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Interdisciplinarity: A complexity approach towards academic research

Adriana Zaiț[1] | **Constantin Bratianu**[2] | **Elena-Mădălina Vătămănescu**[3] | **Andreia Gabriela Andrei**[1] | **Ioana Alexandra Horodnic**[1]

[1]Faculty of Economics and Business Administration, University "Alexandru Ioan Cuza" of Iasi, Iasi, Romania

[2]UNESCO Department for Business Administration, Bucharest University of Economic Studies, Bucharest, Romania

[3]Faculty of Management, National University of Political Studies and Public Administration (SNSPA), Bucharest, Romania

Correspondence
Elena-Mădălina Vătămănescu, Faculty of Management, National University of Political Studies and Public Administration (SNSPA), Bucharest, Romania.
Email: madalina.vatamanescu@facultateademanagement.ro

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Abstract

Placing the issue of interdisciplinarity within a complexity framework, the current paper aims to explore different facets of interdisciplinary research (IDR). The theoretical and empirical analysis revolves around the main factors influencing IDR abilities and achievements, that is, the propelling context, attitude and further awareness of thinking and acting across boundaries in order to reach viable solutions to complex problems. On purpose to test the inferred relationships, the study relies on a questionnaire-based survey conducted with 214 early-career researchers from interdisciplinary departments or enrolled in interdisciplinary projects. The findings revealed that both attitude and context are important for rising researchers' awareness, in forming their abilities and reporting interdisciplinary achievements, the structural model explaining 51.9% in the variation of interdisciplinary research abilities and 17.1% in the variation of the researchers' interdisciplinary outcomes.

KEYWORDS

academic research, complexity, interdisciplinarity, interdisciplinary orientation

1 | INTRODUCTION

The recent COVID-19 pandemic that is fundamentally a health problem generated many crises as a result of the complexity of the real world and of the interdependence between human life, social, natural, economic, political, educational, cultural and religious phenomena. The difficulty of comprehending complexity comes from our limited capacity of constructing *mental models*, which are 'deeply ingrained assumptions, generalizations, or even pictures or images that influence how we understand the world and how we take action' (Senge, 1999: 8).

It is almost a paradox to see how the same phenomenon is perceived, understood and explained in different ways by different people coming from different educational backgrounds or different cultures. For instance, for the European culture, it is almost natural to consider that *future* is positioned in front of us, whereas the past is positioned *behind* us. However, in the Aymara culture that developed around Titicaca Lake, in the Andes, in Bolivia and Peru, the perception of time is different. According to the space metaphor (Lakoff & Johnson, 1999), the *future* is placed behind us, whereas the *past* is placed in front of us. Their logic is that we do not know the future, and thus, we cannot see it. Also, different interpretations come from the perception of time. In the *ego-moving metaphor*, time is stationary, as the space around us, and we are moving towards the future. In the *time moving* metaphor, we are stationary, and time is moving towards us (Boroditsky, 2000). For instance,

the COVID-19 crisis came over us in an unexpected way, creating a state of emergency that made all the deliberate business strategies firms developed before useless (Baldwin & di Mauro, 2020), challenging various actors to explore new intertwined approaches and solutions.

Mental models are a result of education in the family, community and schools, culture, and individual efforts of learning. Geography and historical contexts also play important roles. As Nisbett (2003: xiii) remarks, Chinese people 'pay attention to a wide range of events; they search for relationships between things, and they think you can't understand the part without understanding the whole. Westerners live in a simpler, more deterministic world; they focus on salient objects or people instead of the larger picture; and they think they can control events because they know the rules that govern the behavior of objects'. That could be a starting point in understanding how sciences have been created by decomposing the wholeness of phenomena and searching for some well-defined objects and their attributes. Scientists created, by their discoveries and knowledge accumulation, *paradigms* and scientific *disciplines* as cognitive spaces (Kuhn, 1970). A *discipline* is considered to be a cognitive space composed of a fundamental body of concepts, ideas and theories related to a certain dimension of reality, and 'a communal tradition of procedures and techniques for dealing with theoretical or practical problems' (Toulmin, 1972: 142).

Research itself proves to be broken down into small pieces (starting from domains and fields), and many findings of the research programmes cannot be generalized within a larger cognitive area. When complex problems are decomposed into many parts and linearized, the relations between these parts are superficially treated, and all the findings coming of disciplinary research is to be bounded by reductionist approaches (Bateson, 2002; Senge, 1999).

It may be deemed that the indisputable success of Newton's theories in physics contributed decisively to the propagation of linear thinking in education and society, and in promoting mechanical thinking models. The Newton's logic was a result of the deterministic thinking, for which the linear thinking is the simplest way of manifestation. Without entering the philosophical debates, 'determinism is typically spelled out as the statement that the state of the physical system at one moment of time, together with dynamical equations describing the evolution of the system, uniquely fixes the state of the physical system at any other moment of time' (Doboszewski, 2019: 1). When the dynamical equations are linear, the evolution of the system is easily understood and anticipated. Also, it is easily controlled. However, most of the phenomena and processes in real life do not fit these linear models. 'Hence the most reliable means of dissecting a situation into its constituent parts and reassembling them in the desired pattern is not a step-by-step methodology such as systems analysis. Rather, it is that ultimate nonlinear thinking tool, the human brain' (Ohmae, 1982: 13). This remark applies to all the research focusing on social sciences, strategic thinking, learning processes, knowledge dynamics and intellectual capital (Bandura, 1978; Bird, 2003; Bratianu, 2020; Bratianu & Bejinaru, 2020; Griffiths & Byrne, 1998; Senge, 1999).

Within the scope of the social sciences, problems are becoming increasingly complex due to the interdependence between phenomena and their unpredictability. These phenomena cannot be reduced to single disciplinary research domains and studied by using only their specific methods. 'They are emergent phenomena with nonlinear dynamics. Effects have positive and negative feedback to causes, uncertainties continue to arise, and unexpected results occur. 'Reality' is a nexus of interrelated phenomena that are not reducible to a single dimension' (Klein, 2004: 4). Moreover, because of the increased number of connections between causes and effects, events generate probabilistic effects rather than inevitable ones (Bandura, 1978). There is a translation from deterministic thinking towards probabilistic thinking and from linear theories towards nonlinear ones (Bratianu, 2015). Knowledge accumulation is replaced now by knowledge dynamics based on collaboration and knowledge field transformations.

For such problems, researchers should switch to interdisciplinary research as an approach to complexity (Bird, 2003; Gleick, 2008; Jackson, 2019). Complexity is a generic term for a variety of methods designed to study phenomena that display nonlinear dynamics, chaotic development and far from equilibrium states like pandemics with all the social, economic, political, educational and cultural associated crises (Baldwin & di Mauro, 2020). The theories of chaos and complexity 'suggest that much of the world is not linear and small changes can produce dramatic transformations of an entire system' (Griffiths & Byrne, 1998: 1697). Managing complexity requires new insights in these complex phenomena and new approaches that can be achieved only through collaborative work of researchers coming from different academic fields, and by using shared mental models based on nonlinearity, probabilistic thinking, fractal behaviour and complex responsive processes (Stacey, 2001; Stacey et al., 2000).

Conflating these main perspectives, the current endeavour sets out to disentangle the issue of interdisciplinarity in research under the aegis of complexity, hence availing a novel insight into the studied phenomena.

More specifically, the study aims to investigate the dynamic process of interdisciplinary orientation—regardless of the research field—and to provide a theoretical and a measurement model that enables the research institutions to estimate their researchers' potential of pursuing interdisciplinary projects and achieving results. In order to properly address the inherent issues, several pivotal dimensions are analysed, all of them revolving around the interdisciplinary orientation—a key aspect within the framework of interdisciplinary research (Misra et al., 2015; Rhoten, 2003).

In this light, the paper is organized in different thematic sections as follows: firstly, the conceptual framework is briefly depicted in order to provide an articulate outlook on the meaning of interdisciplinarity in relation to other similar concepts; secondly, the theoretical directions supporting the advanced research model are brought to the fore; thirdly, the material and methods are described followed by the presentation of the findings. The last section summarizes the main conclusions and implications of the study and proposes a future research agenda.

2 | CONCEPTUAL FRAMEWORK: PAVING THE WAY TOWARDS INTERDISCIPLINARITY

Real-life examples have instilled that universities have been created as learning environments for specific scientific disciplines. As a result, their structure even today is composed of departments, schools or faculties defined according to their core discipline. Even within specialized universities, there is a series of different departments. These administrative units reflect different disciplines, and the faculty staff is focused in its teaching and research on topics belonging to these disciplines.

Historical separations of academic disciplines started to erode from the second part of the past century due to new emergent phenomena, which questioned the traditional boundary spanning. Also, 'the inner development of the sciences has posed ever broader tasks leading to interconnections among natural, social, and technical science' (Klein, 2004: 3). The first stage in broadening the area of research by crossing the borders of a well-defined academic discipline leads to *cross-disciplinary* research. In this case, the researcher centres his focus on a traditional discipline but is looking to enrich his investigation by searching for knowledge beyond its borders. The cross-disciplinary research may have a variety of forms and approaches. Due to its fuzziness, the concept of cross-disciplinary research remains a generic term 'involving different areas of knowledge or study' (Oxford Advanced Learner's Dictionary).

An advanced stage in solving complex problems is *multidisciplinarity*. The *multidisciplinary research* is described as 'the coordinated efforts of some set of disciplines designed to achieve some common goal or goals. Here, the contributions from different disciplines are said to be complementary rather than integrative' (Fiore, 2008: 254). In practice, multidisciplinarity results whenever a complex project requires a team of researchers coming from different areas of research, and they may use different methods and knowledge bases to get a larger picture of the phenomenon, without trying to integrate through a transformative process all that knowledge and theories coming from different traditional disciplines. Hence, multidisciplinary research leads to an aggregation of data, information, knowledge, theories and methods, but with very little integration between them. We may say that multidisciplinary research is dominated by a linear logic (Bratianu & Vasilache, 2010), without a significant effect of knowledge synergy.

Interdisciplinary research represents a new approach to solving complex problems because researchers *integrate* knowledge and methods coming from different traditional academic disciplines and create new patterns of study. Thus, the defining characteristic of *interdisciplinarity* is the process of *integration*, not *summation*. Although summation is based on linearity, integration and knowledge building through collaborative work (Bratianu et al., 2011) are based on nonlinearity (Bratianu, 2015). From this perspective, interdisciplinarity is defined as 'interaction among disciplines that may range from simple communication of ideas to mutual integration of organizing concepts, methodology, procedures, epistemology, terminology, data, and the organization of research and education' (Klein, 2013: 190). In a previous tentative definition of interdisciplinarity with respect to university undergraduate studies, Klein and Newell (1997: 395) considered it 'a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession'. Similar definitions can also be found in Huutoniemi et al. (2010), Ejdys et al. (2015), and Fitzgerald and Callard (2015).

The prefix 'inter' suggests the interaction between the fields of knowledge situated in two or more disciplinary fields, bridging this way the cognitive space between them. The synergy produced by interdisciplinary research cannot be situated only in one field or domain of research, a situation that creates many problems in trying to measure the contribution of researchers to their homeland of research. Today, in many universities, there is a strong tendency to measuring the scientific production of researchers and reporting it as belonging to the departments where these scientists work. Thus, the academic

regulations for evaluating the research activity, which is based on the traditional disciplinary research, constitute a heavy barrier in stimulating interdisciplinarity (Bauer, 1990; Porter et al., 2007).

Advanced interdisciplinary research is considered by some authors as being transdisciplinary. *Transdisciplinarity* is defined as 'a common system of axioms that transcends the narrow scope of individual disciplines through an overarching synthesis, such as anthropology constructed as a science of humans' (Klein, 2013: 190). However, there is no clear border between interdisciplinary and transdisciplinary research. Interdisciplinary research looks more like a convergent process, whereas transdisciplinary research is more like a divergent one (Klein, 2006; Weingart & Stehr, 2000).

Nevertheless, the process of integration is not well-defined, and it cannot be actually measured with the tools used for disciplinary research. This is why the existent literature on interdisciplinarity is not so much focused on strict conceptual delimitations—that is, distinguishing related concepts such as multidisciplinarity and transdisciplinarity (Augsburg, 2009; Hvidtfeldt, 2016; Klein, 1990; Klein & Newell, 1998; Lattuca et al., 2012; Müller, 2011)—but rather concentrated on a broader approach pursuant to Borrego and Newswander (2010). The authors posit that 'interdisciplinarity refers collectively to activities that may, strictly speaking, be multidisciplinary, interdisciplinary, or transdisciplinary teamwork, collaboration, integration, interdisciplinary communication, critical awareness.' (Borrego & Newswander, 2010: 63).

Given the intended exploratory nature of the current study, the operationalization of interdisciplinarity is in line with the wider perspective proposed by Borrego and Newswander (2010) in order to mainstream various facets of collaboration and teamwork towards resounding academic achievements. Such an approach is meant to allow a more comprehensive outlook on the scrutinized phenomena, paving the way for more specific future explorations.

3 | THEORETICAL MODEL DEVELOPMENT

Interdisciplinary research requires *teams* of researchers coming from those fields of knowledge they aim to integrate and generate a new one. Sometimes, a single researcher who has got university education in two or several fields of science (i.e. physics and economics, biology and engineering) can transfer knowledge from one field to another, but mostly, there is a need of teams of researchers capable of working together and sharing their knowledge. 'Working in teams increases the likelihood that scientists can integrate multiple and divergent perspectives and, as a result, develop new insights and solutions' (Falk-Krzesinski et al., 2011: 145). From a practical point of view, a team can be effective if its researchers share the same mental models and set of ethical values (Briskin et al., 2009; Katzenbach & Smith, 2003; Vătămănescu et al., 2015; Vătămănescu et al., 2016; Vătămănescu et al., 2018). The integration process between the knowledge fields should be extended to the working team. 'What sets apart high-performance teams, however, is the degree of commitment, particularly how deeply committed the members are to one another. Such commitments go well beyond civility and teamwork. Each genuinely helps others to achieve both personal and professional goals' (Katzenbach & Smith, 2003: 65).

Despite the rather large number of definitions and interpretations of interdisciplinarity, specific measurement tools of interdisciplinary orientation—a paramount dimension within the research interdisciplinarity framework (Stokols, 2013)—are rather scarce. There are very few scales available and they either focus on fragmentary facets of interdisciplinarity (such as research collaboration and productivity) or on specific disciplines, like engineering or medicine (Garner et al., 2018; Kirby et al., 2019; Lattuca et al., 2012; Misra et al., 2015; Stokols et al., 2005). As Kirby et al. (2019: 2) noticed, 'the largest disciplinary divide among scientists is that between the natural sciences (examining biological, physical, and chemical processes) and the social sciences (examining human dimensions of the world). In discussing the differences between social and natural science, it is important to note that both professions consist of a wide range of disciplines, each with their own methodology, jargon, and culture'. Consequently, two major challenges are meant to derive from the state-of-the-art, that is, developing the scales for measuring the main dimensions of interdisciplinary orientation as identified in previous literature and applicable independent of the research field (hard or soft sciences), on the one hand, and capturing the dynamics of the interdisciplinary research (IDR) orientation process, on the other hand.

Aiming to explore the dynamics and complexity of the process itself, and the factors which influence researchers' achievements and abilities, the researchers' attitudes and the context in which the researcher works are invested with pivotal roles (Hall et al., 2008; Kirby et al., 2019; Lattuca et al., 2012; Mâsse et al., 2008). Researchers' attitudes towards complex issues and the extent to which they value and enjoy reading topics beyond their own discipline have a direct influence on the awareness towards the specific methods, tools and limits of different disciplines and also on their abilities

and self-reported achievements. This process has been heavily investigated in previous literature, and there is evidence that the so called 'mere exposure' improves the attitude towards a specific issue (Kirby et al., 2019). Previous studies show that interdisciplinary exposure and learning (e.g. reading journals and books from other discipline) improve motivation towards interdisciplinarity (Lattuca et al., 2004; Misra et al., 2015) and that there is a positive correlation between participation to an interdisciplinary course and self-reporting improved abilities such as critical thinking and knowledge (Astin, 1993; Gero, 2017). Also, a meaningful relationship has been identified between the capacity of viewing complex research problems from various perspectives and the orientation towards interdisciplinarity (Misra et al., 2015; Pohl & Hadorn, 2008). By corroborating these arguments, we thus infer that

H1. An open **attitude** towards topics outside the researcher's own discipline has a positive influence on the researcher's **awareness** in terms of knowledge, methods, and limitations from other disciplines (IDR_attitude → IDR_awareness).

H2. An open **attitude** towards topics outside the researcher's own discipline has a positive influence on the researcher's **abilities** in terms of connecting and integrating knowledge from various disciplines (IDR_attitude → IDR_abilities).

H3. An open **attitude** towards topics outside the researcher's own discipline has a positive influence on researcher's **achievement** in terms of participation in mixed teams and publishing in interdisciplinary journals and/or journal outside researcher's own discipline (IDR_attitude → IDR_achievement).

Turning to the context in which the researcher works, in terms of whether the interaction between researchers from various disciplines is nurtured, either by the institution they work for or by the researchers themselves, previous studies reveal a direct relationship between interacting with peers from different disciplines and how knowledgeable a certain researcher is regarding the methods, tools and limitations of other disciplines and consequently, their abilities and their achievements in interdisciplinary issues. Thus, besides the researchers' attitude towards interdisciplinarity, their participation in meetings and conferences outside their own discipline as well as integrating ideas and methods from other disciplines reflect researchers' interdisciplinary orientation (Misra et al., 2015; Rhoten, 2003) and, consequently, their abilities and publishing choices. Nevertheless, this can be fostered by the institution by exposing the researcher to meetings and events gathering participants from different disciplines. In this respect, a study of US interdisciplinary centres concluded that 'a transformation toward interdisciplinary research has in fact begun in the centers as well as due to the centers we examined' (Rhoten, 2003: 4). Furthermore, 83% of the researchers at these centres included in the study declared that their work within the centre positively influenced their own research agenda, including the work outside the centre, underlining how interactions with researchers from other disciplines influence the researchers` trajectories and academic development (Rhoten, 2003). Similarly, other studies suggest that researchers' interdisciplinary orientation can be fostered by the institution by creating a favourable context for interaction between researchers from various disciplines (i.e. seminars, workshops and meetings) (Bruun et al., 2005). Based on these theoretical insights, we presume the following relationships:

H4. Researcher's **context** has a positive influence on the researcher's **awareness** in terms of knowledge, methods, and limitations from other disciplines (IDR_context → IDR_awareness).

H5. Researcher's **context** has a positive influence on the researcher's **abilities** in terms of connecting and integrating knowledge from various disciplines (IDR_context → IDR_abilities).

H6. Researcher's **context** has a positive influence on the researcher's **achievement** in terms of participation in mixed teams and publishing in interdisciplinary journals and/or journal outside researcher's own discipline (IDR_context → IDR_achievement).

Finally, as briefly described above, not only the researcher's attitude and context influence how aware a researcher is of the tools, methods and limitation of other disciplines (Gero, 2017; Misra et al., 2015) but also the awareness itself has a direct influence on researcher abilities and achievements (Astin, 1993; Gero, 2017; Rhoten, 2003). Once a researcher is better aware of other disciplines' methods and tools, the ability to integrate this knowledge is improved, and it is more likely to conduct and publish interdisciplinary research. These perspectives are consequently conducive to the hypotheses below:

H7. Researcher's **awareness** has a positive influence on the researcher's **abilities** in terms of connecting and integrating knowledge from various disciplines (IDR_awareness → IDR_abilities).

H8. Researcher's **awareness** has a positive influence on the researcher's **achievement** in terms of participation in mixed teams and publishing in interdisciplinary journals and/or journal outside researcher's own discipline (IDR_awareness → IDR_achievement).

By corroborating the aforementioned relationships, the following conceptual model was developed (Figure 1).

4 | MATERIAL AND METHODS

4.1 | Sample and data collection

The targeted sample included early-career researchers from interdisciplinary departments or enrolled in interdisciplinary projects (i.e. doctoral or postdoctoral levels) coordinated by Romanian universities aimed at fostering collaboration among disciplines and an interdisciplinary orientation. Data collection was conducted during March–April 2020, via an on-line survey and based on a non-probability sampling technique, namely, self-section sampling. The sample comprised 214 early-career researchers (26–40 years old; 2–10 years of research experience), from 11 disciplines, belonging to all three main research domains, namely, physical sciences and engineering, life-sciences and social sciences and humanities. Participants were affiliated to one of the top seven universities located in the Romanian academic centres, Bucharest, Cluj and Iasi.

4.2 | Measures and constructs

The proposed model includes five constructs—namely, the IDR context, IDR awareness, IDR attitude, IDR abilities and IDR achievement. The items used for measuring these constructs are detailed in Table 1. Because the focus was on capturing the dynamic process of the interdisciplinary orientation, the dependent variables of the model were defined and labelled as achievement and abilities and not as results and competencies. Abilities, here, are the perceived skills, which later on in the process will transform into competencies (as quality or level of the skills, similar to the European Competencies Framework; in this light, the competence is the demonstrated ability to apply knowledge, skills and attitudes to achieve observable results). Achievement is operationalized as the act of obtaining a result, so the variable referring to self-assessment on previous activities of researchers was measured.

The survey aimed to estimate the influence of the context and researchers' attitude towards interdisciplinary research (IDR) on their acquired level of IDR awareness, IDR abilities and IDR achievement.

The participants to the study were invited to rate on a 5-point scale the items included in the online questionnaire to measure each of these five dimensions of interest (see Table 1). The collected data were evaluated according to the partial least squares structural equation modelling (PLS-SEM) methodology considering the research model (Figure 1) developed via the eight hypotheses detailed above.

5 | DATA ANALYSIS AND RESULTS

The conceptual model was examined according to the PLS-SEM methodology, running the tests for assessing the adequacy of the measurement model, followed by the analysis of relationships included in the structural model.

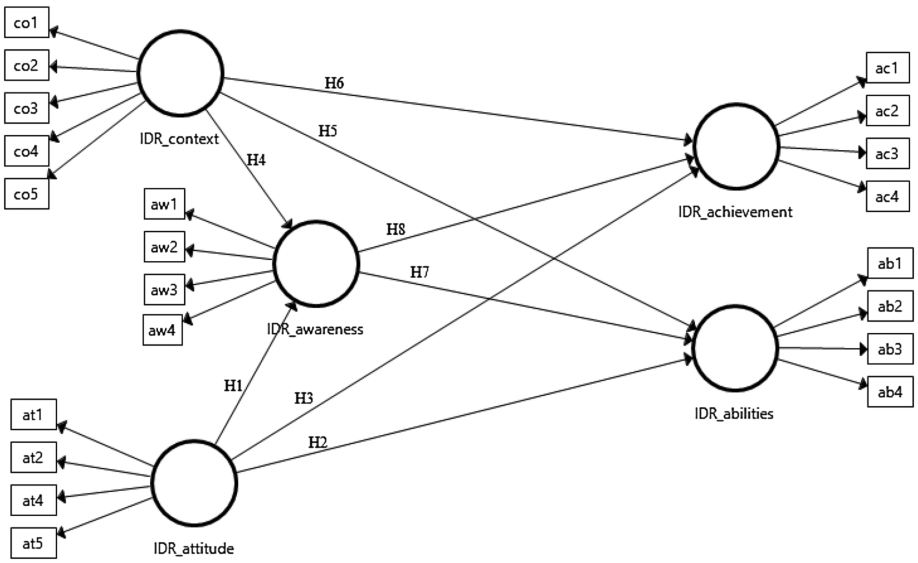

FIGURE 1 Conceptual model

TABLE 1 Constructs and items

Constructs	Items	Support literature
IDR_context Reflective construct Five items	co1. Attending meetings/conferences outside of researcher's primary field co2. Participating in groups/committees meant to integrate different ideas co3. Getting insights into own work from colleagues with different disciplinary orientations co4. Modifying research agenda based on the inputs of colleagues from other fields co5. Linking with colleagues from different fields for collaborative work	(Hall et al., 2008; Mâsse et al., 2008; Misra et al., 2015)
IDR_attitude Reflective construct Four items	at1. I value reading about topics outside of my primary field at2. I enjoy thinking about how different fields approach the same problem in different ways at3. Not all problems in my field of research can be solved by people from my own field at4. In solving research problems in my field of research it is often useful to seek information from experts in other academic fields	(Kirby et al., 2019; Lattuca et al., 2012)
IDR_awareness Reflective construct Four items	aw1. If asked, I could identify the kinds of knowledge, research methods and ideas that are distinctive to different fields of science/research aw2. I recognize the kinds of evidence that different sciences or fields of study rely on aw3. I'm good at figuring out what experts in different fields have missed in explaining a problem or a solution aw4. If necessary, I could use new methods adopted from other disciplines, which are different from the ones I am familiar with from my primary field	(Lattuca et al., 2012)
IDR_abilities Reflective construct Four items	ab1. When I'm given knowledge and ideas from different fields than mine, I can figure out the appropriate way for solving a problem in those fields ab2. I see connections between ideas in my field and ideas in quite different fields. ab3. I can take ideas from outside my field and synthesize them in a way easy to be understood by others ab4. I can use what I have learned in my field in another setting/different field.	(Lattuca et al., 2012)
IDR_achievement Reflective construct Four items	ac1. I published in journals dedicated to another discipline than my primary field ac2. I published in journals labeled under 'interdisciplinary studies' category ac3. The research projects I work on at the moment would be easy to understand and evaluate by researchers/specialists outside my field. ac4. The research projects I work on at the moment would be easy to understand by the decision-makers	Items proposed by authors

5.1 | Measurement model evaluation

The results indicate that the measurement model fulfils the PLS-SEM requirements of reliability and validity, discriminant validity and non-collinearity (Hair et al., 2017; Henseler, 2017). Reliability and validity compliance is indicated by the statistics displayed in Table 2, showing that each construct's values of Cronbach's α and rho_A are higher than 0.7 threshold, composite reliability > 0.8 and the average variance extracted > 0.5 indicating that each construct explains more than half of the variance of its items, as required by Hair et al. (2014).

The discriminant validity is satisfied according to both Fornell and Larcker's (1981) criterion and Henseler et al.'s (2016) HTMT 0.85 constraints. The statistics outlined in Table 3 show that heterotrait–monotrait ratio of correlations HTMT < 0.85 confirms that the constructs are clearly distinct, and each construct reflects its own dimension sharing more variance with its own items than with those of the other construct (Fornell & Larcker, 1981; Hair et al., 2017). The

TABLE 2 Construct reliability and validity

Constructs	Cronbach's α	rho_A	CR	AVE
IDR_context	0.763	0.777	0.837	0.507
IDR_attitude	0.732	0.753	0.831	0.552
IDR_awareness	0.759	0.759	0.845	0.577
IDR_achievement	0.712	0.734	0.821	0.536
IDR_abilities	0.745	0.746	0.839	0.566

TABLE 3 Discriminant validity

	IDR_abilities	IDR_attitude	IDR_achievement	IDR_awareness	IDR_context
Fornell–Larcker criterion					
IDR_abilities	**0.753**				
IDR_attitude	0.630	**0.743**			
IDR_achievement	0.314	0.292	**0.732**		
IDR_awareness	0.557	0.446	0.289	**0.760**	
IDR_context	0.363	0.263	0.323	0.236	**0.712**
HTMT criterion					
IDR_abilities					
IDR_attitude	0.824				
IDR_achievement	0.424	0.394			
IDR_awareness	0.731	0.558	0.368		
IDR_context	0.448	0.327	0.431	0.282	

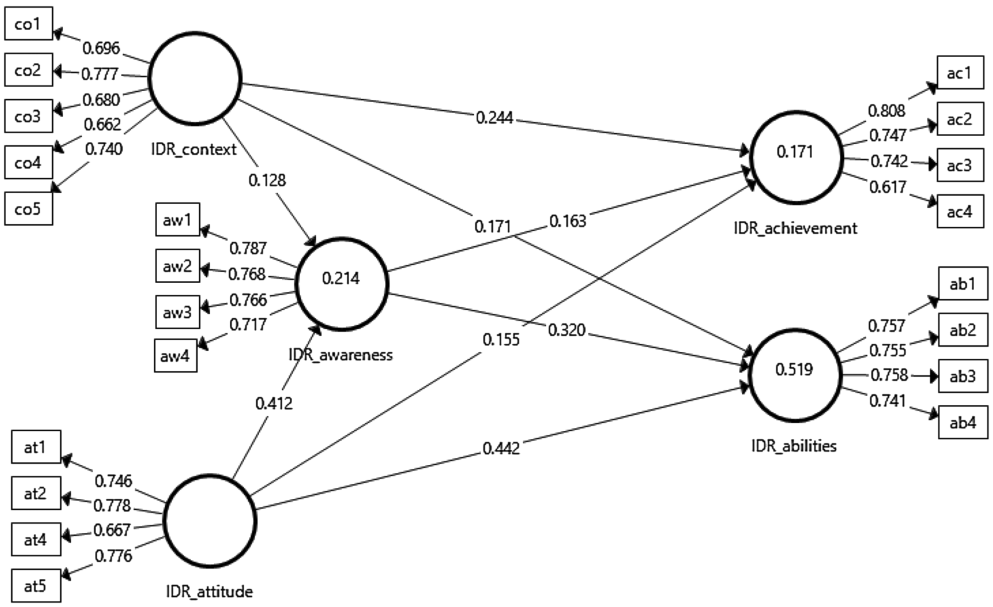

FIGURE 2 Structural model

non-collinearity among constructs (inner variance inflation factor [VIF] values between 1.074–1.291) or items (outer VIF values between 1.241–1.851) was assessed by the values of VIF situated below 3.3 limit which indicates the absence of collinearity (Diamantopoulos & Siguaw, 2006).

5.2 | Structural model evaluation

The structural model (Figure 2) evaluation conducted via a bootstrapping procedure with 5000 re-samples (Hair et al., 2017; Henseler, 2017) allowed a detailed analysis of the direct and indirect relationships between the five constructs considered: IDR_context, IDR_attitude, IDR_awareness, IDR_abilities, IDR_achievement. Here, the results (Table 4) indicate that the research model (Figure 2) explains 51.9% in the formation of interdisciplinary research abilities—*IDR_abilities* ($R^2 = 0.519$) and 17.1% of researcher's interdisciplinary outcomes—*IDR_achievement* ($R^2 = 0.171$). Also, a positive attitude towards interdisciplinary research (IDR_attitude) and a favourable context (IDR_context) explain 21.4% of the researcher's acquaintance about this type of research—*IDR_awareness* ($R^2 = 0.214$).

As hypothesized, the results of the structural model assessment (see Table 5 and Figure 2) show the direct positive influences exerted on *IDR_awareness* by *IDR_attitude* ($\beta = 0.412$, statistically significant at $p < 0.01$, out of zero CI; H1 confirms) and *IDR context* ($\beta = 0.128$, statistically significant at $p < 0.05$, out of zero CI H4 confirms).

TABLE 4 R^2

Construct	R^2	R^2 adjusted
IDR_abilities	0.519	0.512
IDR_achievement	0.171	0.159
IDR_awareness	0.214	0.207

TABLE 5 Effects

Relationship	Effect type	Coefficient	Mean	SD	*t* statistic	*p* value	CI 2.5%	CI 97.5%	Hypothesis
IDR_attitude → IDR_awareness	Direct	0.412	0.414	0.061	6.730	0.000	0.293	0.529	H1 confirms
IDR_attitude → IDR_abilities	Direct	0.442	0.443	0.053	8.290	0.000	0.334	0.542	H2 confirms
IDR_attitude → IDR_achievement	Direct	0.155	0.156	0.077	2.004	0.045	0.002	0.303	H3 confirms
IDR_context → IDR_awareness	Direct	0.128	0.135	0.064	1.996	0.046	0.010	0.259	H4 confirms
IDR_context → IDR_abilities	Direct	0.171	0.173	0.045	3.785	0.000	0.083	0.261	H5 confirms
IDR_context → IDR_achievement	Direct	0.244	0.253	0.067	3.609	0.000	0.117	0.379	H6 confirms
IDR_awareness → IDR_abilities	Direct	0.320	0.321	0.054	5.902	0.000	0.216	0.429	H7 confirms
IDR_awareness → IDR_achievement	Direct	0.163	0.163	0.080	2.044	0.041	0.000	0.310	H8 confirms
IDR_attitude → IDR_awareness → IDR_abilities	Indirect	0.132	0.133	0.030	4.465	0.000	0.080	0.197	Significant indirect effect
IDR_attitude → IDR_awareness → IDR_achievement	Indirect	0.067	0.066	0.033	2.016	0.044	0.000	0.132	Significant indirect effect
IDR_context → IDR_awareness → IDR_abilities	Indirect	0.041	0.043	0.022	1.874	0.061	−0.002	0.083	Non-significant indirect effect
IDR_context → IDR_awareness → IDR_achievement	Indirect	0.021	0.022	0.016	1.307	0.191	−0.001	0.062	Non-significant indirect effect

In what concerns the development of participants' abilities of pursuing interdisciplinary research – *IDR_abilities*, the results indicate the positive direct influence of all the three factors: *IDR_attitude* ($\beta = 0.442$, statistically significant at $p < 0.01$, out of zero CI; H2 confirms), *IDR_context* ($\beta = 0.171$, statistically significant at $p < 0.01$, out of zero CI; H5 confirms) and *IDR_awareness* ($\beta = 0.320$, statistically significant at $p < 0.01$, out of zero CI; H7 confirms), but also an indirect positive influence of attitude via awareness (indirect effect IDR_attitude → IDR_awareness → IDR_abilities: $\beta = 0.132$, statistically significant at $p < 0.01$, out of zero CI).

Similarly, positive direct influences are exerted on researcher's interdisciplinary accomplishments – *IDR_achievement* by all the three factors *IDR_attitude* ($\beta = 0.155$, statistically significant at $p < 0.05$, out of zero CI; H3 confirms), *IDR_context* ($\beta = 0.244$, statistically significant at $p < 0.01$, out of zero CI; H6 confirms) *and IDR_awareness* ($\beta = 0.163$, statistically significant at $p < 0.05$, out of zero CI; H8 confirms). Additionally, the results indicate a meaningful influence of *IDR_attitude* on *IDR_achievement* via the *IDR_awareness* mediation (indirect effect IDR_attitude → IDR_awareness → IDR_*achievement*: $\beta = 0.067$, statistically significant at $p < 0.05$, out of zero CI).

To sum up, the values and statistical significance of relationship coefficients support all research assumptions (H1 to H8), indicating the cumulative influence of the two exogenous variables included in the model (IDR_attitude and IDR_context) on each of the three endogenous variables, namely IDR_awareness, IDR_abilities and IDR_achievement.

6 | DISCUSSION AND CONCLUSIONS

From a bird's eye view, the findings revealed that both attitude and context are important for rising researchers' awareness, in forming their abilities and reporting interdisciplinary achievements, reinforcing the evidence brought forward by the previous studies (e.g. Gero, 2017; Misra et al., 2015). However, the findings point out the importance of favourable circumstances for attaining interdisciplinary-oriented outcomes. In this regard, it should be underlined that the highest influence on interdisciplinary research achievements is exerted by the propelling context, a fact which supports the importance of introducing interdisciplinary departments, and the stimulation of interdisciplinary research projects. This situation is in line with previous studies which underscored how interdisciplinary orientation and results were initiated and nurtured by the hosting institutions (Bruun et al., 2005; Rhoten, 2003).

In another vein, the results emphasize the powerful contribution of the interdisciplinary research attitude to the development of the researchers' abilities (the highest direct effect $\beta = 0.442$ in the model strengthen by the indirect effect via IDR_awareness $\beta = 0.132$). The meaningful influence concludes the relevance of an open attitude towards other disciplines for developing interdisciplinary abilities as also posited by previous research (Gero, 2017; Kirby et al., 2019).

All these theoretical and empirical evidence have practical implications for the academic environment and research. In order to catalyse the interdisciplinary collaboration and teamwork, and consequently provide integrative solutions to complex problems, decision-makers should create propelling contexts for the interaction of scholars from different domains and fields and institutionally foster an agora for knowledge sharing. As facilitators of a collaborative framework for various disciplines, the formal organizational support alongside the individuals' attitudes towards interdisciplinarity favour a higher degree of awareness (in terms of literacy and acumen) which, in its own right, is conducive to better research abilities and achievements. Given the fact that a major criterion for ranking universities resides in the quality of the reported research achievements, the imperative is to start rethinking across boundaries and reconfiguring how research is performed within specialized centres and universities and to pave the way towards a more complex and scientifically-integrative approach liable to stimulate the interdisciplinary orientation and subsequently systemic innovation. Results are also in line with complexity theories applied in various fields. The complexity science is 'at home' in interdisciplinarity, which involves dynamic and multi-dimensional problems, with interconnected relationships and parts (as defined by Benham-Hutchins & Clancy, 2010)—an imperative approach for academic research in challenged times.

Due to its exploratory nature, the current study opens up new research avenues, yet admitting some limitations to be considered by future investigations. Firstly, a broader perspective on interdisciplinarity was operationalized pursuant to Borrego and Newswander (2010). In this respect, future studies should better delineate among related constructs such as interdisciplinarity, multidisciplinarity, crossdisciplinarity and transdisciplinarity. Secondly, the sample was composed of young researchers coming from a single country. Here, the context-driven approach should be surpassed in further undertakings by extending the socio-demographic characteristics of the sample and by availing cross-

national comparisons. Thirdly and finally, the analysis relies on cross-sectional data. Future studies using longitudinal data would enable capturing a larger number of issues related to the dynamic process of interdisciplinary orientation, including career paths and critical factors leading to interdisciplinarity.

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