicate their work to a range of audiences.[10]

Today, there remains numerous gaps in the current state of science communication training and little consensus on how SciComm training should be conveyed. Undergraduate and graduate students are receiving no explicit formal training in the communication of science theories. In this area of academia and pedagogy,

there is a lack of research which examines the communication of science skills at a whole degree level. Furthermore, a significant portion of the research on science communication skills focuses on teaching practises only at a microlevel, such as an individual course or a single assignment. Therefore, these gaps prove there is insufficient formal training in communication of scientific concepts and practises to the lay audience. In addition, evidence surrounding how current students are experiencing the teaching and learning of these skills remains scarce. A current thesis project at McMaster focuses around understanding the effectiveness and impact of current SciComm training, as well as understanding how university students feel about the importance of science communication.

Change is needed in current teaching practises and course design in BSc programs to equip graduates with the proficiency in a diverse range of communication skills. Building these skills are a challenging undertaking, involving the restriction of discipline-specific jargon and effective engagement with the target audience (lay public) to determine their level of knowledge. Higher education needs to be focused on developing these skills in courses that incorporate a balance of knowledge through scientific content, research training, and the ability to effectively communicate to form well-rounded aspiring scientists who are ready to practise in the workforce.

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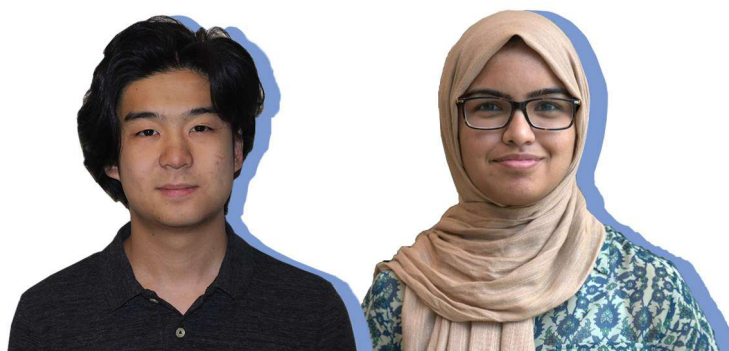Editor
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