Intellectual Virtues for Interdisciplinary Research: A Consensual Qualitative Analysis

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Abstract

Through a qualitative approach, this study identified a specific subgroup of intellectual virtues necessary for developing interdisciplinary research. Cognitive science was initially conceived as a new discipline emerging from various fields, including philosophy, psychology, artificial intelligence, linguistics, and anthropology. Thus, a frequent debate among cognitive scientists is whether the initial multidisciplinary program successfully developed into a mature interdisciplinary field or evolved into a set of independent sciences of cognition. For several years, interdisciplinarity has been an aspiration for the academy, although the difficulties limiting the success of interdisciplinary collaborations have begun to erode that initial optimism. Our analysis suggests that the problems hindering the success of interdisciplinarity can be overcome by fostering certain intellectual character strengths in scholars. The Consensual Qualitative Research method was used to analyze nine semi-structured interviews involving researchers with a long personal trajectory of interdisciplinary research between the sciences and the humanities. Three virtue domains emerged from the interviews' analysis: (i) intellectual virtues, (ii) social virtues, and (iii) interpersonal intellectual virtues. The virtues of the third domain intersect with intellectual and social ones. They are intellectual because they pursue epistemic goods. But, unlike other intellectual virtues, they only develop in interpersonal settings, so they can also be considered to have a social component. Interpersonal intellectual virtues can be thus defined as intellectual character

traits that facilitate the acquisition of knowledge (intellectual motivation) *with* and *through* other people in a reciprocal way (social environment). These virtues are essential for developing any successful collective epistemic enterprise, interdisciplinary research being a privileged context where these qualities manifest themselves in a relevant way.

1. Introduction

During the last century, scientific and technological development led to the emergence of numerous scientific branches and an increasing number of specialists in new disciplines and subdisciplines. Along with this, further investigations of complex phenomena—such as cognition (Collins, 1977), ecology (Keiny, 2009), sustainability (Frodeman, 2014), and religious experiences (Barrett, 2017), among many others—demanded an approach from diverse perspectives, giving rise to a growing interest in interdisciplinarity (Kananika-Murray & Wiesemes, 2009; Lizier et al., 2018).

Cognitive science was initially conceived as a new discipline emerging from various fields, including philosophy, psychology, artificial intelligence, linguistics, and anthropology. The organizational origins of this new discipline date back to the mid-1970s with the formation of the Cognitive Science Society and the publication of the journal Cognitive Science.

Due to its origin, a frequent debate among cognitive scientists is whether the initial multidisciplinary program successfully developed into a mature interdisciplinary field or evolved into a set of independent sciences of cognition. In this regard, the community of the Cognitive Science Society is a privileged case study of the interest in developing an interdisciplinary approach over the past 50 years, as numerous studies show.

According to Leydesdorff and Goldstone (2014), from 1980 to 2000, the multidisciplinary space of cognitive science was built and developed. Studies about this period revealed, among other issues, the relevance of frequent and effective communication efforts between researchers for productive multidisciplinary collaboration to continue (Schunn, Crowley, & Okada, 1998). In the 21st century, the field has been losing diversity due to the increasing influence of psychology (Leydesdorff & Goldstone, 2014; Núñez et al., 2019), but cognitive scientists have continued to affirm the value of diversity (Bender, 2019; also see collection of papers in Gray, 2019). For instance, a bibliometric study based on the particular case of the journal Cognitive Science, which quantifies coauthorship networks, showed that this journal is among the best in this metric of interdisciplinarity compared to other journals in the social and natural sciences (Bergmann, Dale, Sattari, Heit, & Bhat, 2017). More recently, new studies show that, during the period between 2000 and 2019, the contributions to the Cognitive Science Society have become increasingly integrated, that is, more interdisciplinary and less multidisciplinary (DeStefano, Oey, Brockbank, & Vul, 2021). In addition, Alasehir and Acarturk (2022) also highlight that the scholarly domain of cognitive science has been exhibiting more manifest interdisciplinarity over the last decades.

This paper addresses an important issue for research in cognitive science: identifying scholars' intellectual character strengths that favor the realization of any collaborative interdisciplinary work. More specifically, our research focuses on what has been termed *strong interdisciplinary research* (Snow, 2022, p. 59). This is the most demanding situation for a research team, as it requires bridging the "two languages" of the humanities (philosophy) and the sciences, integrating different methodologies and epistemological emphases.

1.1. The challenge of interdisciplinarity

In several areas, interdisciplinarity became an aspiration goal for the academy as it suggested the creation of links between different fields of knowledge, the emergence of new ideas, enrichment from other perspectives, and the promotion of greater collegiality, flexibility, and academic collaboration. (Aram, 2016; Austin et al., 1996). Very early on, Apostel noted the importance of teaching the various disciplines within their dynamic relationships with other areas, and of fostering interdisciplinary research in universities (Apostel, Berger, Briggs, & Michaud, 1972). Attempts were also made to identify the environments that favor a more significant development of interdisciplinarity. To facilitate this, new university policies, research practices, infrastructure requirements, and so on were proposed (Lattuca, 2002).

Interdisciplinarity was operationally defined by the National Academies as follows:

> "A mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice." (NAS, 2005, p. 2)

Several systematic literature reviews were conducted among related sciences to define interdisciplinarity on a more solid theoretical basis, such as the one undertaken for the health sciences by Sally Aboelela et al. (2007).

Since the work of Patricia Rosenfield (1992), it has been customary to distinguish three typologies of relationships between disciplines (Klein, 2017): (i) *Multidisciplinarity*, when researchers work in parallel or sequentially from their disciplinary base on a common problem. (ii) *Interdisciplinarity*, when researchers from different disciplines work together on a common problem while still proceeding from their specific disciplinary base. (iii) *Transdisciplinarity*, when researchers coming from different disciplines work together to develop a conceptual framework or a common system of axioms to address a common problem, developing a synthesis that not only integrates but also transcends the disciplinary perspectives involved in the investigation (Alvargonzález, 2011; Klein, 2004).

Some authors suggested that interdisciplinarity is a process that integrates different disciplines enabling new hybrid scientific approaches to originate (Hvidtfeldt, 2016). Other authors emphasized instead that, as a result of interaction, interdisciplinarity mainly implies further development for the disciplines involved in the research (Grüne-Yanoff, 2016).

One of the significant problems soon detected is the difficulty in assessing the quality of interdisciplinary research since scientific standards vary according to the disciplines (Mansilla, Feller, & Gardner, 2006). Thus, generic evaluation principles (Klein, 2008) and indicators of interdisciplinarity for research proposals (Huutoniemi, Klein, Bruun, & Hukkinen, 2010) were put forward, and the experiences of interdisciplinary researchers were collected for consideration in evaluating new projects (Leigh & Brown, 2021). In addition, scales were developed to measure partial aspects of interdisciplinarity: the degree of integration of researchers' work (Masse et al., 2008), the interdisciplinarity of publications (Abramo, D'Angelo, & Zhang, 2018; Bergmann et al., 2017; Karmakar et al., 2020), the research systems (Wang et al., 2017), and so on. More comprehensively, pathways for assessing interdisciplinarity were also presented recently (Laursen, Motzer, & Anderson, 2022).

Many researchers emphasized that cross-disciplinary research, in general, and interdisciplinary research, in particular, is team-based research that requires complex social and intellectual processes (Fiore, 2008; Stokols, Hall, Taylor, & Moser, 2008). The characteristics of cognitive integration were analyzed in different forms of scientific collaboration (Andersen & Wagenknecht, 2013), highlighting that researchers in an interdisciplinary team are epistemically dependent on each other because they have diverse cognitive abilities (Andersen, 2016). Nevertheless, it was also recognized that it is necessary to learn at least enough to work together with an expert collaborator in the domains in which one does not have expertise (Tanesini, 2018). Moreover, Piso, O'Rourke, and Weathers (2016) proposed an approach for conceptualizing integrative capacity, and Lakhani, Benzies, and Hayden (2012) identified attributes that characterize successful interdisciplinary research teams. Various models of interdisciplinary communication were analyzed, pointing out that "the key issue is not the difference between disciplines or conceptual schemes, but rather the possibility of communication between individuals who may be adherents of such genres of discourse" (Holbrook, 2012, p. 1878). It was shown empirically that the negative impact of disciplinary differences is reduced when there is prior knowledge of the research project among researchers (Cummings & Kiesler, 2008).

From philosophy, there was also an argument in favor of interdisciplinarity, stressing that these investigations offer opportunities for philosophical work since they shed new light on old philosophical problems and open the study to further questions of philosophical interest (Crowley, Gonnerman, & O'Rourke, 2016). It was thus proposed to develop a Philosophy of Interdisciplinarity (Schmidt, 2007) and consider it an area within the philosophy of science (Mäki, 2016).

However, the initial optimism about interdisciplinarity began to wane in recent years. A study on bibliometric indicators between 1975 and 2005 showed that, although interactions between disciplines increased over time, interdisciplinarity tends to occur mainly between close or related areas, such as health sciences (Porter & Rafols, 2009). Several works also began to analyze the difficulties presented by interdisciplinary research (Cooke et al., 2020; Leahey, 2018; Thorén & Persson, 2013). In a critical historical review, Harvey Graff went so far as to consider it a myth to be challenged and revised (Graff, 2016, p. 791). There was also no shortage of skeptical voices regarding the possibility of doing quality interdisciplinary research with the current organizational structures (Jacobs & Frickel, 2009; Kahn, 2011). It

was mentioned, for example, that interdisciplinary PhDs often involve a higher workload, that it is often difficult to have quality supervision, and that the further academic development of young researchers with an interdisciplinary profile is not guaranteed (Kaiser, Kronfeldner, & Meunier, 2016). It was further noted that social coordination between hyperspecialized researchers is complicated, mainly because they often do not understand each other (Millgram, 2015). It was also cautioned that interdisciplinary research is at greater risk of superficiality (Cooke et al., 2020, pp. 148–149).

For Yvan Russell, the difficulties limiting the success of interdisciplinary collaborations can be summarized in three problems: (1) lack of scientific expertise in all the disciplines involved, as acquiring in-depth knowledge in a single discipline is already time-consuming; (2) poor comprehensibility, as a reliable understanding between researchers from different disciplines is difficult; and (3) asymmetry in service, as one discipline generally benefits more than another in interdisciplinary efforts. He thus concludes that successful interdisciplinarity must do a laborious job of translating across disciplines, be fully committed to shared understanding, and respect the slow-growing nature of specialized knowledge (Russell, 2022, p. 15).

In the abundant bibliography on the subject, most studies have focused on: (i) analyzing the institutional obstacles that impede the development of interdisciplinarity (funding allocation systems, peer review of articles, academic promotion, among others) to then developing possible proposals; and (ii) showing the difficulty of effectively assessing interdisciplinary research to propose ways of evaluating one or more of its aspects.

To a lesser extent, some works have also studied the epistemological and cognitive difficulties that the specificity of each discipline presents to interdisciplinary scientific practice. In this regard, Miles MacLeod (2018) has pointed out (i) that opacity between disciplines conspires to the development of interactive expertise, (ii) that conceptual and methodological incompatibilities may occur between the disciplines involved, and (iii) that conflicts concerning the epistemic values of the different disciplines involved in the research are possible.

On the other hand, four cognitive skills that promote interdisciplinary learning were identified (Repko, 2008): (i) developing and applying perspective-taking techniques, (ii) developing structural knowledge of problems appropriate for interdisciplinary research, (iii) integrating expert viewpoints from different disciplines, and (iv) producing an interdisciplinary understanding of a problem. Various strategies for the development of interdisciplinary research were also proposed. For example, a philosophical dialogue about the epistemological, metaphysical, and normative assumptions of the disciplines involved in the research was fostered among researchers in interdisciplinary groups (O'Rourke & Crowley, 2012). Adopting a metacognitive reflective balancing process to integrate disciplinary contributions was recommended, weighing these contributions against the goals and norms of the interdisciplinary team (Keestra, 2017). It was also emphasized that the first task of interdisciplinarity is not an integration of theories and perspectives but a clarification of the specificity of each discipline and how knowledge emerges in each discipline (Boon & Van Baalen, 2019, p. 23). Fostering joint intellectual attention among interdisciplinary researchers was suggested as a path to a deeper understanding of the cognitive approach of disciplines other than one's own (Vanney & Aguinalde Sáenz, 2021). This last paper outlines the ideas that inspired and gave rise to the qualitative research of the present article.

In different works, a variety of qualities of interdisciplinary researchers have been recognized as well. It was philosophically argued the relevance of approaching a study of interdisciplinarity from the perspective of virtue epistemology (Vanney & Aguinalde Sáenz, 2022a). It was mentioned, for example, that they must be curious enough to stay in one mode of inquiry and careful enough to know when it is the right time to go deeper into research (Freeth & Vilsmaier, 2020, p. 63). It was empirically tested that it is relevant that they have an open attitude toward other disciplines (Zaiț, Bratianu, Vătămănescu, Andrei, & Horodnic, 2021). Finally, a case was made about the importance of admitting the limits of one's own expertise and recognizing that, beyond those limits, researchers are *epistemic trespassers* and not experts (Ballantyne, 2019a).

1.2. Virtue epistemology

From the work of Ernest Sosa (1980), a new area within the philosophy of knowledge called virtue epistemology (Battaly, 2008; Turri et al., 2021) has been developed. Scholars in this area consider that intellectual or epistemic virtues are the qualities proper to excellent thinkers (Zagzebski, 1996). Some of the most studied intellectual virtues are intellectual humility, open-mindedness, curiosity, intellectual autonomy, intellectual perseverance, and intellectual honesty. Philosophers and psychologists have also analyzed the role of intellectual virtues in various applied fields, such as education (Baehr, 2021) and scientific research (Hookway, 2003). In turn, relationships between the philosophy of science and the epistemology of virtue were also considered (Fairweather, 2014). Since intellectual virtues are the personal qualities that underpin the pursuit of knowledge across domains, it is reasonable to expect that they also contribute to overcoming obstacles to interdisciplinary research (Snow, 2022).

Intellectual humility has been the focus of attention in the last decade, with numerous works dealing with it. Among the bibliographical reviews that have been made on this virtue, the works of Nathan Ballantyne (2021) and Tenelle Porter et al. (2021) stand out. Various conceptualizations have described intellectual humility as an orientation to recognize one's own intellectual limitations (Ballantyne, 2019b; Church & Barrett, 2016; Hazlett, 2012; Whitcomb, Battaly, Baehr, & Howard-Snyder, 2015). However, its interpersonal character has also been highlighted as intellectual humility places significant interpersonal demands on intellectual behavior (Baehr, 2022). In addition, intellectual humility has been considered a promoter of inquiry and learning (Porter, Schumann, Selmeczy, & Trzesniewski, 2020) and has been proposed as a remedy against polarization (Porter & Schumann, 2017), as a predictor of religious tolerance (Hook et al., 2016) and as a promoter of prosociality (Krumrei-Mancuso, 2017). From psychology, several scales were designed to measure it, such as those of Alfano et al. (2017), Leary et al. (2017), and Krumrei-Mancuso, Haggard, LaBouff, and Rowatt (2019), among others.

Another virtue that has been widely studied is open-mindedness, considered by many authors as a paradigmatic intellectual virtue (Adler, 2004; Riggs, 2019). Open-minded people are characterized by being willing to transcend their point of view to take the merits of a distinct cognitive standpoint seriously because they consider them helpful for reaching the truth (Baehr, 2013; Kwong, 2016a). Open-mindedness predisposes the individual to make room for novel ideas in their cognitive space and to consider them, and it has been seen as

a type of engagement motivated by epistemic goods (Kwong, 2016b). The ability to change perspective is the cognitive skill that characterizes the intellectual virtue of open-mindedness and which allows it to be distinguished from other virtues, such as curiosity or intellectual humility (Baehr, 2021, p. 32).

Curiosity has also attracted the attention of virtue epistemologists in recent years as a quality essential to the pursuit of epistemic goods (Brady, 2009; Kvanvig, 2013; Ross, 2018). A curious person, whose mental life is characterized by wonder, is quick to notice and inclined to investigate issues or topics of importance (Baehr, 2011, p. 19). In interdisciplinary research, curiosity is a crucial motivating factor for successful collaboration as it plays an essential role in initiating, maintaining, and coordinating the activities of the research teams (Watson, 2022). Although curiosity and inquisitiveness are often considered synonymous, they are distinct yet closely related dispositions. The inquisitive person always asks questions, while the curious person can manifest their curiosity in many ways. Inquisitiveness is thus a restricted form of curiosity (Watson, 2019).

For many virtue epistemologists, intellectual autonomy occupies a crucial place because it constitutes an essential part of the very concept of epistemic agency applied to the cognitive actions of an individual or a community (Coady, 2002; Zagzebski, 2015). In general terms, epistemic autonomy is understood by many researchers as epistemic self-sufficiency (Goldberg, 2013; McMyler, 2011). Thus, intellectual autonomy protects individuals from excessive dependence on others for their beliefs. In contrast, when individuals exercise their intellectual autonomy, they bring their reason into play and obtain adequate justification for their beliefs, which has commonly been considered a requirement of their possession of knowledge (Pritchard, 2016). Autonomy, however, does not imply neglecting the social dimension of knowledge or denying the role of trust and faith in epistemic endeavors (Garcia & King, 2009; Grasswick, 2019; Harris, 2012; Zagzebski, 2013, 2014).

Since attaining the truth is an arduous task and implies a continuous effort over time, it also requires a character trait that allows the individual to continue his intellectual project for an adequate time despite obstacles to its success. Such is the virtue of intellectual perseverance. Although this virtue has so far received less attention than other intellectual virtues, noteworthy in its study are the works of Nathan King (2014, 2019) and Heather Battaly (2017) in the field of philosophy, and Angela Duckworth (Duckworth, 2016; Duckworth, Peterson, Matthews, & Kelly, 2007), Camille Farrington (Farrington et al., 2012), and Carol Dweck (Dweck et al., 2014) in the field of psychology.

Intellectual honesty has been characterized as a virtuous disposition whereby the agent does not deceive when presented with an incentive to do so (Guenin, 2005). Its importance was recognized for a variety of academic practices: in publications (Lightner, McKenna, & Steers, 2011), in peer reviews (Bishnu Hari, 2004), and in scientific research (Gallagher, 2007), among others. It is, however, a virtue still little studied by virtue epistemologists. In this context, intellectual honesty was conceptualized as a disposition to express the truth (as we see it) through our thought, word, and behavior, avoiding intentionally distorting the truth (as we see it) because we consider the truth as valuable (King, 2021, p. 145). Recently, a plurality of epistemic motivations that allow distinguishing intellectual honesty from its namesake moral virtue have also been analyzed (Miller, 2022).

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In recent years, social epistemology has studied group deliberative virtues, such as deliberative wit, kindness, charity, and temperance, among others (Aikin & Clanton, 2010). The value of group deliberation and dissent within certain scientific teamwork was studied, and a deeper exploration of the nature of scientific groups or communities was encouraged (Tollefsen, 2012).

In summary, virtue epistemology is characterized by focusing on the study of personal conditions that favor the search for knowledge in all fields. Based on these theoretical considerations, the objective of our investigation was to determine which are the intellectual virtues people should have in order to undertake successful interdisciplinary projects of any kind. This was done by analyzing in-depth interviews with researchers with a long track record of interdisciplinary experience in different areas, not only in cognitive science. Therefore, although the paper does not provide a snapshot of this field, our study's goal is highly relevant to the cognitive science community, as it provides a deeper understanding of the character traits of researchers who engage in collaborative work from diverse academic backgrounds.

The few qualitative studies conducted on related topics have been carried out in the United States, Canada, or Europe, either on interdisciplinarity (Cooke et al., 2020; Lizier et al., 2018; McBee, Leahey, & Nowotny, 2017) or on scientific virtues (Pennock, 2019). Our research will instead focus specifically on Latin America, which still needs to be explored.

The first three qualitative studies mentioned above have sought to deepen the understanding of interdisciplinarity (Cooke et al., 2020), the challenges of interdisciplinary training (McBee et al., 2017), and the teaching of an interdisciplinary topic (Lizier et al., 2018). These studies conducted interviews with (i) 18 tenured interdisciplinary scholars in the humanities (McBee et al., 2017), (ii) 57 members of the College of the Royal Society of Canada (Cooke et al., 2020), and (iii) 7 pioneering teachers and learners of complex systems from the United States, Sweden, and Australia (Lizier et al., 2018). They stress the importance of interpersonal interactions (Lizier et al., 2018), openness to other perspectives (Cooke et al., 2020), and aligning with the concerns, assumptions, and standards of another discipline (McBee et al., 2017). On the other hand, Pennock's fourth study focuses on the scientists' character, arguing that the flourishing of science depends on the ethical values of its practitioners (Pennock, 2019). Curiosity, creativity, honesty, and humility are some of the scientific virtues studied by him. Despite the differences related to the objectives, methodology, and characteristics of the interviewees in all these studies, they constitute a good background for our research.

2. Method

2.1. Participants

The study sample comprised nine researchers with a long personal trajectory of interdisciplinary research between the sciences and the humanities. All these researchers currently carry out their academic activity in Latin American countries (Argentina, Chile, Mexico, and Uruguay). However, it is relevant to note that they have also participated for several years in research conducted in other regions, mainly in the United States and Europe.

The academic background of the participants is as follows: five of them have two degrees, one in philosophy and one in science (three in physics, one in biochemistry, and one in psychology). Of the remaining four, two are philosophers, and two are neuroscientists. Although the university training of the latter four was in a single discipline (philosophical or scientific), all of them were engaged in interdisciplinary research between some science and philosophy for several years.

The selection of the sample was intentional, and the following selection criteria were used: (i) researchers who have at least 7 years of experience in conducting interdisciplinary research between science and philosophy, (ii) who develop their work activities based in Latin America, (iii) who have directed or been members of interdisciplinary projects with international subsidies that accredit this task, and (iv) who have relevant academic publications that accredit their interdisciplinary work. A demographic description of the interviewees can be found in Table 1. Therefore, for our exploratory purposes, all the interviewees were well suited to identify the cognitive dispositions that favor interdisciplinary research.

2.2. Interview protocol

The protocol for the semi-structured interviews applied to the study participants was generated and discussed by two authors of this article. It included the following instructions to the participants: (i) to describe their experience in interdisciplinary research; (ii) to estimate whether the interdisciplinary projects in which they participated were successful; (iii) to mention which personal characteristics of the researchers contributed favorably to the development of interdisciplinary research, and which ones had an unfavorable impact; and finally (iv) to indicate which of the mentioned favorable characteristics were considered by them to be essential for the success of their projects.

2.3. Procedure

The interviewees were contacted by the research project director and invited to participate in the study because of their experience in conducting interdisciplinary work. All the invited academics agreed to participate in the study. Once acceptance was obtained, they were informed in advance of the questions that would be asked. Subsequently, the date and time of the virtual meeting were coordinated with them. One of the psychologists from the research team, an expert in semi-structured interviews, conducted the interviews. The interviews were carried out during the second semester of 2021 and lasted approximately 2 h each. All interviews were individual and were run through the virtual zoom platform, which allowed them to be recorded. The recordings were transcribed verbatim by one of the project researchers. The transcripts were corrected by a second researcher and uploaded to ATLAS.ti version 9 software for further coding.

The participation of the interviewed academics was voluntary, and they were guaranteed the confidentiality of the recorded material. They were informed that the project's research team would only share the contents for academic purposes. They were not given any prior introduction to the topic of intellectual virtues with the intention of not biasing their answers.

Table 1
Participant demographics

Interviewees	Age	Sex	Degree	MA/Ph.D.	Interdisciplinary experience in years	Country of academic activity	Number of interdisciplinary projects led or participated in
Participant 1	62	F	Engineering Philosophy	Ph.D. Philosophy	25	Argentina	15
Participant 2	76	M	Philosophys Theology	Ph.D. Philosophy	30	Argentina	20
Participant 3	63	M	Medicine	Ph.D. Psychiatry	28	Argentina	10
Participant 4	43	M	Philosophy	Ph.D. Philosophy		8 Uruguay	5
Participant 5	38	M	Psychology Philosophy	Ph.D. Psychology	7	Chile	5
Participant 6	76	F	Medicine	Ph.D. Neuroscience		12 Argentina	6
Participant 7	56	M	Biochemistry	Ph.D. Molecular Biology MA Philosophy	12	Chile	3
Participant 8	45	M	Engineering Physics Medicine Philosophy	Ph.D. Philosophy		8 Mexico	13
Participant 9	70	M	Physics	Ph.D. Physics	40	Mexico	13

2.4. Consensual Qualitative Research

The Consensual Qualitative Research (CQR) method proposed by Hill, Thompson, and Williams (1997) was used to analyze the nine semi-structured interviews. The sample size is within the range suggested by the CQR method, which is 8–15 participants (Hill, 2012). We employed this method due to the exploratory nature of the present study and the lack of previous empirical research on the intellectual virtues required for interdisciplinary work. Furthermore, this methodology is inductive and descriptive, and is considered as a rigorous qualitative procedure for analyzing open-ended questions (Hill, 2012). According to Hill, the method allows us to identify the attitudes, beliefs, and experiences of the interviewees. It is thus an appropriate method for our study since it will enable us to identify the intellectual virtues suggested by the interviewees as necessary traits needed by researchers who engage in the practice of interdisciplinarity. On the other hand, since the CQR is a relatively structured method of analysis, it is suitable for opening the doors to the replicability of the research.

The primary group of researchers who analyzed the interviews consisted of: (i) a 56-year-old female physicist with a Ph.D. in Physics and another in Philosophy, with experience in interdisciplinary research and the epistemology of virtue; (ii) a 43-year-old female psychologist with a Ph.D. in Psychology and research experience in social psychology; and (iii) a 48-year-old male with two degrees, in philosophy and psychology, and a Ph.D. in Philosophy. Finally, the auditor was a 76-year-old female psychologist with a Ph.D. in Philosophy and extensive research experience in cognitive psychology. The auditor had the function of integrating and assisting the primary group in the process of reaching a consensus.

The primary group of researchers and the auditor received 20 h of methodological training before coding the interviews. The objective of the course was to train the research team members in the qualitative approach to be used, and was given by a specialist in qualitative methodology.

2.5. Data analysis

The interviews were conducted during the first half of 2021, and coding began during the second half of 2021. Initially, the primary coding team met to read the first interview together. Then, each member independently identified possible domains in that interview using the Atlas.ti program. The formulation of the domain codes was discussed until a consensus was reached among the primary team. This resulted in a list of domain codes the entire primary team agreed upon. Subsequently, each primary group member coded the domains independently in the remaining interviews. Finally, the primary group met again to discuss the domains identified in each interview. Occasionally, more than one domain was identified in the same coding. In those cases, these codes were discussed until a consensus coding was reached.

Following this, each member of the primary group constructed the *core ideas*. Constructing the *core idea* is a process of synthesis in which an attempt is made to capture the essence of what the interviewee wanted to convey about the identified domain. Thus, the primary group individually elaborated the *core ideas* seeking to express clearly, and in a few words, the

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essential ideas expressed by the interviewees. The primary group discussed the *core ideas* of each domain until a consensus was reached.

The auditor checked then the construction of the identified domains and *core ideas* created by the primary group. Next, the auditor read the raw material (the transcript of the interviews) to indicate whether the domains and *core ideas* created were correct. Based on that work, the auditor suggested some division of domains that were discussed until a consensus conclusion was reached. Subsequently, the primary group reviewed all the interviews again to ensure consistency in the coding of the domains in all the cases analyzed.

Once all the interviews were analyzed individually, cross-analyses were performed. The cross-analyses identified similarities between the different interviews. The team examined each simple domain and tried to think of all the categories that could be applied to that domain. The primary group discussed the conceptualization or *core ideas* of the categories, always pointing to evidence from the data for justification. The auditor carefully reviewed the cross analyses considering whether each *core idea* was a good fit for the specified category. He also analyzed whether the category label adequately captured the essence of all the *core ideas* listed. The auditor and the primary team discussed the cross-analyses until a consensus was reached.

Finally, we determined how often the categories apply to the sample, that is, how many interviews each category appears in. If the category appears in most or all the sample (in our study, 8–9), it will be called *general*. If the category appears in more than half of the cases (in our study, 5–7), it will be called *typical,* and if it appears in less than half of the cases (in our study, 3–4), it will be called *variant*. If a category appears in only 1 or 2 cases, it will be eliminated because it was considered nondescriptive of the sample.

3. Results

The use of the CQR method in the analysis of the interviews with the interdisciplinary researchers made it possible to identify the domains and categories of analysis shown in Table 2. This table describes the frequency obtained from the categories by classifying them as *general* (if applicable to all or almost all interviewees), *typical* (if applicable to more than half of the interviewees), or *variant* (if applicable to less than half of the interviewees).

Three domains emerged from the analyses: intellectual virtues, social virtues, and interpersonal intellectual virtues. On the other hand, six categories were identified within intellectual virtues, five in social virtues, and four in interpersonal intellectual virtues. Quotes from the interviewees are used in the presentation of the results.

3.1. Domain 1: Intellectual virtues

Intellectual virtues differ from other virtues because they have an epistemic goal. Within this domain, three categories were identified that applied to the sample with a *general* frequency, that is, they appeared in all the interviewees. They were intellectual humility, open-mindedness, and intellectual perseverance. On the other hand, curiosity and intellectual

Table 2
Domains, categories, and their frequencies

Domains/categories	Frequency	
Intellectual virtues		
Intellectual humility	9	(G)
Open-mindedness	9	(G)
Intellectual perseverance	9	(G)
Intellectual curiosity	7	(T)
Intellectual honesty	7	(T)
Intellectual autonomy	4	(V)
Social virtues		
Friendship	5	(T)
Kindness	4	(V)
Collaborative spirit	3	(V)
Sense of humor	3	(V)
Communication skills	3	(V)
Interpersonal intellectual virtues		
Intellectual empathy	9	(G)
Intellectual respect	6	(T)
Interpersonal intellectual trust	4	(V)
Intellectual generosity	4	(V)

Note. G, general (8–9 participants); T, typical (5–7 participants); and V, variant (3–4 participants).

honesty applied to the sample with a *typical* frequency. While intellectual autonomy had a low frequency (*variant*), that is, it appeared in less than half of the cases analyzed.

3.1.1. Intellectual humility

The interviewees mentioned different manifestations of intellectual humility. The first of these is recognizing the limits of one's discipline. For example, interviewee 4 said: "For me, it was quite useful to become aware of the limits of some questions within my own discipline." Interviewee 5 mentioned that one has to "know the limits of one's own discipline," and interviewee 9 said: "To me, maturity in thinking is not about being complete, rounded, no. Maturity comes, on the contrary, from knowing where the borders are, from knowing that we don't know everything, from knowing that we can't do everything, and that this is why interdisciplinarity is worthwhile. Because knowledge does not end with that which is mine."

Intellectual humility also manifests itself in the ability to recognize one's own cognitive limitations and mistakes in intellectual work or in assuming a change in one's thinking due to new evidence or argumentation. For example, in reference to the limitation of his own knowledge in an area in which he was not an expert, interviewee 2 commented: "the work she did I could not do because it is a lot of literature on (the topic)." Likewise, he added that in interdisciplinary work, it is necessary "to recognize mistakes, to recognize that what one says maybe is not quite so, or even to recognize that one has changed his mind at a given moment." In the same vein, interviewee 4 said: "It is important to realize that at a given moment, there

is a depth I cannot reach. I mean, I cannot suspend my life to sit down and study biology. I won't be able to get there."

Intellectual humility was also identified with seeking guidance from others, even when one has years of professional experience. Interviewee 3 described the attitude that an interdisciplinary researcher should have by saying, "you have to have a lot of humility. You always must look for someone to guide you." Finally, intellectual humility during interdisciplinary work also manifests itself in recognizing that one learns from the other researchers one works with, even if they are from other disciplines. Along these lines, interviewee 1, speaking of a colleague, said, "I then responded by saying: Well, I thank you very much for what you are telling me, and I take this opportunity to tell you that I have learned a lot from what you have said." Interviewee 2 said, "the bibliography they presented to me, I would read it, examine it, and indeed it helped me"; and interviewee 7 reflected that in interdisciplinarity it is necessary to have a "willingness to learn, willingness to listen, willingness to receive criticism."

3.1.2. Open-mindedness

Open-mindedness in interdisciplinary work is manifested as the ability to assume the perspective of the interlocutor who comes from an area of knowledge different from one's own. For example, interviewee 1 said: "if we are talking about epistemic virtues, the virtue of interdiscipline is to put oneself in the place of the other. In every sense, in an epistemic sense, in the sense of perspective, in the sense of trying to know what the other knows. In other words, to try to put oneself in the other's place, not to occupy the other's place, but to put oneself in the other's place in order to see the problem from the other's perspective." For his part, interviewee 4 said that, during the work, "it has happened to me to change my perspective regarding some things."

Interviewees expressed the need to "open up to the other" (interviewee 4) and to "sit down and talk, even if we come from different disciplines" (interviewee 5). Open-mindedness also implies abandoning prejudices in the exchange with colleagues from other disciplines. For example, interviewee 2 reflected: "I have seen after the conversations that they dropped their prejudices," referring to scientists who were open to a philosophical perspective on a given topic after a discussion. In turn, this involves a willingness to listen to others in order to know their opinion on a subject, even if it differs from one's own. In this sense, interviewee 9 remarked: "To learn from someone you don't have to agree with them, you don't necessarily have to be their friend or be totally in the same denomination. Everybody can teach you something."

Interviewee 5 described open-mindedness using the metaphorical expression of coming out of their "little mental boxes" to build a "new language" common to the interdisciplinary group: "if there is a psychologist and a biologist, and the biologist also has a background in something else and the psychologist in something else, well, they already know how to come out of their little mental boxes, they already know how to think in two languages, and they can enter perhaps into a conversation in a third language." In the same direction was the comment of interviewee 2, when he indicated that during joint work the researcher of a discipline "learns a vocabulary that is not theirs and learns a new type of approach." Interviewee 8 observed that "to be able to work, it is necessary to have a common dictionary

of common terms, not only a translator of words but to make sure that the concepts which are being used are used in the same way."

3.1.3. Intellectual perseverance

All interviewees agreed that interdisciplinary work involves a tremendous intellectual effort linked to overcoming specific challenges, such as studying disciplines other than one's own or achieving a reliable understanding between researchers due to their limited knowledge of the epistemic demands of other fields. All of this can require much time and dedication. For example, interviewee 1 said: "interdisciplinarity requires that everyone makes an effort to understand or learn a little more from the other side." Next, she also reflected on the effort involved in interdisciplinary work compared to research in a single discipline: "interdisciplinarity implies a greater effort, that is, interdisciplinarity implies an enormous effort," pointing out that it often requires double degrees or some systematic training in more than one discipline. In the same sense, interviewee 7 said, "the person arrives, sits down, and realizes that there is a lot of work to be done, that it is not automatic, it takes a lot of costs…" And interviewee 2 emphasized the following: "You must have patience to read books that go outside your own expertise, outside your own curricular studies, and you must dedicate time to them. That is necessary."

Interdisciplinarity is not simply work done in collaboration with others but involves learning from other disciplines and being critical about the work done. Interviewee 7 said it requires "a lot of rigors. It requires a lot of rigors, a lot of critical eyes. Not to be satisfied with just getting together, but to go a step further and make a difference." The expression "to go a step further" refers to being able to achieve knowledge that would not have emerged without interdisciplinary cross-linking. Interviewees also referred to the investment of time and effort required. Interviewee 9 reflected, "then again, another interesting discovery is that this interdisciplinary way of thinking demanded all of my time, 24 hours a day, 365 days a year, 366 if it is a leap year. But I mean, all the time."

3.1.4. Intellectual curiosity

Intellectual curiosity appeared in seven of the nine interviewees as an essential factor for interdisciplinary work. In general terms, intellectual curiosity involves a deep yearning for knowledge, which may result in a broad interest in all scientific disciplines. Referring to his personal interests, interviewee 2 commented: "Although I initially studied philosophy, I always liked the sciences in high school: physics, mathematics, biology, and I could have studied any of those sciences. Because I liked them all." Interviewee 9 shared a similar emotional state that led him to study and complete three different university degrees: "The point is that I became infected with a certain restlessness, with curiosity. And that's the mother of knowledge: curiosity, restlessness, non-quiescence. (…) I realized that knowledge, practically everything, is worthwhile."

Intellectual curiosity was also described as a genuine interest in learning from the sciences in the case of philosophers and philosophy in the case of scientists. Thus, intellectual curiosity can manifest itself, for example, in an interest in the epistemic domains of colleagues with whom one does interdisciplinary research. Interviewee 2, a philosopher, narrated: "I started

to read for 2, 3 or 4 years, books and essays by Einstein, Max Planck, Max Born, Heisenberg, that is, by these great physicists; and I also studied, with more philosophical maturity, some books on physics (…) Later I started to read books on neuroscience and artificial intelligence." In the same vein, interviewee 6, a neuroscientist, said: "last year I took a course in phenomenology (…) it is really something that impresses me a lot." Or interviewee 3, a neuroscientist, mentioned: "I am an avid reader, but I have no systematic training in philosophy."

Moreover, another interviewee linked intellectual curiosity with an authentically interdisciplinary approach to the research question. In this regard, interviewee 4 highlighted the importance of "having research projects aligned to genuine questions and not a splatter of interesting topics, but which in the end do not imply a real research commitment."

3.1.5. Intellectual honesty

Intellectual honesty is another crucial element pointed out by the interviewees for the success of interdisciplinary work. Intellectual honesty was described in the interviews as a climate of sincerity among team members. In this sense, interviewee 2, a philosopher, characterized his scientific colleagues as follows: "I saw in them a sincerity and intellectual honesty."

Such sincerity and transparency are required throughout the whole process. For example, referring to the writing of a book, interviewee 3 said: "what helped us a lot in all this work was to have a lot of candor: look, this seems right to me, this doesn't seem right to me, don't put it, this can be, this can't be." In a similar direction, interviewee 5 said: "I try to be very honest about statistics, in the sense of looking at it with a philosophical perspective as well. I mean, here we are not with a microscope looking at the truth of the human mind, but we are making the best possible models with the data we have, which are measurements full of errors that we have to try to minimize and that we have to contemplate thousands of factors. I think my philosophical background helps me to have a more deflationary view of the scientific method in my discipline or other disciplines." Interviewee 8 also stressed the need to be transparent in the formulation of the real scope that a given philosophical theory may have without exaggerating or skewing its empirical consequences: "If the issue we are discussing is an empirical issue, that is, I have my theory, the question is to make clear what the empirical consequences of my theory are, to see if they are falsifiable or not. That is what is intellectually honest."

3.1.6. Intellectual autonomy

Intellectual autonomy appeared in the interviewees' mentions with a lower frequency. This is the virtue that characterizes the independent thinker, who, during the research process, confirms or rectifies his criteria by thinking for himself. Regarding this point, interviewee 9 said: "the fact that someone more experienced knows these things helps me in that it transmits knowledge to me, but it doesn't guarantee anything to me. I have to be the one who understands." On the other hand, intellectual autonomy implies that when researchers from different disciplines do not agree on the analysis of a study, they should present arguments and provide support for their position. For example, interviewee 2 said: "I had fun working with him because he was a bit of a fighter. Suddenly if he did not like something, he would say: No, no, no, no, not that, not that!"

The intellectual autonomy necessary for interdisciplinary research leads to not being influenced by the disciplinary vision of the most experienced researcher in a team. Interviewee 9, for example, noted: "There may be people with more experience, and it is important to know their points of view, but they cannot be the permanent voice in this effort. There is a process of self-organization in interdisciplinarity, which involves all members." Similarly, interviewee 4 stated: "It is important that there is no individual who becomes the authority because otherwise, we always run the risk of reductionism of the individual."

3.2. Domain 2: Social virtues

Social virtues can be distinguished from other virtues because they aim at facilitating interpersonal relationships. Within this domain, friendship was identified with a typical frequency, that is, it appeared in more than half of the cases. The other four virtues (kindness, collaborative spirit, sense of humor, and communication skills) had a low frequency, that is, they appeared in less than half of the interviews conducted but in at least three of them.

3.2.1. Friendship

More than half of the interviewees mentioned the generation of a climate of friendship among group members that favor exchange as a critical element for the success of interdisciplinary work. In this context, interviewee 2 recalled: "perhaps the small workshops give more room for friendship (…) [in them] we talked with a lot of friendliness, with a lot of friendliness." On the other hand, interviewee 3 mentioned: "there is an implicit solidarity, there is an implicit deep affection, there is a friendship." Aristotle said that the fullest form of love is friendship; there is nothing at stake, there is no interest. If there is a deep friendship, everything else works out. They're just details. Interviewees emphasized that friendship fortifies present and future team interactions. Interviewee 3, for example, said: "We have some paper together, but the paper is an anecdote; we have a friendship of more than 20–30 years," and interviewee 4 said, "we all became friends, and we keep in touch, we write to each other, we participate together in different activities."

3.2.2. Kindness, collaborative spirit, sense of humor, and communication skills

These four social virtues achieved only one *variant frequency*, that is, they were mentioned by three or four researchers, as seen in Table 2.

Kindness in the relationship was mentioned in four interviews. For example, interviewee 2, a philosopher narrating an exchange of ideas with scientific colleagues, noted: "so in my very kind and delicate answer, I tried to tell him that all this required a certain ontological basis." Discovering kindness points of encounter rather than criticism and addressing others with affection and courtesy was also highlighted. Interviewee 3 said: in a climate of "good treatment of others, trying to validate rather than criticize," it is necessary to favor "courtesy, good human relations." The importance of knowing how to disagree with others with delicacy and courtesy was also mentioned. Interviewee 4 pointed out: "the most important thing of all is to be able to criticize without offending."

The collaborative spirit was mentioned in three interviews as a necessary virtue for interdisciplinary research. Interviewee 8 emphasized that "interdisciplinary work is essentially teamwork," and interviewee 1 said: "I think the best thing is collaborative work, and that is what I try to foster in the group." Interviewee 8 used the following analogy to describe interdisciplinary work: "it takes a street that we want to walk down together."

Another social virtue mentioned in three interviews is the sense of humor. Interviewee 3, for example, emphasized: "the sense of humor was extremely favorable" in interdisciplinary work.

Finally, communication skills, whose goal is to facilitate the exchange of ideas within the group, were also mentioned in three interviews as virtues required in collaborative interdisciplinary research. For example, interviewee 4 said: "what was being sought, I think consciously, was that habit, that virtue of dialogue. I have a lot of confidence in that, in the criteria of Socratic dialogue ethics," and interviewee 2 added: "based on what he said, I then would make some brief comments to encourage dialogue and then the discussion would be extended among all of us." Finally, assertiveness was also mentioned, understood as the ability to disagree with the opinion of others by communicating it positively. Interviewee 3 commented: "to make clear or explicit the goals one pursues, which very often are not those pursued by the other, but in this, unity in diversity. I am not interested in that; I would like to do this, and you are not interested in that. Well then, let's sit down at the table and see how we can give shape to a common project."

3.3. Domain 3: Interpersonal intellectual virtues

A third domain emerged from the interviews conducted, which is at the intersection of the two previous domains: intellectual virtues and social virtues. We call this third domain "interpersonal intellectual virtues." These virtues are intellectual because, like other intellectual virtues, they aim at epistemic goods; but, unlike other intellectual virtues, their immediate sphere of application is necessarily interpersonal, and this is what they have in common with social virtues. In this sense, interpersonal intellectual virtues focus on the *interpersonal relationship itself*, helping in the process of thinking *along with* others by making the social aspects of knowledge-seeking go well. Thus, they can be defined as personal character traits that facilitate the reciprocal acquisition and distribution of knowledge (intellectual motivation) *with and through* other people (social environment). These intellectual virtues are necessary to develop any collaborative intellectual work and are especially relevant in interdisciplinary research.

Within the domain of "interpersonal intellectual virtues," four virtues were identified: intellectual empathy, intellectual respect, intellectual trust, and intellectual generosity. It is important to emphasize that these intellectual virtues cannot be exercised individually or intrapersonally but require an "other" to exercise them by their very nature. That is, they are virtues that always occur in the context of interpersonal relationships.

3.3.1. Intellectual empathy

Intellectual empathy was the interpersonal intellectual virtue most mentioned by the interviewees, reaching a general frequency. It was described as the ability to "see things" from the

other's point of view, "being able to understand" the *way* the other understands to think like him.

Interviewee 1 argued that for the success of interdisciplinary research, it is necessary to be able "to internalize the way of reasoning also in the other area (…) Acquire something like the language of the other (…), the way of reasoning of the other." She exemplified this: "I want to understand how chemists think. Because they think differently, they don't think like physicists." In addition, interviewee 8 stated that it is about "being able to feel comfortable doing what the other does or working with what the other does, even if you are not an expert [in that other discipline]."

Intellectual empathy requires both the ability of perspective-taking and the cognitive flexibility to change one's way of thinking and doing research. Interviewee 7 stated: "we are obviously going to have to change the way we do things, from everyday things to the way we do research (…) I think it is critical to be sure that we are not only sitting in a common place, working together, but that this meeting really leads us to a different understanding." Despite their similarities, intellectual empathy is fundamentally distinguished from open-mindedness by its interpersonal dimension. Interviewee 4 noted that in order to develop intellectual empathy, there must be a real interpersonal exchange between interdisciplinary researchers: "It seems to me that we must address the problems in real dialogue, not merely in bookish dialogue. Especially because if what we want is to acquire methodologies and ways of working that generate good practices, because at the end of the day, practices are intersubjective." Additionally, he described his experience working in interdisciplinary projects as follows: "It was a training and coexistence between different minds (…) It seems to me that I learned to understand in a different way. And also, to understand the role of my discipline in that conversation."

Interviewee 2 related his experience in the following words: "They learned a vocabulary that is not theirs, and they learned a type of approach that is not theirs (…) [Interdiscipline implies] not being blinded by one's method, willingly accepting that one is capable of thinking in another way (…) [Acquiring] another way of thinking, which if one is used to the scientific method, to the laboratory, is very shocking at the beginning." Interviewee 5 stated, "I think that there cannot be good interdisciplinary dialogue with monism, that is, with methodological monism."

3.3.2. Intellectual respect

Intellectual respect was the second most mentioned interpersonal intellectual virtue by the interviewees. It was mentioned in six interviews with a *typical* frequency, that is, it was mentioned by more than half of the interviewees.

According to the interviewees, intellectual respect in interdisciplinary work is based, in the first place, on a positive valuation of the contributions of disciplines other than one's own. In this sense, interviewee 1 asserted: "I have to value the discipline of the other as I value my own. And it's not that easy. (…) You must feel that the other discipline is as important as yours, it is no more or less important because one does not master it."

This appreciation of the knowledge of others leads to respect for researchers coming from different disciplines. Interviewee 5, for example, stated that it is essential "to recognize that

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the knowledge of the other is valid knowledge and that, even if I don't know it or do not cultivate it, I understand at least that it has a logic. It is different from mine, but at some point, we can meet." Intellectual respect also implies grasping the possible complementarity between disciplines. In this sense, interviewee 2 mentioned: "there is a certain equality and complementarity so that each contributes its own and enriches the other."

3.3.3. Interpersonal intellectual trust and intellectual generosity

These two interpersonal intellectual virtues reached a *variant frequency*, as four respondents mentioned both, as seen in Table 2.

The interviewees referred to the importance of a climate of trust in the interdisciplinary research team to generate a sincere exchange without fear of criticism or being negatively evaluated by others. For example, interviewee 3 pointed out the need for "groups bound together by mutual trust," and interviewee 4 stressed the importance of "creating a trust for dialogue (…) Through dialogue, perhaps those ideas that seem absurd, in a context of trust I can tell them, and I can put them to the test."

Finally, according to the interviewees, intellectual generosity has diverse manifestations. Generosity is required to transmit knowledge, communicate ideas, and teach others. Interviewee 2 recalled with gratitude one of the colleagues with whom he had worked saying: "he explained his ideas to me a lot (…) he had the desire to transmit his own experiences and knowledge (…) The desire to communicate seems to me to help a great deal in interdisciplinary dialogue." Finally, intellectual generosity also manifests itself in a desire for one's work to transcend one's own life in favor of others. In this sense, interviewee 1 said: "the only thing I would like is that when I retire or die, the research group will continue."

4. Discussion

As we mentioned in the introduction, the field of cognitive science is currently facing the challenge of achieving greater dialogue and integration among the disciplines that contribute to it (Bender, 2019). The establishment of fruitful multidisciplinary collaboration in this field was initially achieved through effective and assiduous communication between researchers from diverse areas (Schunn et al., 1998), which then gradually declined throughout the 21st century (Leydesdorff & Goldstone, 2014). The results of our study show that in order to achieve a successful and sustained interdisciplinary dialogue over time, researchers must develop in themselves a series of character qualities that predispose them to adequately deal with such demanding collaborative work.

In recent decades, many studies have focused on the excellences or virtues of good thinkers and knowers. These studies mainly seek to deepen our understanding of intellectual virtues, although many also explore how to cultivate them in educational settings. Interdisciplinary research, an activity in which a multiplicity of cognitive approaches converges and is often conducted collaboratively, is another exciting area for exploring the application of virtue epistemology. It is logical to wonder about the specific qualities researchers must have to develop research with these characteristics.

Given the absence of empirical evidence on the subject, our research aimed to identify, through a qualitative approach study, the strengths required to carry out successful interdisciplinary studies. Nine researchers with extensive experience in interdisciplinary research participated in the investigation. Three clearly defined domains emerged from the analysis of the interviews: intellectual virtues, social virtues, and interpersonal intellectual virtues.

The first domain is *intellectual virtues*. The interviewees identified the following qualities as critical characteristics that researchers should possess to develop successful interdisciplinary work: intellectual humility, open-mindedness, intellectual perseverance, intellectual curiosity, intellectual honesty, and intellectual autonomy. The results are consistent with previous research that highlighted the relevant role of these virtues in acquiring, preserving, and transmitting knowledge (Baehr, 2021; King, 2021). However, previous studies have yet to focus on analyzing these virtues in interdisciplinary contexts. Moreover, as interdisciplinary work requires researchers to integrate diverse approaches, these virtues emerged with new manifestations in our study.

For example, it is well known that *intellectual humility* implies recognizing one's intellectual limitations (Ballantyne, 2019b). An intellectually humble interdisciplinary researcher must also acknowledge their discipline's scope and methodological limits. *Open-mindedness* consists of a disposition to transcend one's point of view by opening oneself to that of others (Baehr, 2013). An open-minded interdisciplinary researcher should also be open to diverse methodological approaches and abandon disciplinary prejudices in the dialogue with researchers from other areas. *Intellectual perseverance* is the disposition required to overcome obstacles and continue carrying out the intellectual actions necessary to achieve the objectives set (Battaly, 2017). In interdisciplinary investigations, researchers will need this virtue to sustain the effort required to learn a new vocabulary and the methodologies used by other disciplines over time. *Curiosity* stimulates virtuous inquiry by formulating good questions (Watson, 2018). An intellectually curious interdisciplinary researcher will manifest a genuine interest in research not only in their area but also in the contributions and epistemic approaches of researchers from other disciplines. *Intellectual honesty* implies a reliable willingness not to intentionally distort the facts as the agent sees them (Miller, 2022). In interdisciplinary work, intellectually honest researchers will also share the scope and limitations of their disciplinary approach honestly. Finally, *intellectual autonomy* involves being able to think for oneself, maintaining a wise dependence on the knowledge of others, along with the firmness to cope with various forms of pressure that may arise (Roberts & Wood, 2007). In the interdisciplinary dialogue, an intellectually autonomous researcher will confirm or rectify the ideas acquired through his disciplinary approach, being able to incorporate other complementary knowledge but without being influenced, if not convinced, simply because the opinions come from other disciplines.

The second domain that emerged from the study was the domain of *social virtues*. Friendship, kindness, collaborative spirit, a sense of humor, and communication skills were considered core virtues for the success of interdisciplinary research. These results reinforce the idea that interdisciplinary research requires social virtues that foster, enhance, and maintain interpersonal relationships among the members of a research team. Our findings are, moreover, in tune with the statements of (Fiore, 2008) and (Stokols et al., 2008), who argued that

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interdisciplinary research requires not only intellectual processes but also complex social processes as it is usually carried out in teams.

Our findings showed that the interviewees identified core elements for successful interdisciplinary research: a climate of friendship, kindness, and collaborative spirit that favors the exchange among group members. *Friendship* was described as a factor that consolidates the interactions in the team and sets the stage for fruitful interactions in the future. In addition, *kindness* and *collaborative spirit* were pointed out as traits that promote a comfortable work environment favorable for dialogue and discussion. Finally, a *sense of humor* and *communication skills* were mentioned as qualities that contribute to generating a positive attitude that helps to face the challenges of achieving a good interdisciplinary understanding. In summary, the social virtues included in this domain help create more relaxed and favorable collaborative work environments for decision-making and resolving complex research problems.

Finally, a third domain, *interpersonal intellectual virtues*, emerged in our study. The interviewees identified four relevant virtues as central categories of this domain: intellectual empathy, intellectual respect, interpersonal intellectual trust, and intellectual generosity. These virtues have so far received little attention among virtue epistemologists, perhaps because they have focused mainly on determining the criteria that justify the validity of the knowledge attained by the individual so that the interpersonal or social aspects of knowledge were only tangentially addressed. Social virtue epistemology is a new area of study that has only recently begun to be explored (Alfano et al., 2022).

As we mentioned before, the interpersonal intellectual virtues identified by the interviewees are at the intersection of intellectual virtues and social virtues. They are intellectual virtues because they pursue epistemic goods. But, unlike other intellectual virtues, they only develop in interpersonal settings, so they can also be considered social virtues. Therefore, we understand interpersonal intellectual virtues as character traits that facilitate the acquisition of knowledge (intellectual motivation) *with* and *through* other people in a reciprocal way (social environment).

In the interviews, *intellectual empathy* was described as the ability to understand *how*—or the way in which—the other person understands in order to be able to start thinking in the same way as a result of interpersonal interaction. In interdisciplinary research, intellectual empathy helps to understand disciplinary approaches other than one's discipline and to be able to follow them jointly with an expert in the new methodology. We argued philosophically, in a previous paper, why some of the notions that emerged during the interviews can be considered intellectual virtues in the context of virtue epistemology, with a special emphasis on the notion of intellectual empathy (Vanney & Aguinalde Sáenz, 2022b).

According to the interviewees, *intellectual respect* leads to a positive valuation of the other for their knowledge. Recognition of the complementary value of researchers' knowledge from other disciplines generates a climate of intellectual respect in an interdisciplinary team. In addition, *interpersonal intellectual trust* promotes a sincere exchange between researchers from different disciplines; and *intellectual generosity* is fundamental for researchers from different disciplines to teach each other their own conceptualizations and methodologies.

In conclusion, interdisciplinary researchers must cultivate intellectual virtues, which are necessary for all epistemic work (as it was mentioned by all the interviewees). They must

also cultivate social virtues, which are necessary for all teamwork. But in this study, we have also detected a specific subgroup of intellectual virtues, which we have called interpersonal intellectual virtues, that are essential for developing any successful collective epistemic enterprise. Interdisciplinary research is a privileged context where these qualities manifest themselves in a relevant way.

In this sense, the virtues most emphasized by the interviewees, for example, intellectual humility, open-mindedness, intellectual perseverance, and intellectual empathy, highlight in the first place the need for researchers to be aware not only of their own limitations, but also of the particular discipline in which they find themselves. The study of a phenomenon of such complexity as that of cognitive processes requires an approach that takes into account the specific contributions of very diverse areas, but which at the same time can be integrated by researchers within a joint understanding of this phenomenon and not only in a mere juxtaposition of epistemically different contents.

4.1. *Limitations and future studies*

The current article has limitations that open exciting perspectives for future studies. The two main ones are related to: (i) the methodology and sample size, and (ii) the characteristics of the sample where the study was conducted. The CQR methodology suggests a sample size of 8–15 participants (Hill, 2012).

In CQR, only some participants are included in the study to obtain more in-depth data. However, as occurs with every exploratory study, the drawback of including few participants (in our research, nine interviews) is that it limits the sample's representativeness and the generalization of results. Therefore, exploratory studies should be followed by other studies to obtain representative and generalizable results.

In addition, the fact that all interviewees were from Latin America may limit the perspective of the paper's findings, as the social and cultural characteristics of the interviewees' environment might have influenced the virtues identified as most important for interdisciplinary research.

In the last 15 years, the principal authors of this article have directed eight interdisciplinary research projects involving mainly physicists, biologists, psychologists, neuroscientists, philosophers, and theologians. A total of 433 researchers (312 Latin American) from 135 universities in 20 countries (9 Latin American) contributed to these investigations. From these experiences, we note that Latin Americans highly value warm interpersonal relationships among group members to ensure a supportive team climate. In this context, it is unsurprising that interpersonal intellectual virtues have emerged with greater emphasis in this research as a new domain. It would be very interesting to compare the results obtained here by interviewing researchers from successful interdisciplinary groups in other cultures, who may be used to working more individually.

Further investigations could examine whether the structure of the university facilitates or hinders the development of the intellectual virtues required for interdisciplinary research. Some studies have analyzed the diverse models of universities in Latin America (Bernasconi, 2008). In this study, the interviewees work in universities with different institutional models

of structure and organization: four of them in large public universities (created, funded, and governed by the state), four in private universities closer to the American model of research universities, and one in a Catholic university with a mixed public−private model. In addition, all the interviewees have also worked for several years in Europe or the United States, so it is not possible to relate the results of this study to the structure of the university where the researchers are working now.

It could also be interesting to analyze in future studies if the virtues identified as most important for interdisciplinary research depend on the disciplines involved. Indeed, it would be promising to consider the extent to which certain categories within each domain were more associated with one field or another. In this sense, preliminary results of research we are currently developing among Argentine university students show that students' intellectual character (psychometrically determined by six intellectual virtues) varies according to their careers. It would be reasonable to expect this difference to be even more pronounced among researchers from different disciplines, which could probably influence teamwork.

In summary, our study opens paths to new questions and identifies critical areas in studying the virtues necessary for interdisciplinary research.

Acknowledgments

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