Developing interdisciplinary consciousness for sustainability: using playful frame reflection to challenge disciplinary bias

Annemarie Horn (✉), Marjoleine G. van der Meij (✉), Willemine L. Willems (✉), Frank Kupper (✉) and Marjolein B. M. Zweekhorst (✉)

Athena Institute, VU Amsterdam, Amsterdam, Netherlands

ABSTRACT
A major challenge for interdisciplinary teamwork on complex sustainability issues is the often-conflicting disciplinary perspectives and underlying values and assumptions among collaborators. Interdisciplinary collaboration among researchers and practitioners therefore requires interdisciplinary consciousness (IC): epistemological and metaphysical understanding and appreciation of one’s own and others’ disciplinary views and their differences. Since it cannot be assumed that professionals have IC, there is a need for explicit training, for instance in higher education. We developed Frame Reflection Lab (FRL)—a playful intervention to stimulate the development of IC through frame reflection—and investigated its application across disciplinary student teams collaborating on sustainability issues. We aimed to understand how frame reflection can contribute to enhancing IC, by analyzing the written and oral reflections of 23 Master’s degree students. We found that the FRL intervention contributed to the development of IC as it sparked cognitive, affective, and critical reflection; created a safe space for reflection; helped participants to articulate values and assumptions; and balanced structure and freedom. Our findings demonstrate that to prepare sustainability professionals for interdisciplinary collaboration, deeply rooted and possibly unconscious preconceptions have to be challenged to build awareness and appreciation of disciplinary differences. This calls for explicitly facilitating affective processes, for instance using playfulness, whereas training in reflection and interdisciplinarity usually focuses on cognitive processes. These findings are promising in terms of informing and inspiring future efforts to use playful frame reflection in education, research, and practice to support interdisciplinary collaboration to address complex sustainability issues.

Introduction
It is widely acknowledged that the complex sustainability issues societies currently face require interdisciplinary approaches (Rylance 2015; O’Rourke, Crowley, and Gonnerman 2016). Challenges such as the climate crisis, economic inequality, and resource scarcity emerge from the interplay of many diverse and multifaceted interactions and transcend disciplinary boundaries (IPCC 2022). Research and practice addressing such issues require broader expertise than any single academic perspective can provide and demand collaboration among experts from different fields to jointly frame and address them (Lundershausen 2018; Ryser, Halseth, and Thien 2009; You 2017). This joint action depends on integrating different perspectives and knowledge bases, such that they are related to each other in order to understand the given issue more comprehensively (Klein 2017; Pohl et al. 2021). This joint framing through integration distinguishes interdisciplinary approaches from other cross-disciplinary approaches such as multidisciplinarity (Klein 2017). It is important to stress that this does not necessarily mean reaching consensus or arriving at a single conceptualization that fuses different knowledge bases, but rather collectively making sense of the subject by relating previously unrelated elements (Pohl et al. 2021).

Although necessary to address complex problems, diversity of knowledge and perspectives also poses one of the main challenges to collaboration and integration across disciplines (Crowley and O’Rourke 2020). Collaboration among professionals trained in different disciplines demands communicating and relating insights across different technical jargon, methods, and theoretical underpinnings (Morse et al. 2007; Regeer and Bunders 2009). These differences in practice are symptomatic of the variety of often conflicting and underlying views of science to which researchers from different fields subscribe (Eigenbrode et al. 2007; Grin and van der Meij 2017; Pohl et al. 2021).
Different research methods and practices are rooted in different value systems and they are built on (implicit) assumptions of what comprises good scientific knowledge (Knorr-Cetina 1999; Lélé and Norgaard 2005). These values and assumptions shape how researchers frame the pursuit of knowledge (epistemology) and how they represent the inherent nature of the world in their investigation (metaphysics) (Eigenbrode et al. 2007). Moreover, collaborators with different disciplinary backgrounds are enculturated in their respective fields, may have preconceptions about other fields, and experience a hierarchy in which some disciplines are considered to generate more valid knowledge than others (Harris, Lyon, and Clarke 2009; Maglaughlin and Sonnenwald 2005).

Cross-disciplinary teamwork thus inevitably confronts collaborators with widely diverse views of science. If these differences are not acknowledged, this may lead to a focus on similarities rather than differences, which prevents capitalizing on the rich range of perspectives represented in the team (Mansilla 2005). Alternatively, differences that are experienced (or assumed) but remain unresolved may cause disagreements and tensions (Klein 2017; Maglaughlin and Sonnenwald 2005; Strober 2006).

Both of these dynamics—conflict and neglecting difference—are reported among collaborators in cross-disciplinary teams (Mansilla 2005; Strober 2006) and both hamper realization of the potential of diverse perspectives to address sustainability issues through interdisciplinary approaches (Souto 2015). In response to these numerous challenges, cross-disciplinary collaboration requires myriad competencies (Horn, Urias, and Zwekkehorst 2022; Parker 2010).

One of these competencies is that in interdisciplinary collaboration it is essential that collaborators are aware of and appreciate disciplinary differences and thought styles to be able to navigate these differences and pursue integration—based on acknowledging and using the diversity of knowledge and perspectives without glossing over the differences (Horn, Urias, and Zwekkehorst 2022; Pohl et al. 2021; Souto 2015). This, in turn, demands making explicit the underlying implicit mindsets, value systems, beliefs, and assumptions (Gosselin et al. 2020).

Kjellberg, O’Rourke, and O’Connor-Gómez (2018) captured this challenge as the need for interdisciplinary collaborators to develop interdisciplinary consciousness (IC), which they describe as follows: “IC is a kind of know-how exhibited by individuals involved in a group process who can actively empathize with different disciplinary perspectives. This consciousness entails the ability to recognize differences and similarities among disciplinary perspectives, including one’s own” (Kjellberg, O’Rourke, and O’Connor-Gómez 2018, 49).

The interdisciplinary consciousness that Kjellberg, O’Rourke, and O’Connor-Gómez (2018) consider necessary for interdisciplinary collaboration can be further developed and enriched with the notion of reflective practice coined by Schön (1983). He argues that well-trained and experienced professionals, be they teachers, architects, or researchers, working in interdisciplinary teams, possess the competency of reflection-in-action: the ability to switch between diverse frames in order to solve the unique problems that arise in their work practice. These frames are structures of belief, perception, and appreciation that underlie one’s positions (Schön 1983). In later work (Grin and van der Graaf 1996; Schön and Rein 1994) this competency is further developed as frame reflection, which is the ability to reflect on one’s own and others’ perspectives in terms of practices (first-order notions) and the underlying values and assumptions (second-order notions) to understand one’s own and others’ positions and engage in perspective-taking. The structures of belief, perception, and appreciation that underlie one’s view of science can thus be considered scientific frames, and frame reflection may contribute to developing the competency of reflection-in-action for interdisciplinary, or interdisciplinary consciousness.

Both frame reflection and interdisciplinary have been reported to require competencies that are not self-evidently held by all professionals (Boerwinkel, Swierstra, and Waarlo 2014; Dewulf et al. 2013; Di Giulio and Defila 2017). This situation suggests the need for explicit training in acquiring such competencies (Boud and Walker 1998; Di Giulio and Defila 2017). As higher education delivers future sustainability professionals for whom such competencies are reported to be essential (Parker 2010), universities are key in preparing graduates who are equipped to address sustainability issues through interdisciplinary approaches (DuPuis and Ball 2013), and thus are able to master IC and reflective practice capacity.

Training on reflection is often focused predominantly on cognitive activities (Beauchamp 2015). But as IC requires both awareness and an appreciation of different disciplinary perspectives (Kjellberg, O’Rourke, and O’Connor-Gómez 2018), it deals not only with knowledge but also with attitudes. We argue that interdisciplinary requires what John Dewey (1910) called “a playful attitude of mind,” which is characterized by intellectual curiosity, flexibility, and the absence of dogmatism and prejudice. In order to develop this playful attitude, developers of tools can use narration, imagination,
action-reflection, and co-creation to spark playfulness (van der Meij, Broerse, and Kupper 2017). Interventions using playful tools have been shown to prompt frame reflection and can help to create awareness of diverse types of frames (Kupper et al. 2007).

At our department, we have extensive experience with (playful) interventions for frame reflection to engage researchers, practitioners, and students in reflection on societal issues (Edelenbosch, Kupper, and Broerse 2015; van der Meij et al. 2018). However, to date frame reflection, and the use of playful tools to prompt such reflection, has not been researched as a means for developing IC in the context of interdisciplinary research and education for sustainability. This article contributes to understanding the potential of frame reflection in enhancing IC in the context of interdisciplinary collaboration. To study this process, we developed the playful Frame Reflection Lab (FRL) intervention aimed at stimulating reflection on different views of science. We implemented this intervention in an interdisciplinary Master’s degree course in which students work on sustainability issues through cross-disciplinary teamwork. By implementing and studying the FRL intervention, we aimed to further understand the role of frame reflection in the development of IC to support interdisciplinary teamwork for sustainability issues and to acquire practical insights on how to train interdisciplinary competencies for sustainability in higher education. In the following sections, we describe the design of our FRL tool, the setting in which we conducted the current study, and our research approach. Subsequently, we report our experiences with implementation of the tool in a Master’s degree course, and the implications of these findings for educational and research practice.

Methods

Setting

We collected the data for this study in the context of an interdisciplinary Master’s degree course offered at VU Amsterdam (VUA) called “Interdisciplinary Community Service Learning: Defining Challenges in a Multi-Stakeholder Context” (iCSL). The course can be taken by students enrolled in any Master’s degree program at VUA. Students usually do so on an extra-curricular basis, meaning that they volunteer to enroll and the credits awarded upon completion do not count toward the requirements of their degree program; rather they are mentioned as additional credits on their transcripts.

One of the learning objectives of the course is for students to become familiar with, and acquire practical experience in, interdisciplinary research. In the course, they collaborate in cross-disciplinary teams on producing a report that integrates their diverse views and knowledge bases to describe a complex sustainability issue. Activities to stimulate interdisciplinary learning include: joint project work, learning materials (lectures and readings) about interdisciplinarity, an interdisciplinary “journal club” to which students bring papers from their own disciplinary backgrounds and read and discuss one another’s contributions, and different reflection activities, described in the following section.

For this study, we collected data in November–December 2020. As this was during the COVID-19 pandemic, the classes followed a hybrid format, giving students the option to participate either on-site or online (via Zoom), at their discretion. A hybrid setup with microphone, speakers, and camera allowed for group discussions in which all students—attending online and offline—could participate. Only the final meeting took place entirely online because of the national lockdown measures at that time. In practice, some students attended all meetings online, and some attended partly online and partly in person. The in-class discussions on the reflection intervention took place in smaller groups of three or four students. In all groups at least one student joined the discussions online. In this way, the students engaged in their projects via Zoom and in breakout rooms if they were working online. The students who joined the meeting on location connected with their peers who were online through their own devices (e.g., a laptop or tablet).

As the data collection took place in the context of the course that we also designed, implemented, and taught in our department, we as researchers had multiple roles. The first author (AH) was involved in teaching the course meetings and conducted the reflection interviews with the students.

The frame-reflection intervention

We developed a Frame Reflection intervention with the goal of engaging the students in frame reflection throughout the course in order to support the development of IC. The reflection intervention included different activities: individually written reflection exercises, interactive reflective group discussions, video portraits, and a one-to-one reflection session with an instructor. These activities were organized around the Frame Reflection Lab (FRL) tool that we redesigned based on a tool previously developed at our department (van der Meij et al. 2018) and
applied in the context of interdisciplinary collaboration in the iCSL course.

To give a stage to affective processes, to spark reflection, and to support a “playful attitude of mind” (Dewey 1910), we aimed to engage students in playful learning. We designed our FRL tool on the basis of the playful activity principles proposed by van der Meij, Broerse, and Kupper (2017) which are narration, imagination, action-reflection and co-creation. In our design, we focused mainly on narration and action-reflection principles. The FRL tool centers around four characters who have diverse views of science and explain them through stories about their research experiences (narration). The students reflected on the views of science demonstrated by the characters, their peers, and themselves in written reflections and through group discussions. These group discussions were highly interactive and involved using a digital workspace in which they visualized their views and ideas (action-reflection).

Moreover, the FRL tool taps into affective processes as the four characters are fictitious but are also realistic early-career researchers to whom the students can relate. And finally, the tool stimulates interaction and aims to create a safe space for students to experiment, to express, and to revise their ideas.

The four characters are based on two classic debates in the philosophy of science and epistemology involving, on one hand, positivism/realism and constructivism (Hacking and Hacking 1999) and, on the other hand, science as representation and science as practice (Pickering 1993; Hacking and Hacking 1983). We reduced the four positions in these debates to two sets of two opposing presumptions that most scientists have internalized during their scientific training: (1) the relationships between scientific findings and the real world, which ranges from science as neutral report of objective truths to science as value-laden construction of complex realities and (2) the relationship between research practices and the topics under study, which runs from conducting research through observation to research as an interactive process of intervention and evaluation. Figure 1 depicts a matrix with these two characteristics on the horizontal (x) and vertical (y) axes, respectively. The characters were inspired by our experiences with students in the iCSL course in 2019 and further shaped and developed based on literature (Eigenbrode et al. 2007; Hazard et al. 2020). We defined the characters in several conversations with the research team, which resulted in a matrix consisting of four characters that informed the production of the video portraits. It is important to note that these four characters are not the only possible characterization of views of science and do not represent an exhaustive overview of the full range of the possibilities.

The four characters were performed by actors, using our scripts. The tool comprises three videos, each of which features all four characters. In the first video, the characters present themselves and describe what their research is about. In the second video all four characters answer the question of what they consider to be good scientific knowledge and in the third they answer the question of how scientific research (outcomes) can or should contribute to addressing societal issues. As such, the narratives develop from first-order notions (practices and approaches in their research field), to second-order notions (values underlying their approaches), and the main characteristics of their views of science.

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then loop back to first-order notions (approaches to deal with the science-society interface) (van der Meij et al. 2018).

The students watched these videos at different points throughout the course, and reflected on their own views, the views of the characters in the videos, and the views of their peers in the individual and group reflections. During the latter, the students worked in a digital workspace (Mural) to map the views and the relationships between them. The exercises in this workspace comprised four steps: (1) positioning themselves in relation to the four characters and discussing their positioning; (2) describing the differences and similarities between the characters in their own words; (3) deepening the mapping with so-called value and assumption cards (van der Meij et al. 2018); and (4) positioning the so-called “knowledge-strategy cards” and discussing them to reach consensus on the most appropriate knowledge strategy in the context of the course. Figure 2 shows the twelve value and assumption cards and the four knowledge-strategy cards that we developed as part of the FRL tool. Compared to the earlier tool on which our current tool was based (van der Meij et al. 2018), we more extensively prescribed the storytelling in the video narratives, adjusted the discussion format to suit the hybrid educational setting, and embedded the FRL tool in the course through spreading the discussions over multiple sessions and aligning them with written exercises and oral reflection sessions at different points during the course.

For the remainder of this article, we use the term “reflection intervention” to refer to the whole set of reflection activities and the term “FRL tool” when it concerns the video-based tool and the interactive discussions and online-workspace activities specifically.

Participants
A total of 23 students completed the iCSL course in 2020. These students represented a wide range of study backgrounds, coming from fifteen different Master’s degree programs and eight faculties: science (n = 9), social sciences (n = 4), behavioral sciences (n = 3), business and economics (n = 3), medicine (n = 1), law (n = 1), engineering (n = 1), and theology and religious studies (n = 1). For the group-reflection exercises, the instructional staff divided the students into eight groups with the aim of maximizing diversity in terms of study backgrounds. The cohort consisted of 16 female students and seven male students. There were nine international

Figure 2. The (a) value and assumption cards; and (b) knowledge strategy cards as used in the FRL tool.
students and 14 Dutch students. To ensure anonymity, we refer to all students as women and their study backgrounds—which are reported only when relevant to the interpretation of the data—are referred to in broad categories. It is important to note that many Master’s degree programs do not correspond directly with disciplinary fields. As well as disciplines in themselves not being straightforward categories (Klein 1983), many programs also teach theories and methods from different disciplinary perspectives, and some are even designed and taught through cross-faculty collaboration. This means that students have varying disciplinary breadth, which is further accentuated by the possibility that some are trained in different areas or have prior degrees in different fields.

**Data collection**

The body of data we used consisted of the students’ written reflection entries and transcripts of the oral reflection session with the first author. We conducted the reflection sessions in the form of semi-structured interviews that followed up on the students’ answers to the written reflection questions they had completed at that point. The interviews focused on the students’ experiences with the reflection assignments, their views of science, the origin of these views, the relation of their own views to those of their peers on the course and the FRL characters, and how their views shaped the collaboration with their fellow students. The interviews lasted for an hour and took place via Zoom. For students whose mother tongue was Dutch, the interviews were conducted in Dutch ($n = 15$), for the others ($n = 9$) they were conducted in English. The interviews were recorded and transcribed verbatim.

**Ethics**

All students who participated in the study gave their written informed consent about the use of their data for scientific research and could withdraw from the study at any time, with no consequences for their participation in the course or their relationship with the teaching staff. The BETHCIE ethical committee of VU Amsterdam gave ethical approval for the research project, of which this article is a part.

**Data analysis**

The first and second authors analyzed the data in a sequential deductive-inductive approach. After initial joint coding and discussions with the research team, the inter-researcher consistency proved sufficient to continue analysis independently. The first author analyzed the data from 19 interviews and the second author the other four. Uncertainties were discussed in the research team and solved through consensus when they arose. The initial deductive coding approach served to select data for further analysis including any instances of frame reflection, affective responses, and experiences with the reflection intervention. For the frame-reflection category, we distinguished between first-order and second-order notions (Grin and van der Graaf 1996). In the context of interdisciplinary collaboration, first-order notions include field-specific practices such as methods, topics, and writing styles and second-order notions are the values and assumptions behind those practices—the “why” of the practices. We also distinguished between statements made about one’s own view of science, and those about others (teammates and/or FRL-characters) (van der Meij et al. 2018). Affective responses were selected when students expressed or non-verbally displayed emotional responses or value judgements. We identified learning effects through the students’ subjective descriptions of experienced changes in knowledge and attitudes and changes in views and attitudes as observed by the researchers. In the subsequent inductive analysis stage, we developed themes within the broad categories of data that we extracted. This step took place in several iterations of discussing the findings, building the narrative, and revisiting the data. Coding of the interview transcripts was complemented by listening to the audio-recordings to incorporate insights from non-verbal cues such as silences, laughter, and sighs.

**Results**

To understand how playful frame reflection can contribute to the development of IC, we looked at how the students in our course developed IC and how the frame-reflection intervention contributed to it. In the following sections we outline our findings about (1) their development of increased awareness of different disciplinary frames; (2) their development of greater appreciation of different disciplinary frames; (3) the added value of playfulness to build awareness and appreciation; and (4) some examples of instances in which the playful FRL tool did not add any value to student learning.

**Developing interdisciplinary awareness through frame reflection**

In the context of our interdisciplinary master’s degree course, we observed that the frame-reflection intervention contributed to the development of IC competence in most students as we observed that
they gained new insights or they themselves reported a change in perspective. There were students who departed from the (implicit) perception that different disciplines merely cover different topics with different methods, without (fully) realizing that this also implies different framing of research topics, value systems, and assumptions. This seemed to be mostly the case for students with little experience with interdisciplinarity and a background that was shaped by specialist rather than broad training. Those students became aware of the existence of different views of science, and thus that their own view is just one of many alternative perspectives. This is the first step toward IC, as it acknowledges the plurality of views of science and thus paves the way for exploring, understanding, accepting, and appreciating the views of others. The following quote is an example from a student who describes that she developed awareness of the existence of a multitude of different views of science.

A key lesson for me this week is that different disciplines not only bring different topics to study but can also have entirely different views about what you can know. It is a topic I had never considered before...I have never taken the opportunity to [question] what I consider scientific knowledge and have for the first time tried to formulate my own definition of it. (Student 3, written reflection)

Encountering other diverse perspectives made students aware of the existence of different views of science and thus urged them to question the underlying values and assumptions that had previously been implicit. Their views of science had often been a given up to that point, as their predominantly disciplinary training had not presented the practices of their field as one of many possible approaches, but rather as a given way of doing things in the field in which they had been acculturated. But now their views were being challenged. The quote above demonstrates that due to the highly diverse cohort enrolled on the course, students interacted with people who held views to which they had not previously been exposed. This exposure to different views was seen as important in creating learning potential to broaden the students' views ("I think the interaction with the other students was the most valuable part of this course" (Student 7)).

The exposure in itself, however, was not enough to develop interdisciplinary awareness. Contrasting the different views and actively trying to make sense of the differences seemed to be important in this regard. However, since most students did not naturally reflect on these different perspectives in terms of second-order notions, the reflection exercises were important in stimulating them to do so. These included the group discussions during the sessions that required them to take a stance and to explain it to each other, the written exercises that prompted relating their own views to those of others, and the reflection interviews in which they were prompted explicitly and repeatedly to explore the "why" behind their statements and to make sense of differences between themselves and others. In the following quote a student reflected on how she experienced her reflection interview. She noted the importance of comparing her own and other views, and explained that the repeated questioning by the interviewer helped her gain this insight.

I found this conversation interesting. I must say that you [interviewer] ask me quite different questions than I generally ask myself. You continue longer, for instance asking 'what may be the cause of that?' and 'what does that tell me about you?' So that was a kind of [a] reminder to me that I can also do that more myself... Quite in the beginning of the conversation I came to realize that by comparing myself with others, I am better able to consider my views relative to theirs...this helps me understand others, but also to understand myself. (Student 6, interview)

We saw that explicit questions to compare their own with the views of others in the written reflections and repeated critical questioning in the interviews helped spark second-order reflection. But even when they were prompted repeatedly and differences were pointed out to them explicitly, many students did not succeed in making sense of and articulating their own scientific views and the scientific views of others in terms of second-order notions.

In summary, the above indicates that students developed awareness of different views of science through exposure to diverse views and reflection on these views. However, they did not naturally engage in second-order reflection and may not have succeeded in doing so even with extensive support. This limited the development of a full understanding of the values and assumptions that shaped their own views of science and the views of others.

**Building interdisciplinary appreciation through critical and non-defensive reflection**

Besides the raised awareness of the existence and meaning of different views of science, we also observed the increased appreciation of other views due to the reflection intervention. In the following example, a student explains how she came to better appreciate the views of others—and specifically a fellow student with a social sciences background.

My opinion changed, because I value all of [the FRL characters] better now. For example, at first, I did not identify with Anthony, but when he
explained his vision on the relationship between science and society and the ways science should be conducted, I thought better of him. (Student 7, health and life sciences, written reflection)

Appreciation centers around normative judgments about the relative value and importance of different disciplinary perspectives. While the development of awareness comprises expanding knowledge about and understanding of differences, building appreciation requires a shift in attitude toward one’s own view and the views of others. As the quote above also demonstrates, awareness and appreciation are closely related and affect each other. But we observed that increased awareness did not necessarily lead to increased appreciation. For instance, Student 1, with strong quantitative grounding in her own field, expressed the view that she considered the qualitative data in a paper from the social sciences did not provide “any real evidence,” but when asked explicitly to outline her opinion on qualitative social sciences research, she said she finds it equally useful and valuable to research in her own field. So even though she understood that their different approaches stem from different training and different values and assumptions (awareness), her immediate “gut response” implies that she regards the social sciences as less legitimate or valuable than her own discipline, because according to her first response qualitative approaches do not yield any real evidence.

We observed that some students showed (e.g., giggling, stammering during the interviews) and/or expressed being uncomfortable with their negative normative responses to other disciplines as these may not be socially desirable behaviors and/or because they failed to substantiate them rationally. How students dealt with these responses and addressed their judgments defined their learning from these instances. We saw that when students acknowledged those differences and critically reflected on them, it provided very fruitful and possibly transformative learning experiences in changing their attitudes. This obviously required courage and openness to deal with the value judgments that they considered undesirable. The following quote is an example from a student who critically and openly reflected on her own previous value judgments about other disciplines.

I turned out to be more prejudiced than I thought and hoped. While I considered myself a very open-minded person who values every [discipline] equally, I realized that I secretly think my own science is good science, and hers [social sciences] is fake science. (Student 22, health and life sciences, interview)

We saw that this student’s open critical reflection during the interview also translated into a more appreciative attitude toward other disciplinary perspectives, as became clear from her written reflections and attitudes during the remainder of the course. This example shows that this student overcame substantial discomfort and showed courage in doing so, because it required admitting and embracing that she was more prejudiced than she hoped, and was not as open-minded as she thought. We also observed instances in which students did not address misalignments between their normative and their rational statements. In some cases, this displayed itself as not recognizing that there was a misalignment to begin with. This was the case in the earlier example of Student 1 who denied holding a critical (possibly judgmental) attitude when asked about it. This prevented her from learning from this occasion and building more appreciation for other disciplines. Similar things happened when students were asked why they made a certain remark that implied a value judgment about other disciplines and they nuanced or retracted their statements. The following quote from an interview provides an example of a student (exact sciences) who reflected on the video characters and changed her statement out of what seems to be a state of discomfort (as also became apparent from stuttering and halting when speaking).

Student 15: [Jane’s research] is something which we didn’t know and it’s important…this is the most important. And [Anthony’s research] this is just text … there is not a single number there …

Interviewer: So why do you think what Jane does with the ice is the most important?

Student 15: Well, I’m not saying it’s the most important. I’m saying… I will… she suits me the most.

We make sense of this behavior to ignore, to retract, or to nuance negative value judgments as (unconscious) defense mechanisms to avoid the discomfort described before. In the example of Student 22 we saw what it took to realize the potential to learn from her prejudices: facing up to the fact that she was not as open as she had assumed and hoped. So, critically yet non-defensively reflecting on one’s own value judgments can be a potent driver of an attitude shift toward increased appreciation of others and their disciplines. Defensive responses to (too much) discomfort, by contrast, may prevent this learning.

**Playful tool invites reflection**

We observed that several properties of the FRL tool served their function of stimulating students to engage in frame reflection about their own and others’ views of science. These features included
safety of reflecting about fictitious characters, making second-order notions explicit, and providing a vocabulary to articulate their views of science in terms of second-order notions.

Compared to reflecting on their interactions with fellow students, students seemed to experience it as safer to reflect on, and disagree with, the fictitious FRL characters. Students seemed reluctant to reflect on fellow students, saying that this was due to not wanting to gossip about them with an instructor and make wrong assumptions about them. This was indicated by the fact that students often made bolder statements about what they thought of and how they related to the FRL characters (“I personally do not relate to Anthony at all. He only talked about subjectivity and observing without influence,” Student 4) than about their fellow students, despite being invited explicitly to speculate (“I don’t think I can answer the question [of what S18 found important] because we haven’t talked about that.”). Moreover, in group discussions they sometimes had the tendency to agree with each other, whereas they were more inclined to disagree with the FRL characters. One of the students expressed the following about her tendency to agree with others during group reflections.

“I agree less with my teammates than I initially thought. I think the reason we had very similar opinions while discussing in the meeting was time pressure and peer pressure. When the first person states their opinion and as I do not think we differ to a large extent [about] each other’s opinion it is very easy to just agree to what the first person said.” (Student 2, written reflection)

Furthermore, the FRL tool helped students talk about their views, without depending on their own ability to articulate them. The characters have well-defined and diverse views of science and communicate them explicitly and concisely. In the following quote a student explains how she better understood one of her fellow students thanks to the explanations of the FRL characters.

“When [S12] explains herself,... it is not necessarily very specific. It is more of a superficial explanation than when I’m watching those videos where those people are asked a very specific question and have 30 seconds to answer. I think in that sense those videos help me understand [S12]’s point of view better, because they go more in depth and she doesn’t. So, they help me to fill in the blanks of what [S12] says. (Student 9, interview)

Moreover, the videos and cards introduced terminology for talking about values and assumptions. This seemed to be useful for a subset of students whose vocabulary to articulate their views seemed underdeveloped. They expressed themselves in everyday language and relied on mundane examples. But through exposure to the FRL tool they adopted some of its terminology and became better able to express themselves. Finally, the FRL tool encouraged taking a stance as it required every student to position herself relative to the characters. This prevented students from taking a passive role in the discussions and the visual board with their positions gave them a starting point for their conversation and invited discussion.

The exceptions: when FRL was not of added value

Throughout the course, we noticed that not everyone benefited to the same extent from the frame-reflection exercises. First, there were students for whom they did not add any new learning because they already had a well-developed understanding of their own and others’ views of science. Second, there were students who did not much rely on the FRL videos or discussion format for their learning because their reflective group discussions were already sufficiently rich for them to learn from without the more structured format of the playful tool. Finally, it became clear that reflection and corresponding learning also heavily depended on intrinsic motivation which was in some cases overshadowed by other course activities.

To illustrate this, we observed a student who scribbled “social constructivism” and “positivism” on the digital workspace straight away and had already a well-formed scientific identity along that spectrum. She also mentioned that this is something that she has been taught explicitly in her studies and is important in her field (social sciences). For her, the videos with the FRL characters, discussions with fellow students, and reflection questions did not provide any new insights to further her understanding of her own or others’ views. This seemed to go both ways; owing to the higher competence level at the start of the course, there was less room for growth, but she also seemed to be less open to learning and further expanding her understanding and appreciation because she was convinced that she was already well-informed on the topic.

Furthermore, we observed that there were student teams that learned from the reflection exercises (written and oral) and discussions, but relied less on the videos and digital collaboration space of the FRL tool than other teams. Members in those teams held diverse views of science, were well able to articulate their understandings, and asked each other questions. This meant that the conditions for a meaningful, constructive conversation were present in the team without the need for the FRL
intervention. One of the students said the following about it.

[I’m really learning from] the discussions with the others. I was in a group with [S11] both times. [She] is from a very different background than me, and that also makes it easier to reflect, because it makes you pause and think for a second and realize that that is also a way to see it. And she can also put to words very well what she thinks about science, that also helps. I notice in the discussions with the others that they have also thought about it a bit, but [S11] can put to words very meticulously why [she] views it in a certain way. (Student 3, interview)

This diversity in how the students used the FRL tool and how their conversations unfolded without the tool demonstrates that not all students may have had the same need for all of the elements of the course, depending on their—individual and the team’s—ability to engage in frame reflection without the support of the FRL tool. Moreover, whether the potential of the reflection intervention was achieved seemed to also depend on the students’ motivation, time, and commitment. One student mentioned that she enjoyed the group discussions with her teammates, because of their diverse perspectives, and that she wanted to learn from them (intrinsic motivation). However, she was under time pressure and experienced tension with the graded assignments (extrinsic motivation) which led to a sense of urgency and pushed them to opt for quick fixes and away from the meaningful, in-depth discussions.

What you strive for, is to exchange ideas, that you question yourself and each other, and that you thereby take it one step further, so that you may come to new insights. And now it was more like “OK, we’ve got this insight, now how can we fit our perspectives into that? So, that is really a pity.” (Student 11, interview)

Taken together, the above examples show that the FRL tool does not provide a universal solution to facilitate the development of IC through frame reflection and that its potential also depends on prior competence level, group composition, and motivation.

**Discussion**

To contribute to understanding the role of frame reflection in enhancing IC to prepare (future) professionals for interdisciplinary teamwork on complex sustainability issues, we provided in this study insights into the implementation of our playful frame-reflection intervention and how it shaped the development of IC in Master’s degree students. We showed that our respondents developed greater awareness of disciplinary differences through exposure to and reflection on disciplinary differences. As contrasting their own and others’ views and reflecting on the underlying assumptions increased their understanding, second-order reflection contributed to developing IC. Moreover, we saw that some students developed enhanced appreciation of other disciplinary views. A shift to a more appreciative attitude toward different disciplinary perspectives was aided by enhanced awareness and understanding of disciplinary differences, but also showed the importance of requiring critical non-defensive reflection on one’s own value judgments. In this way, the study shows that besides rationally making sense of disciplinary differences to understand underlying value systems and assumptions, developing IC for interdisciplinary research, practice, and education also demands addressing normative judgments and affective processes to deal with inner conflict and discomfort. Often training for interdisciplinarity and reflection focuses heavily on cognitive processes, but the implementation of a playful tool proved powerful to stimulate cognitive as well as affective processes to support the development of IC.

Our observation that attitudes and value judgments toward different views of science was shaped by an interplay of cognitive and affective processes resonates with earlier findings of the cognitive and affective roots of judgments in other contexts, such as technological risks (Roeser 2008). For instance, we saw that automatic and sometimes even unconscious negative value judgments about other disciplines could get in the way of this valuation of others’ knowledge and perspectives. These preconceptions often manifested themselves as immediate, almost instinctive, “gut responses” that were sometimes misaligned with their rational understanding and opinions. This result is consistent with earlier findings that interdisciplinary collaboration relies not only on intellectual abilities and cognitive processes, but also on emotional and social processes (Mansilla, Lamont, and Sato 2016). Besides (overcoming) bias and judgment, the literature also reports on the importance of intuition for knowledge integration (Repko and Szostak 2020), further emphasizing the importance of looking beyond cognitive processes when engaging in, designing, and guiding cross-disciplinary work. So, researchers and practitioners involved in interdisciplinary teamwork, as well as instructors and project coordinators facilitating cross-disciplinary collaboration, should also focus on cognitive processes that tap into emotional and social engagement. As playful approaches invite affective processes, they hold a powerful promise to spark reflection and creativity for cross-disciplinary collaboration and learning.
Moreover, we saw that only when students acknowledged possible misalignments and reflected openly, critically and non-defensively on their stances—including those unconscious, automatic judgments—was there transformative learning toward a more appreciative attitude. This is in line with earlier reports of the relevance of critical non-defensive self-reflection for interdisciplinarity (Nurius and Kemp 2019) and the importance of open-mindedness and flexibility to critically assess one’s own understanding so new ideas can emerge (Oughton and Bracken 2009). Our reflection intervention succeeded in sparking such a mind-shift in a subset of students. This observation hints at a third process dimension that the approach invited in addition to the cognitive and affective—that of critical engagement with the topic. Consistent with previous experiences with similar methods (van der Meij et al. 2018) intensive one-to-one facilitation in the reflection interviews, and instructors’ intervention during the group discussions, seemed to support this critical engagement with the learning materials. This demonstrates that critical engagement is not self-evident and that facilitation serves to complement the other assets of our playful reflection approach. Cognitive, affective, and critical engagement seem to be closely interwoven. For instance, defensive responses to the discomfort of addressing judgments that students considered undesirable, prevented critical self-reflection and revision of attitudes and convictions. This contention aligns with the earlier finding that both too little discomfort (comfort zone) and too much discomfort (discomfort zone) impair learning for interdisciplinarity (Freeth and Caniglia 2020). Better understanding of how the interplay between cognitive, affective, and critical processes shapes interdisciplinary collaboration and learning calls for further research.

The role of affective processes in reflection that we observed resonates with previous critiques of Schön’s work, which conceptualizes reflection as a cognitive process, with too little emphasis on the importance of emotions (such as surprise; Yanow and Tsoukas 2009) and a lack of support for affective processes, including the creation of a safe environment for reflection (Beauchamp 2015). Our findings underline the importance of not overlooking affective processes when designing for reflection. Our FRL tool invited affective reflection processes by introducing realistic characters that provided a basis for feelings of identification and relatability, and because reflecting on fictitious characters proved safer than doing the same thing with regard to fellow students. And the reflection interviews provided the opportunity to identify and point out mismatches between automatic or unconscious normative judgments and rational explanations. We thus recommend designing reflection approaches for interdisciplinarity to stimulate affective as well as cognitive processes and paying explicit attention to relatability, creating a safe environment to share emotions, and non-defensiveness. Follow-up research to gain more detailed understanding of the underlying mechanisms of affective processes and the relationship between frame reflection on views of science and scientific identities could help to further inform the design of reflection to support affective processes for the development of IC.

We observed that many students on our course needed extensive support (e.g., explicit prompting, repeated questioning) to engage in frame reflection, and even then several did not appear to reach second-order reflection. The observed need for support is in keeping with earlier reports indicating that training reflection without a clear focus might render the processes “disparate and diffuse” (Boud and Walker 1998, 193) and lead to uncritical insights that do not go beyond personal interests, worries, and concerns. This has been reported to be a challenge especially in the area of interdisciplinary education. For example, a literature review reported that interdisciplinary learning overly relied on students guiding their own practice and reflection (Parker 2010). And another literature review reported that interdisciplinary courses often predominantly depended on diverse student cohorts without actively guiding them in learning how to collaborate across disciplines (Horn, Urias, and Zweekhorst 2022). We created structure in our intervention by introducing the video portraits that provided perspectives to which the students might otherwise not have been exposed. Moreover, the structured weekly written exercises and the group discussions probed concrete questions on which to reflect, explicitly requiring the students to make comparisons between themselves and the FRL characters. Based on these findings, we recommend providing sufficient structure to prevent undirected and diffuse reflection that remains limited to concepts and topics from the direct experiential world of the learners. The extensive support that students in our course needed also emphasizes that it is not easy to engage in frame reflection and that it cannot be assumed that either students or professionals have the competence to do so unless they are trained in this activity. Therefore, explicit instruction in these competencies, while providing “handles” appropriate to the learners’ competence level is key to prepare (future) professionals for interdisciplinary teamwork on sustainability issues, and it is also necessary to equip instructors for this task.
By contrast, a commonly reported pitfall of training reflection is that it becomes too structured, and thus an exercise in “recipe following” (Boud and Walker 1998). We also saw that for some students, our reflection intervention offered more structure than they needed; this was because they were already more experienced in reflecting on their own views of science. Despite the freedom in discussions and the explicit instruction that there are no right or wrong answers in reflection, some students still seemed to approach the reflections as “tickbox exercises.” They expressed being afraid of giving the wrong answers, assumed that some characters were more favorable than others, and experienced a situation where their intrinsic motivation to engage in in-depth reflections and discussions suffered from extrinsic motivators such as deadlines for graded assignments. We had the luxury of a student cohort that can be assumed to have had an exceptionally strong intrinsic motivation given the voluntary and extracurricular nature of the course. But even so, extrinsic motivations proved powerful in directing their learning approaches and intent. Transformative learning that springs from intrinsic motivation is thus at odds with our dominant educational system which relies heavily on extrinsic incentives and production of graded assignments under high time pressure (Kahu 2013). We therefore recommend refraining from formative assessment of reflection exercises and creating enough time to engage in unpressured reflection, as well as providing more freedom for people with greater competence in IC and interdisciplinary collaboration.

Overall, we observed a tradeoff between structure and freedom. Structure helped create favorable conditions for reflection. For instance, the videos of the FRL characters ensured exposure to diverse views, even when students did not have strong differences of views or could not fully articulate their own perspectives and thus did not learn about each other’s outlooks. Moreover, reflecting on fictitious characters helped create safety for students to reflect on their viewpoints when they did not feel comfortable about reflecting on their peers. The value and assumption cards also provided the terminology to articulate their views even when they lacked the vocabulary to do so. But students and student teams for whom those conditions were already in place could experience these same structures as restricting their freedom and acting as a barrier to transformative learning. They felt that a format with more flexibility would have been more inspiring and motivating to them and may have aided their transformative learning. The diversity of students’ prior experience with and competence in cross-disciplinary collaboration at the start of a course is a common challenge in interdisciplinary education that deals with diverse student cohorts. Therefore, we recommend that designers of training and education carefully consider the level of structure—and thus of freedom—of their interventions, taking the learners’ abilities, prior experiences, and motivation into account. This calls for training reflection through scaffolding in which learners receive guidance with a degree of structure that fits their competence levels and become gradually prepared for more self-directed learning. For diverse groups of people like the students in our course, this poses the extra challenge of providing a single approach that caters to different competence levels. Therefore, training reflection in diverse groups of learners calls for flexible approaches—and even then, there will probably not be a perfect solution that caters to everyone’s training needs in interdisciplinary collaboration.

Methodological considerations

Our course and reflection intervention proved powerful as a means to study the role of playful frame reflection in developing IC. A few points regarding the reflection intervention and our own research approach should be kept in mind. With respect to the FRL tool that we developed, we observed that students sometimes made different sense of the characters than we had intended, which raises the question of whether they were sufficiently clear and explicit, and how that affected their learning from the reflection exercises about the characters. For example, we saw that the students often leaned toward Ellen because they appreciated her (personal) commitment to making a societal contribution, but showed little reflection on what her approach meant to the research that she conducted and the data she collected. This raises the question whether those implications were sufficiently emphasized in the tool materials. Moreover, we observed that not all FRL characters were represented equally in the students’ positionings; and that several students expressed that they especially identified little with Calvin, regardless of whether they agreed with his statements. Given the finding that relatability plays a role in the frame-reflection activities, this raises the question whether this character seemed less appealing to the students because of the view of science it represents, or because of other factors such as similarity and likeability of the character’s personality. The fact that this character seemed harder to understand for the students than the other three and was thereby less relatable, urged us to take critical look at how we scripted the character and the view of science that he represented. This resulted in the redesign of this character for future use of the tool.
Finally, the hybrid setting in which the course took place affected the students’ learning experience. In line with other reports on online teaching and learning (e.g., Hewson and Hughes 2005; Smeltzer, Leon, and Sperduti 2020), the students reported that it was harder to get to know their fellow students, especially if they participated in the course on a fully online basis. Considering the importance of safety and familiarity, the online setting of the course probably affected the affective and reflective processes to develop IC.

In relation to the research approach, several points demand attention. First, we stress that we did not set out to study the effectiveness of our intervention, but rather to understand how frame reflection and playfulness can contribute to developing IC. For this reason, we did not assess IC competency levels quantitatively nor compare competence levels before and after the reflection intervention. Rather, we identified learning experiences as reported by students and observed by instructors/researchers. We subsequently focused on trying to understand the students’ reasoning and learning processes. We also did not assess student or team performance on interdisciplinary collaboration or integration in this study; we instead studied the students’ IC, relying on literature (Kjellberg, O’Rourke, and O’Connor-Gómez 2018) that reports IC as an essential competency for interdisciplinary collaboration. We also note, however, that although essential, competence in IC alone does not guarantee competence in interdisciplinarity (Horn, Urias, and Zweckhorst 2022).

Second, understanding the causal relationships between mechanisms and outcomes was challenging because of the fact that the reflection intervention comprised many components: videos, group discussions, written exercises, and reflection interviews. Moreover, the diverse student cohort also confronted us with an extensive array of personality traits and experience levels, which inevitably also affected student IC competence levels and learning processes. This diversity included a wide range of experience with interdisciplinarity and breadth of students’ prior education. The cohort included some students with a strong monodisciplinary background in which they received specialist training, but also students who had taken several different degrees, or followed a broad, interdisciplinary education. This probably translated into different levels of intrapersonal “multidisciplinarity” and readiness for interdisciplinary work (Heinze and Bauer 2007; Locatelli et al. 2021). It is thus virtually impossible to disentangle the contribution of each of the individual components of the intervention from other factors related to the students’ learning. Therefore, we cannot make any grounded claims on the effects of particular components of characteristics of the reflection intervention aside from a few exceptions of students who offered explicit insight into what triggered certain insights for them.

Third, we saw that the group discussions greatly affected the individual reflection. Collecting additional data from these group discussions to complement the data on the individual processes might have provided additional insights about this situation. Due to the challenging hybrid setting in which the discussions took place, this was, however, not feasible. By contrast, the combination of written reflections and interview data gave us a rich vantage point on the experiences, views, and learning patterns of individual students and listening to the audio recordings rather than analyzing the transcripts helped us to detect emotional responses more sensitively and accurately. In the results section, for instance, we provided an example of a student who reflected on her prejudices in the reflection interview and then demonstrated having acquired new insights and attitudes in the subsequent written reflections. The combination of different data sources thus allowed us to triangulate. This does not detract from the fact, however, that we relied heavily on self-reporting, which inevitably affected our results, especially considering that we found that students were often not very aware of their assumptions and judgments. Consequently, relevant processes have undoubtedly escaped our attention because students did not recognize these issues themselves and thus did not report them.

Finally, we decided to address our research question in the context of an interdisciplinary Master’s degree course. This proved to be a very appropriate context for student interdisciplinary learning as it gave us access to an extremely diverse group of participants that was highly motivated to develop interdisciplinary competencies. It would be interesting to see how the findings from this study apply to other contexts, such as inter- and transdisciplinary collaboration among more experienced academics, practitioners, or in multi-stakeholder settings. We hope that our study inspires and supports the design and implementation of similar tools and investigations in other fields and contexts. Follow-up research into similar applications in other settings has the potential to further expand understanding of frame reflection for interdisciplinarity.

**Conclusion**

We have shown in this article that playful frame reflection on views of science holds the potential to contribute to the development of IC and thus
interdisciplinary collaboration and integration. Although awareness of disciplinary differences and appreciation of other disciplinary perspectives by no means suffice to engage in successful interdisciplinary collaboration, IC is a key competency that is necessary for interdisciplinary collaboration and integration (Horn, Urias, and Zweekhorst 2022; Kjellberg, O’Rourke, and O’Connor-Gómez 2018).

Our intervention supported affective, critical, and cognitive reflection processes, and offered support as well as freedom. We found affective processes to be important for reflection to build interdisciplinary appreciation and thus require explicit attention in developing reflection to aid interdisciplinary collaboration. Our work stresses the importance of supporting affective processes, whereas interdisciplinarity and reflection are usually approached cognitively. This common focus on cognitive approaches may fail to challenge the unconscious, automatic “gut responses” or biases that collaborators may hold and thus fail to support the development of interdisciplinary appreciation. And a lack of appreciation for the contributions of others may present a serious barrier to interdisciplinary teamwork to tackle sustainability issues holistically. Moreover, we experienced a tradeoff between structure and freedom, as people with lower levels of competence and in less favorable conditions for interdisciplinary collaboration benefit from structure, but those with higher competence levels may be limited by it. In other words, learners of different competence levels require varying levels of support. As the IC competence levels in our cohort varied widely, a flexible approach proved helpful, but it is virtually impossible to design an approach that caters to the full range of learning needs. This cautionary observation stresses the importance of scaffolding frame reflection for IC to gradually train learners in the required competencies and to support them according to their competence level.

Overall, these insights are promising in terms of informing the implementation and development of interventions to aid preparing (future) sustainability professionals to address complex sustainability issues in interdisciplinary teams. Collaborators need both to understand and appreciate each other, and this needs to be learned in ways that engage cognitive and affective processes and provide an appropriate balance between structure and freedom to challenge possible prejudices.

Note
1. Here, and in the remainder of this article, when we use the term “science” we refer to the full breadth of academic fields, including the social sciences and humanities, similar to the use of the term Wissenshaft in German.

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We invite readers to implement the FRL tool in their own context. The necessary materials are available via: https://vu.nl/en/about-vu/more-about/frame-reflection-lab-tool-athena-institute.

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ORCID

Annemarie Horn http://orcid.org/0000-0002-5888-2232
Marjoleine G. van der Meij http://orcid.org/0000-0003-3240-2357
Willemine L. Willems http://orcid.org/0000-0001-5439-1332
Frank Kupper http://orcid.org/0000-0003-1476-1911
Marjolein B. M. Zweekhorst http://orcid.org/0000-0001-7015-4951

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