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Development of a Framework for Identifying Science Giftedness in Middle School Students

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Abstract

Science giftedness exists at the intersection of intellectual academic ability in science and psychosocial characteristics of gifted individuals (Feist, 2013). However, the specific characteristics of science giftedness have not been fully investigated for identification purposes. This study seeks to fill this research gap by developing a framework for science giftedness and by identifying a distinct set of characteristics of science giftedness. Perceptions of science giftedness were gathered from middle school science and gifted teachers from a variety of school types, locations, and socioeconomic settings, as well as science education and giftedness/gifted education researchers using a qualitative Grounded Delphi Method (GDM). As a result, a framework and set of characteristics for identifying science giftedness were developed to help educators recognize and better support science gifted students. This proposed framework serves as a guide for educators and researchers in identifying gifted science students during the middle school years.

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Introduction

Students with exceptional or advanced scientific abilities should be offered advanced and accelerated science opportunities (VanTassel-Baska, 1998) to allow for the nurture and guidance to achieve a level of "greatness [that] is synonymous with eminence and creative genius" (Feist, 2013, p. 259). Feist (2013) claimed that science giftedness exists at the intersection of intellectual academic ability in science and psychosocial characteristics of gifted individuals. Science giftedness has experienced sporadic focus in giftedness research, with all areas of science often considered as one collective intelligence domain for science giftedness identification, despite the specialization of sciences into physical sciences, natural sciences, and psychological/social sciences. Current science giftedness identification is based on grades and/or mathematics performance on standardized tests (Sternberg, 2018). While many studies about giftedness have been done in general areas (Dai et al., 2011; Plucker & Callahan, 2014), there is a lack of studies specifically about the science domain of giftedness. Studies have not been found that clearly define science giftedness nor delineate or describe characteristics of those who are scientifically gifted. Therefore, this study seeks to create a framework of science giftedness, with a set of identifying characteristics of science giftedness in children. The purpose of this study is to develop descriptive characteristics of science giftedness for use in K-12 settings, which will help researchers and practitioners identify students who exhibit science giftedness. Specifically, it is important to define science giftedness in middle school students so that these individuals can have access to richer, more focused, and deliberate learning experiences in science. This approach aims to provide science gifted students with the opportunities necessary to cultivate their abilities, talents, and creativity in the subject. Attention to scientifically gifted middle schoolers is necessary to stave off the decline in the pursuit of science-focused careers for the best and brightest in science to meet their educational needs and goals. Identifying these characteristics can help educators or researchers to identify gifted science students as early as possible and to provide encouragement and opportunities to engage them in advanced science and scientific inquiry opportunities. The following research questions guided the study:

- What characteristics of science and giftedness in middle school age students form a framework for science giftedness?
- What criteria do expert science educators, gifted educators, gifted/giftedness researchers, and science education researchers recognize as determinant characteristics of science giftedness?

Literature Review

One of the critiques prevalent in gifted education is the lack of a consensus definition of giftedness (Carman, 2013). Also, classroom teachers need to have access to the pragmatic side of giftedness to better understand how to work with gifted children (Carman, 2013). This section provides an overview of definitions and models of giftedness to establish a better understanding of the concept.

Definitions and Models of Giftedness

Definitions of giftedness are as varied as the programs that service gifted and talented students, with intellectual giftedness remaining the most dominant component of giftedness definitions. A federal definition of giftedness in the U.S. is vague and open-ended, leaving states to create their own definition of giftedness for identifying gifted students and gifted education programming (National Association for Gifted Children & The Council of State Directors of Programs for the Gifted, 2015). A comprehensive definition of giftedness has been proposed by Subotnik et al. (2011) that can shape discussions of giftedness by researchers and educators alike. They define giftedness as exceptional performance or production at the upper end of a talent domain, even among high-functioning individuals in that field. They also emphasized that giftedness is a developmental process and psychosocial factors play a crucial role. Although comprehensive, the question arises as to how this definition helps with giftedness research, especially when identifying individuals as gifted and determining the criteria that identify individuals as gifted, especially in domains.

Giftedness identification methods tend to fall across nine categories: intelligence tests; achievement test; academic achievement; teacher, parent, counselor, and committee recommendation; extracurricular activities, and additional evidence sources (Carman, 2013), with IQ and intellectual ability still trending to the number one identifying characteristics, with some gifted programs still using only IQ to identify gifted individuals (Carman, 2013; National Association for Gifted Children & The Council of State Directors of Programs for the Gifted, 2015; Subotnik et al., 2011). Giftedness models may help to clarify some of the questions of identification and areas of identification, with a large number of models falling within a talent development paradigm (Dai & Chen, 2013; Subotnik et al., 2011). Several models are presented to include definition aspects and the model's components of giftedness.

Tannenbaum's model (1983 as cited in Subotnik et al., 2011) states that talent is developed over the course of childhood, and developed talent is present only in adults. Tannenbaum's model identifies giftedness in childhood, thus signaling a child's potential to become a renowned, talented adult in a sphere of activity, as long as certain interdependent components, along with encouragement and diligence, lead to the achievement of an exceptional level in adulthood.

The Wisdom, Intelligence, Creativity Synthesized (WICS) model, developed by a team of researchers led by Robert J. Sternberg, also describes ability or giftedness as a progression from childhood to adulthood. WICS defines giftedness as the development of expertise while possessing an excellence compared to one's peers. WICS builds on the idea that to attain the level of expertise, one must have inherent motivation, intelligence, creativity, practical intelligence, as well as inside access to domain specific knowledge and those who "hold" the knowledge (Subotnik et al., 2011).

Renzulli's Enrichment Triad model (1977, 2005 as cited in Subotnik et al., 2011) proposes that talent development occurs in a sequential manner beginning in childhood and continuing through youth in those individuals who are in the top 15-20% of above average cognitive ability, creative ability, and task commitment. Sequential development in the Enrichment triad model begins with multiple domain development, leading to specific, higher-level instruction in the domains of focused interest and finally to a level of creativity and productivity that could lead to adult contributions to society.

Another model of talent development is Gagné's Differentiating Model of Giftedness and Talent (Gagné, 2004, 2017). This model has values similar to Tannenbaum's (Subotnik et al., 2011) but gift transformation is in sequence from natural gifts to high-level mastery or expertise in a specific domain (2004) and ultimately a level of eminence and greatness (2017). This model includes multiple competencies including intellectual, creative, social, and perceptual at the base of talent development with gifts at the top. In this model, gifted individuals are in the top 10% of their age peers with the same interests while acknowledging the impact that environment and chance have on the developmental process. This model also includes the psychosocial traits of motivation and persistence. All of these models have features that address aspects of giftedness, but not all of them address the needs of students who possess science giftedness.

Theoretical Framework of Giftedness

Due to the multiple facets and definitions of giftedness as well as the mindset of a researcher, educator, or others involved in gifted education, giftedness may focus on innate or developed intelligence, multiple intelligences, multipotentiality, domain specific, or a drive for success or eminence. The determination of giftedness is as varied as there are researchers and organizations involved in the identification and education of gifted individuals. Nature versus nurture, the idea that people have innate areas of natural abilities versus areas of ability that are developed over time to become areas of giftedness (Silverman, 2012) is perhaps one of the most argued points regarding giftedness. Our study focuses on science giftedness as an innate ability in the specific domain of science that is a separate construct from talent. The idea of giftedness as natural abilities that are distinguishable from developed competencies forming the basis of talent is put forth in the Differentiating Model of Giftedness and Talent (DMGT) (Gagné, 2017) . The DMGT framework as well as the utilization of science as a domain of giftedness will be described in this section.

The Differentiating Model of Giftedness

The Differentiating Model of Giftedness and Talent (DMGT) (Gagné, 2017) provides a clear distinction between giftedness and talent. DMGT identifies an individual as possessing and using natural abilities in an area of giftedness with the individual being in "the top 10% of the relevant reference group" (Gagné, 2017, p. 155). The theory proposes that a gift is potential that originates from biological and genetic beginnings (Gagné, 1985, 2004, 2017), with a specific definition of giftedness as follows:

> *Giftedness* designates the possession and use of biologically anchored and informally developed outstanding natural abilities or aptitudes (called gifts), in at least one ability domain, to a degree that places an individual at least among the top 10% of age peers. (Gagné, 2017, p. 152)

This definition of giftedness refers to untrained ability that is spontaneously expressed in a domain or domains possessed by an individual in one or more domains as opposed to talent that refers to performance or outstanding mastery of systematically developed abilities and knowledge within at least one singular domain (Gagné, 2004). Individuals targeted as gifted are considered above average and 'non-normal' (Gagné, 2004). According to DMGT, giftedness is rooted in genetic, innate abilities that fall into one of four domains—intellectual, creative, social, and physical-that can be developed into various talent areas including academic, technical, science and technology, arts, social service, business, business operations, games, or athletics (Gagné, 1985, 2004, 2013, 2015, 2017).

Science Giftedness as an Innate Ability

General giftedness is often determined through general abilities or intelligence testing using instruments such as the Cognitive Abilities Test (CogAT), HOPE Scale, or Naglieri Nonverbal Ability Test (NNAT) (Carman, 2013). These instruments identify cognitive giftedness but do not possess science-specific items or components that identify skill, content abilities, or intelligence specific to science giftedness (Matthews and Foster, 2014; Office of Gifted Education CDE, 2020). Identification of individuals as gifted in science is often determined by high ability in mathematics portions of standardized tests, general intelligence, classroom grades, or a combination of the previously mentioned components (Feist, 2013; Sternberg, 2018). Without identifying individuals as having exceptional, innate abilities in specific intellectual areas, those who work with these individuals may lack the insight needed to determine how or where to support them, particularly in science.

Characteristics and Skills of Science

A strong foundation in science knowledge is crucial for success in science and engineering, as noted by Berlin and White (1991). This foundation is outlined in the national science standards, such as the Next Generation Science Standards (NGSS Lead States, 2013). One component of the NGSS is the Scientific and Engineering Practices (SEP), which sets a baseline of skills for all U.S. science students. Exploring the extensions of these skills that exceed expected competencies in SEP can help identify the characteristics of science-gifted students. While characteristics observed in a science laboratory setting can offer valuable insights into cognitive skills, it is important to also consider other abilities not explicitly mentioned in the NGSS, such as imagination and creativity. Imagination and creativity are two characteristics that are commonly considered to identify science giftedness (Innamorato, 1998; Peters-Burton & Martin-Hansen, 2016; Root-Bernstein & Root-Bernstein, 2004). Creativity is viewed as being a divergent process as well as an ability to produce distinctive solutions that are logical (Peters-Burton & Martin-Hansen, 2016). Creative thinkers are also able to create models using mental imagery and associations that are not necessarily linear in approach. Those who are highly creative possess some psychosocial abilities that should be considered in identifying science giftedness. Highly creative individuals tend to be more open to new experiences as well as prefer a certain level of complexity in problem-solving. Along with non-linear thinking, creative individuals tend to revel in novelty and a sense of ambiguity. Creative individuals' ideas also tend to be on the original and creative individuals often have the ability to go into elaborate detail in their explanations.

Science Giftedness

Science is considered a component of intelligence in giftedness discussions (Gagné, 2017). Therefore, science giftedness could be considered as possessing advanced intellectual ability. However, it should not be limited to identification with only identifiers for intelligence, in particular IQ or mathematics ability. Science giftedness needs its own set of constructs to identify scientifically gifted students, which needs to include an appreciation for evidence of potential as well as performance (VanTassel-Baska, 2005).

Some attempts have been made to create a construct for science giftedness, but a consensus has not been reached due to issues with construct perceptions, inability to use a construct to complete empirical research, and practicality of the research (Innamorato, 1998). In exploring literature about science giftedness, most research has been completed with a psychoanalytic perspective while most gifted science programs emphasize technical knowledge and skills (Innamorato, 1998). Science is becoming more and more specialized, which requires considerable experience and preparation to achieve eminence in the field and to contribute to society in the field of science (VanTassel-Baska, 2005). Because of the complex nature of science and its increasing specialization, input on science giftedness is needed from not only giftedness researchers, but also science educators and professionals, as well as educators of the gifted. Science giftedness has been sparsely discussed in research and characteristics considered to determine science giftedness have been highly separated from each other. Factors and characteristics of science giftedness need to be determined to formulate a framework of science giftedness that can be used as a tool in identifying students who possess science giftedness to better provide instruction and enrichment for these students.

Methods

The goal of this research is an exploration into the characteristics of science giftedness to formulate a framework and description of science giftedness. In this study, the science giftedness framework and accompanying characteristics are formed using a Grounded Delphi Method (GDM) (Howard, 2018; Päivärinta et al., 2011). GDM combines key characteristics of two research methodologies, the Delphi method and Grounded Theory.

Grounded Delphi Method (GDM)

The combination of Grounded Theory (GT) with Delphi methods enhances data collection and analysis, thereby strengthening the theory developed in a study utilizing GDM. Using the data analysis processes from grounded theory allows categories and relationships between the categories to make key contributions to the theory by complementing the data collected through the Delphi method (Howard, 2018; Skulmoski et al., 2007; Päivärinta et al., 2011). Data analysis and coding in grounded theory studies are typically a continuous process (Charmaz, 2014), but in the GDM process, open, axial, and selective coding are more clearly delineated between the phases of GDM. GDM methods utilized in this exploratory study on science giftedness follow the four phases of GDM as proposed by Päivärinta et al. (2011): 1) Data Collection, 2) Concept Discovery, 3) Concept Prioritization, and 4) Theory Development. Following is a brief overview of the four phases.

1) *GDM Data Collection Phase:* Formation of the expert panel is a key component of this phase, setting the stage for a study's reliability and validity (Okoli & Pawlowski, 2004; Päivärinta et al., 2011). The expert panel is formed using an initial questionnaire to collect demographics, thoughts, information, and feedback from panelists. This initial data is the basis of the subsequent rounds of data collection as the concepts are discovered and prioritized between each round of data collection.

2) *GDM Concept Discovery:* As happens in the grounded theory data analysis process, greater depth of analysis that is often not found in the Delphi process on its own is a component of the GDM process, allowing for concept discovery (Päivärinta et al., 2011). Ideas, themes, and meanings are identified from the expert statements that are organized and compiled into statements that become the basis of second- and third-round data collection.
3) *GDM Concept prioritization:* The second-round questionnaire is disseminated to the panelists to validate the results of the axial coding from the round-one responses. It is at this point that panelists are asked to provide rationale for their responses in the questionnaire to help validate responses and outcomes. Selective coding then takes place to develop a final theory from the core category of the study (Baskerville & Pries-Heje, 1999; Charmaz, 2014; Howard, 2018; Päivärinta et al., 2011; Saldaña, 2016) that is verified through a final round questionnaire to determine consensus of the categories and ideas from the expert panel.
4) *GDM Theory development:* This phase utilizes the selective coding results that are verified through a final round questionnaire. Relationships are still identified in the collected data laying the groundwork for the grounded theory of the study related to the research questions. In this phase, the researcher analyzes the panelists' responses to in combination with the coding levels to determine the top issues and reasoning for the responses.

Research Process

Figure 1 illustrates an overview of the GDM process as implemented in this study on science giftedness. An important aspect of GDM is the processes that take place to verify ideas and concepts in each round of data collection. Subsequent rounds of data collection are based on the results from the previous round, with coding occurring between each round.

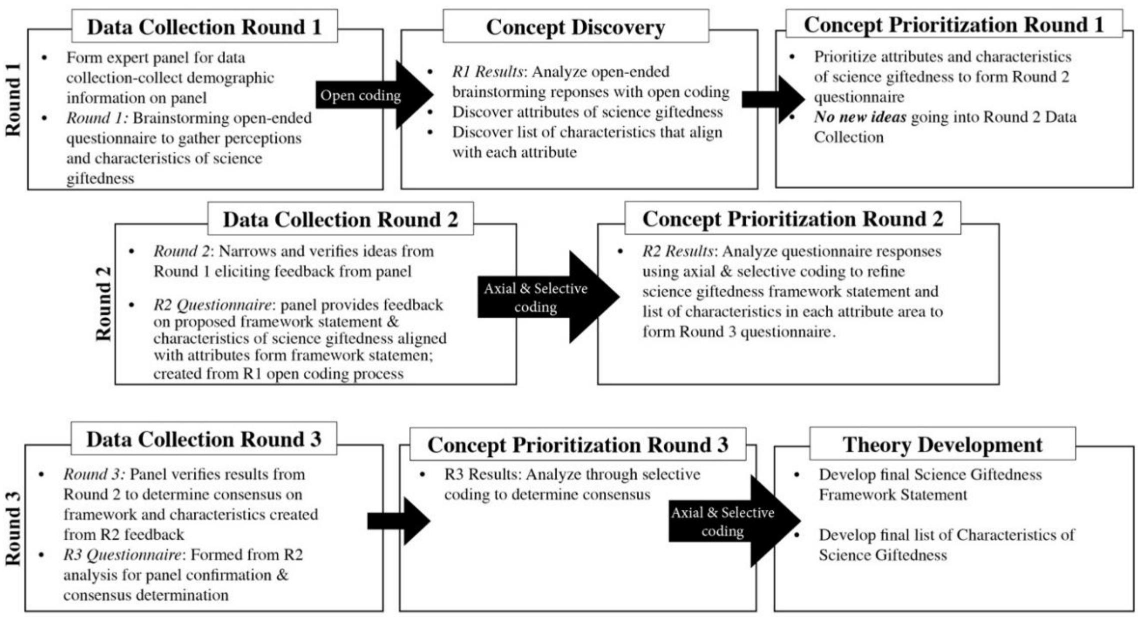

Figure 1. GDM Phases in Exploratory Study of Science Giftedness

Composing an Expert Review Panel

Key to the GDM process is an expert review panel to achieve consensus on views regarding science giftedness. The Knowledge Resource Nomination Worksheet (KRNW) (Okoli & Pawlowski, 2004) suggests identifying individuals for participation based on relevant disciplines or skills; academics, practitioners, and organizations with a goal expert group size of 10-18 individuals. The expert group panelists were purposefully selected to include experts who possessed specific characteristics of being active in at least one of the following areas: middle school science teachers, middle school gifted teachers, science education researchers, and giftedness/gifted education researchers. Panelists were recruited through professional educational organization discussion boards, gifted and talented association message boards, national science teacher associations and teacher professional learning social media platforms, and a national science teaching association listserv. The first-round questionnaire had several purposes: to determine individuals willing to participate in the expert panel, gather demographic information to attain panelists' professional education or researcher involvement, as well as brainstorm questions to determine these experts' perceptions of science giftedness.

Panelists Information

36 individuals completed the initial round one questionnaire and agreed to participate in all rounds of data collection. Panelists selected were: five researchers, two middle school teachers and researchers, and 29 middle school teachers (18 were middle school science teachers, two were middle school gifted teachers, and nine were teaching both middle school science and middle school gifted). Among them, 17 teachers were teaching in public schools; four were in magnet, specialty, or charter schools; and 10 were in private, parochial, or independent schools, whose school environments were in a variety of locations and socioeconomic settings.

The data collection rounds of this science giftedness study occurred during an uptick in COVID-19 cases, which contributed to attrition as the study progressed, which is not an unusual issue in Delphi type studies (Avella, 2016; Fink-Hafner et al., 2019). As the goal for the study is that participant consensus for final framework and characteristics of science giftedness was to be created from the contribution of all four subgroups of experts, the number of panelists determined by the researcher to be needed to reach consensus at the end, was 8-10 panelists agreeing with the final framework and characteristics for consensus to be reached (Habibi et al., 2014; Hsu, 2007; Okoli & Pawlowski, 2004; Päivärinta et al., 2011). In order to meet consensus, each round's questionnaire link was sent to all 36 panelists who agreed to participate in the study.

Data Collection Phases

Data collection in GDM is achieved through Delphi method processes, so it is not a one and done process. Data collection was asynchronous and carried across the remaining phases of the study's GDM process. Each data collection round utilized a questionnaire that was developed in Qualtrics, with the link to each round's questionnaire shared with all panelists who agreed to participate in the study. Round one data collection involved collecting the panelists' demographic information alongside exploratory, brainstorming open-ended questions.

The questions were designed to determine each panelist's perceptions of science as an area of giftedness, their idea of key characteristics of science giftedness in middle school age students, and to briefly provide reasoning for their perceptions and characteristics of science giftedness. Responses were collected over the course of four weeks until a saturation point was reached, meaning panelists' responses were similar enough to be consistent or recurring among panelists. Round two data collection occurred as part of the concept discovery phase as its purpose was to narrow and verify ideas and concepts collected from the round one questionnaire. The round two questionnaire data analysis carried over into the concept prioritization phase, providing the base for the round three questionnaire and data collection that verified responses and analysis of the round two data. Round three data collection involved verification of the results from the round two questionnaire that led to the final theory development.

Concept Discovery Phase

The Concept Discovery Phase of GDM involves compiling all responses to the questions in the round one questionnaire regarding science giftedness. Concept discovery *only* takes place in round one of GDM as no new ideas are added past the first round of data collection. Round one questions were worded to allow the researcher to discover if panelists perceived science as an area of giftedness or not as well as deterministic characteristics of science giftedness in middle school age students. Round one questionnaire responses were analyzed using grounded theory open coding principles that are inductive in nature (Baskerville & Pries-Heje, 1999; Charmaz, 2014; Miles et al., 2020; Saldaña, 2016) allowing the panelists' responses to be identified, named, and categorized on a deeper level in this phase of GDM, becoming the basis of the round two questionnaire.

Panelists who regarded science as an area of giftedness were asked to provide reasoning for their thoughts. As these responses were read by the researchers, patterns emerged that indicated extra cognitive and cognitive abilities to suggest that science is an area of giftedness outside of the realm of general intelligence assessments. Extra cognitive responses from panelists showed aspects that were non-verbal and behavioral in nature that could be observed through non-curricular or non-classroom interactions with individuals. Non-verbal aspects were indicative of a mindset or way of thinking toward science not particularly seen as a part of classroom curriculum or standards. Extra cognitive behavioral characteristics were identified as such through association with general giftedness identification (Gentry, et al., 2015; McCallum & Bracken, 2018; Renzulli, et al., 2004; Ryser & McConnell, 2003). Behaviors gleaned from the scales such as creativity, curiosity, observant, and high interest that are observable and measurable were used as a starting point for the science gifted behavior coding. The open coding process categorize characteristics provided by the panelist was the initial step of discovering concepts related to science giftedness and set the stage for concept prioritization, which is the basis for round 2 and round 3 questionnaires and data collection as data from each of these rounds is utilized to verify the previous round's panelist responses.

Concept Prioritization Phases

Round one open coding led to the concept discovery of four unique attributes of science giftedness. Determination of these attributes led to the following initial framework statement as to what science giftedness is based on the panelists' responses:

> Middle school students who possess science giftedness exhibit a unique combination of the following attributes: attitudes towards the sciences, behaviors that demonstrate natural abilities in the sciences, advanced abilities in practicing science skills, and a depth of understanding and application of science content and concepts.

The next step in prioritizing the concepts of science giftedness was creating lists of characteristics provided by panelist responses for each attribute of science giftedness. The characteristics were sorted into four attribute categories based on descriptors of the attributes as summarized in Figure 2.

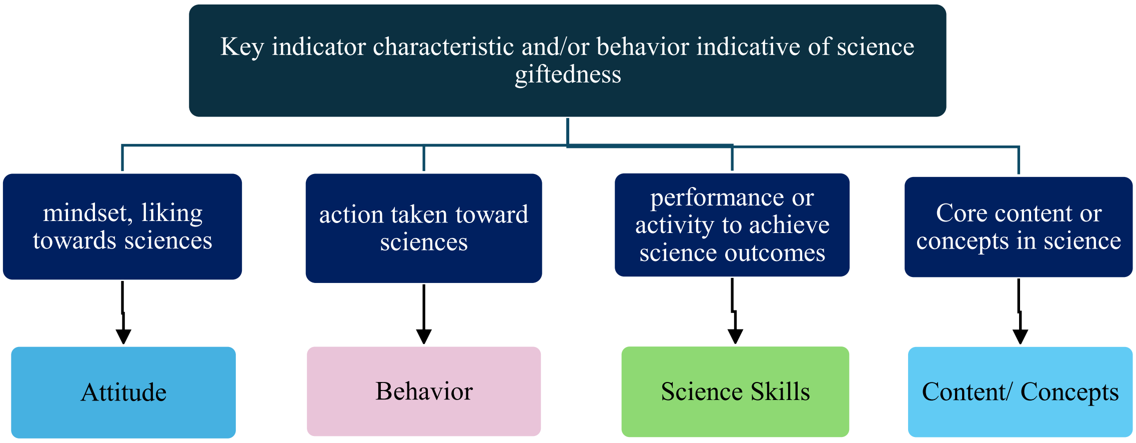

Figure 2. Code Descriptors for Science Giftedness Attributes

Round one panelist responses determined to be indicative of attitude were sorted through the descriptor filter of a non-verbal, innate mindset (way of thinking) or liking towards science. For example, "confidence" and "high curiosity toward science" responses were classified into Attitude; "high enjoyment of science" and "high question ability" were classified into Behavior. Similar characteristic responses were combined, and all responses were compiled alphabetically for use in the round two questionnaire to prioritize the characteristics of attitude in science giftedness.

Responses that indicated performance or activity to achieve science outcomes within the context of a classroom setting were identified as characteristic of skills (e.g., understand cause and effect, design science experiments independently). The final group of responses about science giftedness are aligned with the core content and concepts of science, such as those whose roots could be found in the disciplinary core ideas or crosscutting concepts of the NGSS (e.g., grasp concepts easily above level, make deep and interesting connections), with the caveat that the expression of these characteristics by students is above the level of their peers. The results of the round one data analysis established the second-round questionnaire, formed to prioritize the aspects of the science giftedness framework statement and characteristics.

The round two questionnaire proposed a framework statement based on the attributes developed and contained a broad list of characteristics connected to each attribute in the framework. The round two questionnaire asked panelists to provide feedback on the framework statement by prioritizing the components that should be included and/or refined to form a clear statement on science giftedness. The list of characteristics of science giftedness were sorted into the attribute categories and listed alphabetically. Panelists were asked to select an unranked "top ten" list of characteristics in each attribute that best describe a student as science gifted. Panelists were also asked to provide reasoning for selecting the chosen characteristics as a whole for each attribute. Responses from the round two questionnaire were analyzed using axial coding, producing a final science giftedness framework statement and list of top characteristics for each attribute for verification by panelists in the third and final round questionnaire round.

In the round three questionnaire, panelists were asked to indicate their agreement or not with the final revision of the science giftedness framework statement and characteristics of science giftedness in middle school age students. The statement and characteristics were formed through an axial coding, deeper dive process to better understand the relationships in the data categories as well as selective coding to develop a final science giftedness framework statement and science giftedness categories with characteristics that align with the framework attributes.

Theory Development Phase

The goal for the study was to reach a consensus for a final framework and characteristics of science giftedness. Consensus is typically considered to be 70% agreement in the third or final round (Vernon, 2009) and was thus reached in this study with six out of seven (85.7%) round three panelists agreeing with the final framework statement and all seven (100%) of the round three panelists agreeing with the characteristics presented for confirmation in the round three questionnaire. With consensus reached, the Science Giftedness Framework Statement and Science Giftedness Characteristics met the purpose of the study to develop a framework of science giftedness with a list of attributes and characteristics of science giftedness of middle school age students.

Validating Data

Validity is an important consideration in qualitative research. The selection process of the expert panel members provided a level of validity as the criteria for participation in the panel was thoughtfully determined and a demographics questionnaire utilized to provide the needed background on each panelist who participated in the research to "help categorize the experts before identifying them" (Okoli & Pawlowski, 2004). Validation also comes from the panelists' opportunities to view the consolidated responses from the other panelists in the round two and round three questionnaires.

The data collection process of GDM also establishes validity. As this research is exploratory in nature, the expertise of the panelists provides a level of trustworthiness in the answers to the research questions. The Delphi method aspect of GDM is a form of data validation through member checking, with panelists providing data in the form of responses to the questionnaires on science giftedness as well as reviewing the analyzed and coded data from each round in order to come to a consensus, thus decreasing possible interference by the researcher (Okoli & Pawlowski, 2004). Panelists also provided rationale for their responses in rounds subsequent to the initial round of data collection. By evaluating the responses to data and providing rationale, the determination of a final definition and collection of characteristics of science giftedness was created through the consensus of the panelists, thus providing another step in the validation process of the research (Okoli & Pawlowski, 2004).

As validity in qualitative research refers to the appropriateness of what is used in a study as far as tools, processes, and data (Leung, 2015), the completeness and detail of the research process validate the study. A researcher audit trail consisting of a rationale that demonstrates the development of the question set that was created was used to increase credibility and perceived rigor of the study.

Findings

Of the 36 individuals who completed the round one questionnaire, 33 individuals indicated that *science is an area of giftedness*. Panelist responses of note were: a) individuals who are science gifted possess abilities in science on a higher level than peers; "grasp scientific concepts much more quickly than their peers (Panelist 18)", b) being more advanced than peers; "students show a natural ability to the extent of exhibiting a marked talent in understanding areas in the sciences (Panelist 13)", c) higher level cognitive abilities such as questioning, understanding, advanced thinking skills; "Science is a subject that gifted students can often explore broadly and ask advanced questions as they conduct discovery learning (Panelist 32)."

After coding the round one responses, the key categories emerged of attitude toward science, behaviors, skills, and content/concepts (see Figure 2). In round one, panelists were asked to brainstorm specific characteristics and/or behaviors that are key indicators of science giftedness in middle school age students. Those indicators included acute thinkers in science, creativity, curiosity, high interest in science, high intellect, inquisitive, natural born scientists, ability to understand deeply, critical thinking skills, making diverse and unique connections etc.

Axial coding of the round one results led to a deeper understanding of the panelists' responses allowing for creation of a preliminary framework statement of science giftedness and characteristics of science giftedness. The round two questionnaire asked panelists to provide feedback to the framework statement in terms of agreement or disagreement with the statement as well as any refinements needed for the statement. Panelists suggested that creativity, innovation, and problem solving should be included in the framework statement. One comment in particular offered confirmation that the science giftedness framework statement provided helpful insight into gifted science students as it "allows a gifted student to be identified in many different aspects and I agree with it in whole. I think this captures the abilities of gifted science students well and should be used universally for gifted science students."

The anonymous suggestions and feedback from the panelists were collected and analyzed using selective coding to determine refinements for the final statement to be used in the round 3 questionnaire as shown in Figure 3.

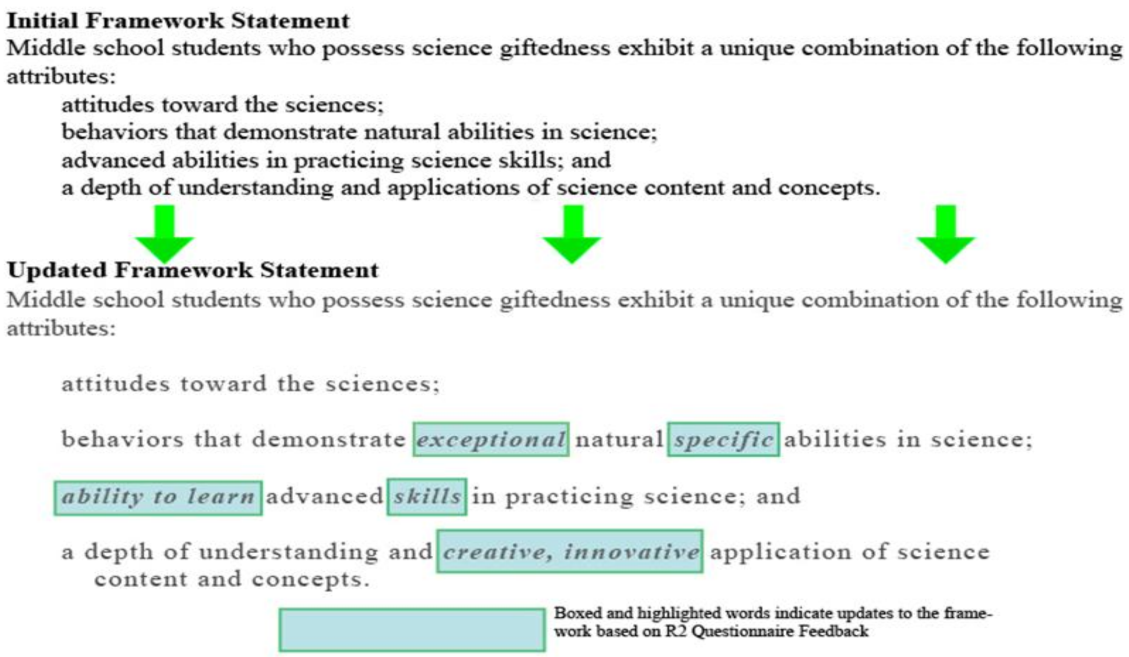

Figure 3. Changes from Initial Framework Statement to Updated Framework Statement for Round 3 Verification

In round two, the characteristics of science giftedness were shared with the panelists, and they were asked to identify their top ten characteristics for each key category, henceforth called attributes of science giftedness. Responses in each attribute area were ordered from high to low as determined by the number of panelists selecting a descriptor in an attribute. Raw data numbers were then converted to percentages of panelists selecting an attribute to allow for a determination of responses attaining 50% or greater selection by the panelists and selected for inclusion in the third-round questionnaire to confirm characteristics of science giftedness for each attribute.

Attitude Characteristics

The top attitude characteristics shown in Table 1 highlighted the inquisitive, curious, and motivated innate nature of science gifted students.

Table 1. Round 2 Attitude Characteristics Results

Attitude Descriptor	**% Panelists selecting descriptor (n=10)**
High inquisitiveness in science	80
Questioning mindset	80
High motivation toward science	80
High curiosity toward science	70
Passion for science related topics	60
Creative problem solver	60
Abstract thinker	60
Determined	50
Complex thinker towards science ideas	50

Reasoning for the choices focused on non-verbal, extra cognitive aspects of attitude such as the "disposition toward a given topic or area…that reflect one's feelings about science" as well as a passion and innate, questioning curiosity for science.

Behavior Characteristics

Behavior characteristics selected by panelists focused on the way individuals respond to their passion and interest in science as shown in Table 2. Reasoning for selected behaviors centered on thinking and questioning of science gifted students to seek answers to the big picture of science due to their passion and curiosity for science.

Table 2. Round 2 Behavior Characteristics Results

Behavior Descriptor	% Panelists selecting descriptor (n=10)
Learns from mistakes	80
Makes higher level observations about nature	70
Considers how details fit big picture	70
Applies knowledge at a higher/greater level than peers	60
Questions extensively	60
Researches independently outside of expectations	50
Divergent thinking	50
Views science in multi-facets	50

Skills Characteristics

The skills on the list were cognitive in nature and focused on the performance of and practices related to answering questions in science on an advanced level that exceeds peers. The skills were specifically tied to a science gifted middle school age student's ability to perform science through actions, thoughts, and questions. Despite having the most characteristics to select from the number of skills characteristics agreed upon by 50 percent or more of the panelists was less than any other attribute.

Panelists agreed that the selected skills are at a higher level of complexity than in an average science classroom. It was mentioned that gifted science students "tend to be innately interested in science and this interest generates strong scientific processing skills." Advanced level problem solving leads to the application of the selected skills by science gifted students "more often than others." One participant specifically mentioned the skills they selected as speaking to "how an effective scientist looking to innovate in their field would have to go about it.

An interesting observation from the responses is that math abilities were mentioned as being indicative of science giftedness by *only one* panelist, despite longitudinal studies of gifted math individuals who pursued science related careers (Lubinski & Benbow, 2006; Lubinski, et al., 2014); "Giftedness is characterized and often identified by areas of aptitude and achievement…a student who shows aptitude and even achievement in mathematics does not guarantee success in Science (Panelist 1)." Table 3 shows the skills characteristics results from round 2.

Table 3. Round 2 Skills Characteristics Results

Skills Descriptor	% Panelists selecting descriptor (n=10)
Recognizes patterns and detail at a level above peers	70
Advanced thinking skills in science	60
Asks interesting, testable questions	50
Advanced problem-solving skills	50
Comprehend content easily on higher level	50
Makes diverse and unique connections with line of scientific questioning	50

Content/Concepts Characteristics

The content/concepts characteristics (Table 4) show an application of scientific knowledge across multiple areas of science to understand how things work and to explore new areas of science or existing areas of science more deeply. Reasons offered as to why particular characteristics were chosen included student "interest in concepts and use of concepts" that can cause an intensity of learning by science gifted students as they "connect the dots…[being] easily able to see how concepts fit together."

Table 4. Round 2 Content/Concepts Characteristics Results

Content/Concepts Descriptor	% Panelists selecting descriptor (n=10)
Applies understanding and relationships across multiple science concepts	90
Applies concept(s) in various settings	80
Uses science knowledge and resources to pose creative solutions to complex problems	60
Desire to understand how things work	60
Interprets science related graphics and interprets the concepts and information represented	60
Understands science processes and thinking	50
Desire to inquire and explore science concepts	50
Advanced ability to apply concepts to new novel situation	50
Sees big picture of science concepts	50

Final Framework and Characteristics

Feedback and characteristics from round 2 were compiled and analyzed using selective coding to create a final Science Giftedness Framework Statement and Characteristics of Science Giftedness for verification. The round three statement and characteristics, Science Giftedness Framework Statement and Characteristics (see Figure 4) were sent to panelists for verification.

Panelists were asked to verify the statement by providing feedback to this final iteration of the framework statement and characteristics of science giftedness to determine if consensus has been met. Thirteen panelists viewed this final round questionnaire, with seven completing the final questionnaire, not an atypical return for Delphi type questionnaires (Vernon, 2009). Of the seven respondents, six agreed with the statement with one respondent perceiving the statement as being too broad for identifying science giftedness. Respondents mentioned that the statement provides a balanced approach of attitude, behavior, skills, and content and concepts as well as capturing the "nuances of gifted and talented middle school students in the science." One respondent alluded to the inclusive nature of the framework statement by referring to the "unique combination" aspect of the framework statement as "the best way to make it a definition to meet the differences in our science gifted students."

Science Giftedness Framework Statement:

Middle school students who possess science giftedness exhibit a unique combination of the following attributes: attitudes toward the sciences; behaviors that demonstrate exceptional, natural, and specific abilities in science; advanced skills or the ability to learn advanced skills in practicing science; and a depth of understanding of science content and concepts in combination with creative and innovative applications of science content and concepts.

Four categories of science giftedness characteristics emerged during this study: attitude (mindset), behaviors, skills, and content and concepts. Characteristics in each category were determined through a majority feedback from the participants in the study. This is not an exhaustive list, but rather a starting point in determining science giftedness in middle school-age students.

Attitude Characteristics
- High inquisitiveness in science
- Questioning mindset
- High motivation toward science
- High curiosity toward science
- Passion for science related topics
- Creative problem solver
- Abstract thinker
- Determined
- Complex thinker toward science ideas

Behavior Characteristics
- Learns from mistakes
- Makes higher level observations about nature
- Considers how details fit the big picture
- Applies knowledge at a higher/greater level than peers
- Questions extensively
- Researches independently outside of expectations
- Divergent thinking
- Views science in multi-facets

Skills Characteristics
- Recognizes patterns and detail at a level above peers
- Advanced thinking skills in science
- Asks interesting, testable questions
- Advanced problem-solving skills
- Comprehend content easily on higher level
- Makes diverse and unique connections with line of scientific questioning

Content/Concepts Characteristics
- Applies understanding and relationships across multiple science concepts
- Applies concept(s) in various settings
- Uses science knowledge and resources to pose creative solutions to complex problems
- Desire to understand how things work
- Interprets science related graphics and interprets the concepts and information represented
- Understands science processes and thinking
- Desire to inquire and explore science concepts
- Advanced ability to apply concepts to new, novel situation
- Sees big picture of science concepts

Figure 4. Round 3 Science Giftedness Framework Statement and Characteristics

For the categories and the characteristics of science giftedness for each category, respondents said that the characteristics were well done and were accurate for the purpose of identifying science giftedness in middle school age students. One respondent expressed the connection between the framework statement and the characteristics as expanding "the statement on the prior page [framework statement in the questionnaire], but in greater detail for specific qualities that an evaluator could look for in a student to determine giftedness. There is no indication of level of giftedness, however the above construct is a good tool to use to distill the characteristics one would use to determine level of giftedness in a student of science," thus confirming the acceptance of the Science Giftedness Framework and Characteristics as a viable option to identifying middle school age students as science gifted. The responses from the round three questionnaire indicated consensus and allowed for the acceptance of a final framework of science giftedness in middle school age students as determined through this exploratory study on science giftedness.

Discussion and Conclusion

Despite science often being considered a domain specific ability (Makel & Plucker, 2008, as cited in S.I. Pfeiffer, 2008), empirical research on science giftedness, its characteristics, and identification remains limited. While screening assessments are widely used to identify gifted students, they contain few science-related items (Sumida, 2017, as cited in Taber & Akpan, 2017). Therefore, the development of the Science Giftedness Framework and Characteristics provides a tool for educators who work with middle school age students with input into the components provided by educators.

This Grounded Delphi method study resulted in a qualitatively grounded framework statement and set of descriptive characteristics for science giftedness in middle school age students. Panelists' responses provided the basis for creating a framework statement of science giftedness. Attitudes toward the sciences were indicated in responses that focused on a mindset, predisposition to a cognitive behavior or action toward science, or liking towards the sciences (Altmann, 2008; Seel, 2012). Behaviors responses demonstrated exceptional, natural, specific abilities in science as indicated by responses that exhibited actions taken toward the sciences, with a natural relationship between attitudes and behaviors existing between the two because attitude often impacts behavior (Altmann, 2008; Chaiklin, 2011; Pear, 2012).

As this exploratory study takes place within the context of NGSS, the skills and content/concepts coding were based on ideas found within the NGSS. The ability to learn advanced skills in practicing science were indicated by responses based on performance expectations (PE) as well as science and engineering practices (SEP) in the NGSS and focus on science performance skills that are primarily observed within the context of a classroom or formal educational environment. Lastly, content and concepts were based on the disciplinary core ideas (DCI) and crosscutting concepts (CC), both of which focus on science content found in the NGSS.

The Science Giftedness Framework statement and characteristics align with Gagné's Differentiating Model of Giftedness and Talent (DMGT) (2017) in which giftedness in an individual comes from a place of natural abilities in a domain. These natural abilities include intellectual domains that can lead to competencies, otherwise known as talents. This result also aligns with Feist's (2013) assertion that greatness, which "combines originality and novel achievements" (p.259) can be attained in science through the nurturing of individuals' innate natural science-related cognitive abilities. During this study, panelists provided rational for their responses as to why they perceived science as being an area of giftedness. The round one responses which lead to the four science giftedness attributes, often referred to the natural and innate abilities middle school age students who are gifted in science possess.

Panelists' responses discussed natural abilities that exhibit talent in sciences. One particular response discusses a student who struggles in verbal areas of academics but has a natural inclination towards thinking and solving complex problems indicative of the abilities of gifted students in science. The overarching perception from the panelists was that science gifted students naturally have the abilities and aptitudes to excel in science in a manner that is well above the levels of their age and grade level peers. It is this ability or potential to excel that Gagné

(2017) refers to as being the "raw elements (p.156)" that allow for an ease and increased rate of talent development in a specific area, in this case science. Thus, according to the DMGT framework (Gagné, 2017) individuals who possess science giftedness would be able to develop their level of science ability, knowledge, and skills before their peers of the same age.

Middle school age students are a prime age for identification as their cognitive abilities are beginning to mature, allowing for more reliable identification of giftedness in science (Luna, 2009; National Academies of Sciences, Engineering, and Medicine. 2019). Identification of these science gifted individuals can provide great insight for teachers who work with these students in a classroom context to guide them in developing their natural abilities into talent.

The proposed Science Giftedness Framework and Characteristics provides a holistic approach that can be used in an observational context over time in a middle school setting without the need for IQ, standardized achievement tests, or grade-based identification. Using the framework and characteristics to identify middle school age science gifted students offers an opportunity to provide advanced programming for science gifted students and follow their progress to determine pursuit, eminence, and leadership within various scientific fields as careers. The impact of identification as science gifted can offer opportunities for enrichment or extended learning opportunities to gifted middle school science students as well as guide middle school science teachers to implement enrichment and extended learning opportunities to allow scientifically gifted students to continue to progress in this area of giftedness past the basic standards (NAGC, 2014). This interaction with middle school age students can have lasting significant effects for several years past middle school, including the selection of a career in the sciences (Lloyd & Schachner, 2021).

While Delphi variants offer anonymity, opportunities for feedback, and the ability to engage a diverse panel across a broad geographical area (Avella, 2016; Vernon, 2009), this study had some limitations. In the first-round questionnaire, 31 of the 37 panelists were middle school science teachers or gifted educators, potentially skewing the data toward educators' perceptions. Panelists initially agreed in the participation agreement to complete all three rounds of questionnaires. However, data collection spanned three months in the spring of 2021, during the COVID-19 pandemic, which likely contributed to panelist attrition due to increasing teaching and work-related challenges. Although the distribution of expert panelists was not balanced, the proposed framework and characteristics were developed with the goal of providing middle school teachers with a useful tool for identifying students who exhibit science giftedness.

Future research should focus on refining the framework and characteristics into an observational identification tool that can be field-tested in middle school (grades 6–8) science classrooms. This would allow for verification of the framework's characteristics and assessment of its usability in real-world settings. Additionally, tracking the impact of early identification and subsequent enrichment opportunities could help determine whether students pursue science-related careers and achieve eminence in the field, similar to the SMPY studies (Lubinski & Benbow, 2006), with a specific emphasis on the science-gifted characteristics used for identification.

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