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Going beyond the AHA! moment: insight discovery for transdisciplinary research and learning

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In this paper, we develop and apply the concept of 'insight discovery' as a key competence for transdisciplinary research and learning. To address complex societal and environmental problems facing the world today, a particular expertise that can identify new connections between diverse knowledge fields is needed in order to integrate diverse perspectives from a wide range of stakeholders and develop novel solutions. The capacity for "insight discovery" means becoming aware of personal mental representations of the world and being able to shape and integrate perspectives different from one's own. Based on experiences and empirical observations within the scope of an educational programme for Masters students, PhD candidates and post-doctoral researchers, we suggest that insights are the outcome of a learning process influenced by the collective and environment in which they are conceived, rather than instant moments of individual brilliance. The process which we describe, named the insight discovery process (IDP), is made up of five aspects. Within a group setting, a person begins with an "original mental model", experiences an "insight trigger", processes new information within the "liminal space", "formulates an insight" and eventually forms an "adapted mental model". There is a potential for incorporating such process as a fundamental competence for transdisciplinary curricula in undergraduate and graduate programmes by cultivating specific practices and safe learning environments, focused on the enquiry, exchange and integration of diverse perspectives.

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Introduction

What are the necessary competences to tackle the challenges related to sustainable development, climate change, social unrest and other societal dilemmas? Authors have referred to such problems as "wicked" (Rittel and Webber, 1973), "complex" or "ill-defined" (Dörner, 1996). A common characteristic of this type of problem is that its definition depends on the perspective of the individual confronting the problem. The solution or the means by which to arrive at a solution to the problem is therefore also open-ended (Rittel and Webber, 1973; Dörner and Funke, 2017; Alford and Head, 2017). This paper argues that what enables effective engagement with this complexity is "insight discovery", defined as the ability and willingness to identify and overturn one's own assumptions by assimilating new experiences and knowledge. Insights are important for addressing the complex problems in transdisciplinary research and learning, because they cannot be effectively addressed by "reproductive solutions" (Weisberg, 2014, p. 6) or technical answers that can be easily transferable between different contexts. In the case of climate change, for example, effective solutions are likely not to be derived from established ways of thinking and will also depend on the cooperation of diverse groups of people to be implemented. They require "new ways of knowledge production" (Lang et al., 2012, p. 25), learning from a wide range of disciplines and the inclusion of knowledge from outside of academia. While the need for such a transdisciplinary approach to enquiry has been acknowledged (Gibbons et al., 1994), how this approach can be implemented in practice is still being developed. For example, how can different perspectives be brought together in a way that *consistently* results in a greater understanding that goes beyond divisions? How might we, as transdisciplinary researchers and practitioners, restructure our own assumptions such that these new understandings will be incorporated into future climate change actions? We propose that one way to address these questions is to foster a willingness and capacity for discovering and acting on insights. The focus of this "insight discovery process" (IDP) is not only on acquiring a greater quantity of information, but on improving how we can better interpret information that is already available to us.

In the following sections, we first give an overview of concepts and knowledge gaps related to the concept of "insight" in the literature. We then present the components of our IDP framework, together with evidence of how this process is experienced by Masters students, PhD candidates and post-doctoral researchers as a part of a transdisciplinary winter school that took place in Switzerland. Finally, we discuss possible implications of the IDP for transdisciplinary research, learning and societal transformation.

What do we already know about insights?

A dictionary definition of "insight" is the "capacity to gain an accurate and deep understanding of someone or something" (OUP, 2021). Common terms associated with insights include—the "AHA! Moment" (Kaplan and Simon, 1990; Kounios and Beeman, 2009), the "Eureka Moment" (Klein, 2013), the "light-bulb moment" (Danek et al., 2014) or a "flash of illumination" (Metcalfe and Wiebe, 1987, p. 239). The concept of "insight" as a research subject was introduced in the 1920s in Austria and Germany by Gestalt psychologists interested in understanding the process of problem solving (Köhler, 1925; Davidson, 2003; Maier, 1940; Wertheimer, 2020). This work revealed that people solved problems by restructuring available information that, suddenly, leads to the emergence of a new understanding. These can be moments in which an impasse is overcome, for example, by solving a puzzle. Initial ideas about the role of insights in problem solving were developed in the context of well-defined problems, characterized by a fixed framing of the problem and existing solutions.

When taken into the context of complex problem solving in groups, there is an opportunity to further develop the insight concept in relation to the process of joint problem framing in transdisciplinary research. In an attempt to engage with the complexity of real world problems, scholars in the field have identified problem framing as an important element of transdisciplinary research (Hirsch Hadorn et al., 2006; Pearce and Ejderyan, 2019; Pohl and Hadorn, 2007; Rossini, 2009). Problem framing is the process of eliciting, searching and selecting relevant perspectives that restructure one's perception of a situation, to determine the appropriate goals and criteria for the creation of effective solutions (Pearce and Ejderyan, 2019). Joint problem framing takes place in a group setting, when diverse points of views are integrated to create a shared understanding of a problem and its possible solutions. The integration is made possible when individuals are open to changing their individual mental representation of the problem—their mental model—by identifying, exchanging and incorporating insights from inside and outside the group such that a shared group mental model can be developed (details of this process are described in Pearce and Ejderyan, 2019). This paper continues the development of the insight concept from this perspective.

In a transdisciplinary learning setting, the use of insights as the basis of joint problem framing has formed the foundation of the transdisciplinary "integrated systems and design thinking" methodology (Pohl et al., 2020)—intended to help Bachelors students develop the capacity for environmental problem solving. Working in groups, students have to discover "insights" from literature reviews, discussions with stakeholders and field visits to identify the problem and solutions they want to work on during a year-long course. As opposed to a fact, or a single piece of data, an insight has explanatory power, addressing the "why" or "how" of a situation, rather than only the "what". Based on observation, insights often also indicate a contraposition in the current understanding that defies intuition and can be explained concisely. Following existing concepts, insights are also explained as being information that restructures previously held assumptions, resulting in an "AHA!" experience for the individual.

The literature provides support for this definition of insight based on these key characteristics:

(1) *Subjectivity*: Although a group of people might receive the same piece of information, it is not automatically guaranteed that all of them will arrive at an insight (Klein, 2013, p. 30, 116; Danek et al., 2014). Insights can also yield a "realization about oneself" that is unique to each individual (Kounios and Beeman, 2009, p. 210).
(2) *Suddenness*: In contrast to incremental problem solving, where the solver has an estimation on how to solve the problem and reach the solution in an incremental, analytical manner (Wieth and Burns, 2000), having an insightful experience can be compared to a light bulb that suddenly switches on.
(3) *Certainty:* People who have an insight are confident "that the solution is correct without having to check it" (Danek et al., 2014, p. 4).
(4) *Emotions:* People who have insights report positive feelings such as "a jolt of excitement" (Klein, 2013, p. 9), but also experience a release of tension in sight of having overcome the experienced impasse.

In the next section, we identify gaps in the definitions and understandings of insights in the literature and propose how we

will address them within the context of promoting transdisciplinary practices in higher education and research.

What is missing from existing definitions?

The existing literature and practice provides a starting point for advancing our understanding of insight discovery as a competence. However, there are three knowledge gaps in operationalizing the concept for transdisciplinary teaching and learning. The first aspect of the insight concept yet to be fully developed is that insight discovery is a part of an emergent, collective *process*, rather than merely a single moment in time. Conventional wisdom would have us believe that insights are ideas that "pop[s] into mind, as if from nowhere" (Schooler and Melcher, 1995, p. 97). In our empirical work, however, we observe that insight formation is the result of a dynamic process occurring over a period of time. This process includes assimilating observations and reflections of an individual within a collective and environmental context in which the individual is situated. Insights are therefore created through an individual's engagement with their environment and context. It follows that the discovery of insights can be enabled or hindered by factors of an individual's environment and group interactions. External conditions, such as a deviation from the routine, learning that takes place in a new setting, having to adapt to new surroundings, exposure to a diversity of people and contexts that requires confrontation with different ways of thinking, and/or having a need to solve a problem may facilitate the process of insight discovery.

The second aspect of the insight concept to be fully developed is the inclusion of affective capacities within the insight discovery process. The existing literature emphasizes mainly the cognitive nature of insights. For example, puzzle-solving exercises, where factual information serves as the trigger for a change of perspective that enables a solution to be found, are the basis of many of the Gestalt experiments. In our work, we noticed that insight discovery also requires a high tolerance for ambiguity, openness for plurality, curiosity, reflexivity and perceptiveness, resilience as well as engagement with crises. These affective qualities have to do with a mindset that enables the discovery of insights. They are related to an ability to reflect upon one's position in relation to others and the ability to observe and assess one's own thinking and reaction in relation to newly available knowledge. This observation is supported by findings in educational psychology. Bloom et al. (1956), for example, describe the affective abilities as those that pertain to feelings, emotions and attitudes. The five subdomains of this area of learning include "receiving", "responding", "valuing", "organizing", and "characterizing". For example, the ability to perceive self and others accurately and the ability to identify, prioritize and act according to one's values belong to this affective domain. Overlooking the role that affective capabilities can play in the insight discovery process would limit our understanding of the full potential of insights for transformative and transdisciplinary learning.

The third aspect of the insight concept to be fully developed is to understand how insight discovery occurs in educational settings, rather than in closed experimental settings, as is the case for most studies (Ohlsson, 1984). These studies focus on factors that could be easily manipulated and quantified (i.e., Kaplan and Simon, 1990; Kuonios and Beeman, 2009) and therefore tend to emphasise the importance of cognitive capacities linked to insights. This study, on the other hand, takes place in a natural setting in which people interpret insights within a transdisciplinary and multicultural learning setting. We are therefore able to explore the group and affective components of insight discovery in tandem—aspects of insights often overlooked in the literature.

Methods

The concept of "insight discovery" was first developed within the context of a Bachelors level course at Swiss Federal Institute of Technology (ETH Zurich), known as "Tackling Environmental Problem Solving" (for more details of this course, see Pohl et al., 2020). Over 4 years of conducting the course, we observed that students' ability to understand complex systems, pinpoint key leverage points for transformation and to find viable solutions for problems was rooted in their capacity for the stage of problem solving that we identified as "insight discovery". As a result, the Transdisciplinarity Lab (TdLab) Winter School, a programme that was run for 10 years, was also the responsibility of the co-lecturer and co-curriculum developer of the original "Tackling Environmental Problem Solving" course. The co-lecturer saw the potential for deepening the concept of "insight discovery" by examining whether the concept is also relevant for researchers with a specific interest in transdisciplinary research. This paper is based on the experiences during the last year of this programme.

The goal of the 8-day TdLab Winter School was to help participants learn and apply concepts and tools from transdisciplinary research while working on a real-life issue of immediate interest to the local community. The topic was chosen by the mayor and community secretary ('Gemeindeschreiber') of the town together with the coordinators of the winter school. Seventeen Masters students, PhD candidates and postdoctoral researchers worked together with local community members from the small village of Wislikofen in Switzerland on the topic of "community amalgamation". The participants came from 13 countries, 10 universities and spoke more than 10 languages. The students stayed, worked and ate together in a former monastery (Propstei Wislikofen) which also serves as a center for community life in rural Wislikofen, about 1.5 h travel by train and bus from the city of Zurich. The Propstei served as the key meeting point for all workshops and events of the TdLab Winter School, such that all stakeholders knew where to find the group at all times.

The task of the participants was to design a "community interaction event" for the residents of Wislikofen and neighbouring villages that would help the local stakeholders in the process of community amalgamation in some way. This task was intentionally kept open to give participants the opportunity to apply the concepts and tools learnt during the course of the winter school. The community interaction event took place at the end of the TdLab Winter School. In the first four days, participants were asked to collect their ongoing learnings about the town and the theme of community amalgamation in Wislikofen through conversations with local stakeholders and visits of the surroundings. They made "rich pictures" of new information, which were image-rich system maps that connected pieces of information they were finding out about the topic, adapted from original use as a part of soft systems methodology (for more details see Checkland, 2000, pp. 22–23). They also had the opportunity to discuss their learnings with local stakeholders to check if their initial understanding was indeed correct. In the last 4 days, building on these learnings, groups were asked to identify the key insights that they thought represented the most important learnings they got from the first 4 days. They identified the stakeholders most affected by the agreed upon insight and the formed "problem statements" about the insight. Each problem statement named the original insight, who the stakeholder was and the particular need that the stakeholder had. This problem statement formed the motivation for the design of the "community interaction event". The lecturers used an ideation process from design thinking to help participants arrive at a final design. In parallel, the participants: (1) were introduced to concepts and tools of transdisciplinary research, (2) practiced moving out of

disciplinary silos by learning about one another's research projects, and (3) were introduced to joint problem framing, soft systems thinking and design thinking that serve as the foundation of integrated systems and design thinking (Pohl et al., 2020).

Data collection. During the programme, participants were asked to document and reflect on their learning and moments of insights with the help of an online insight journal. The following guiding question was provided to the participants in order to steer their reflection:

> "What was your AHA! Moment of today? If there was none, what was something new that you learned?"

Participants were asked to answer this question each day for the whole duration of the winter school as a journal entry on an online platform provided by the coordinator. Although strongly encouraged, there were no consequences if the participant chose not to fill out the journal. Each participant completed at least 6 out of the possible 8 entries. No participant voiced any concerns about keeping such a journal. Participants expressed interest in reading others' entries out of curiosity to learn what others' experiences were during the programme, thus entries were available to all participants, anonymized. The coordinator of the winter school informed the participants that the answers could potentially be used for research on insight discovery. The participants, whose qualitative quotes were used to illustrate the insight discovery process, were asked for permission prior to publishing.

This self-reporting approach allowed us to explore the nature of insights beyond a laboratory setting, as was also suggested by previous studies (Danek et al., 2014, p. 8). In that study, the authors stated that "there is a wealth of information to be gained through subjective self-reports". They recommend the use of such direct, qualitative self-reports as a tool to "learn more about the phenomenological aspects of insight problem solving" (Danek et al., 2014).

Data analysis. Insight diaries were sequentially analysed by all co-authors by identifying quotes relevant to the concept of insights and deriving categories by "open coding" (Strauss and Corbin, 1998; Flick, 2018). By differentiating these categories and relating them to each other, we could obtain an initial model for an insight discovery process. Finally, we went back to the most relevant citations and identified quotes for illustrating the core phases, as well as quotes that captured the entire process in which multiple categories of the latter could be identified.

Our choice to use personal journal entries, thus self-reports, for studying insight discovery processes presents learning opportunities and limitations. Since insights are discovery processes that are inherently subjective, internal and personal learning processes that cannot always be captured by an external observer—at least not in its entirety. Thus, such processes need to be reported by the individuals themselves. In addition, as insights are subjective, it is key to include the participant's interpretation of this process instead of exclusively relying on interpretation by third parties. A potential limitation of this approach are perceptual differences (Thomas et al., 2000), that is when participants have different definitions of 'insight' in mind when writing their journal entries. Nevertheless, this is in line with our perspective that insights can have different facets and mean different things to different people, which enriches our final definition. Additionally, the potential bias of social desirability (Edwards, 1957) may have influenced the journal writing process. The organizers tried to limit this bias by emphasizing that the journal entries were voluntary and anonymous, and ensured that they could be easily entered online.

We engaged with the perils of self-reporting by relying and balancing the multiple perspectives of analysis that each member of the writing team brings. The collective nature of this analysis is what Naomi Oreskes (2019, p. 104) describes as "the social processes of collective interrogation" which offers a means for conclusions to be arrived that is non-idiosyncratic, especially when those carrying out this interrogation form a diverse collective of many different professional and cultural backgrounds. For example, the concept of insight was described and analysed independently by each author. This was based on their diverse experiences (i.e., as previous winter school participants, as professional intermediaries, as coordinator and coaches of the programme). Although different in our training, disciplinary backgrounds (i.e., sociology, ecological economics, biology, microbiology, environmental chemistry) and experiences working at the boundary between science and practice. We looked for a common understanding of the insight discovery process. With multiple iterations between the data and the abstraction of the data, we reached an integrated framework that all co-authors agreed upon, which will be presented in the following section.

Results

Components of the insight discovery process. Based on the analysis of the insight diaries we were able to differentiate the insight discovery process into two states and three different phases. These are (Fig. 1):

State 1: Original mental model
Phase 1: Insight trigger
Phase 2: Liminal space (including reflection, re-framing and signal processing)
Phase 3: Insight formulation
State 2: Adapted mental model

We give a detailed description of each in the following paragraphs.

State 1: Original mental model. The original mental model represents the original state of knowledge before the introduction of any new experiences or information. It is an individual's mental representation of any situation before any new encounters. An individual's mental model is determined by their set of personal experiences, attitudes and prior knowledge, which defines the way in which an individual perceives, understands and frames a problem or a specific situation (Johnson-Laird, 1983; Morgan et al., 2002; Newell and Simon, 1972).

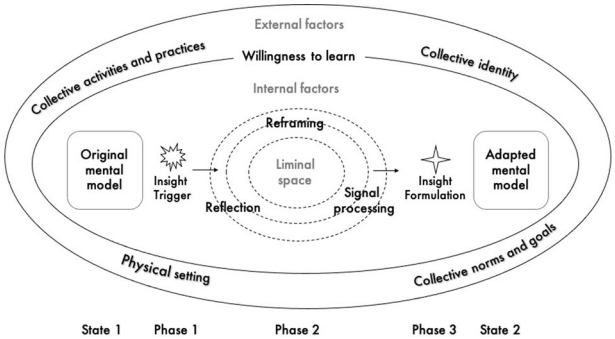

Fig. 1 The states and phases of the insight discovery process. The process begins with the original mental model (State 1), which is disrupted by an insight trigger (Phase 1), moves into a liminal space characterised by reframing, reflecting and signal processing (Phase 2), leads to insight formulation (Phase 3) which contributes to an adapted mental model of the problem or situation (State 2).

Phase 1: Insight trigger. The first phase of the IDP model is the trigger in which an 'AHA!' moment occurs. A trigger is caused by the acquisition and incorporation of new pieces of information, both individually as well as collectively (i.e. such as in a group), which challenges the current mental model. An analogy to a trigger is the concept of activation energy in thermodynamics. In order to initiate a transformation bringing a system to a more stable state, energy is required to "jump-start" the system. The trigger is information that does not fit into an existing mental model of an individual—leading to cognitive dissonance (Festinger, 1957; Aronson, 1969). This is the mental discomfort that arises from holding conflicting values, beliefs or attitudes. This tension can be relieved by rejecting, creating rationale for or avoiding new information. However, we propose that in the case where insights are discovered, individuals move towards a deeper reflection and exploration of this tension rather than avoid it. Klein (2013, p. 104) developed a typology for systematizing different (insight) triggers, the Triple Path Model: First, identifying contradictions can be an insight trigger. Klein noted that paradigm shifts qualify as insights because "the result is a shift from a mediocre frame to one that provides a better understanding of the same phenomenon" (p. 75). Secondly, Klein emphasizes the role of making connections. Connections happen when one receives new information and "sees how it combines with other information to form a new idea" (p. 41) or refers to a new combination of 'old' information and ideas. The third path is creative desperation and refers to brilliant ideas and solutions people come up with when they feel trapped in a troublesome situation. In order to do so, it becomes necessary to disarm flawed assumptions, which are trapping people in the first place (Klein, 2013).

Phase 2: Liminal space. The insight process is also characterized by the presence of a liminal space. In making the decision to leave the comfort zone, one acknowledges the limits of the original mental model. The individual is moving into "unchartered territory" at this point. The process requires time, is challenging and can be associated with contrasting emotions, including those of uncertainty or ambiguity. The need of individuals to feel safe and supported during their time in the liminal space is important (Freeth and Caniglia, 2020; Förster et al., 2019).

> "It is exactly this discomfort that opens room for new insights— leaving your comfort zone as a crucial prerequisite for learning processes" (Winter School participant A, 2020).

The liminal space requires a willingness to learn which underpins three sub-phases, which are reflection, re-framing and signal processing, all of which are conceptually distinct, yet intertwined. Willingness to learn has been defined as an individual's psychological state, which shows a desire to learn new things and an impulse or readiness to acquire new knowledge (Hotifah et al., 2020). In psychological studies, it has also been associated with the high value that students attribute to tasks (Gorges et al., 2013). Additionally, it is a student's "… engagement with, and appreciation of, the values and ideologies that go along with the discursive structures of educational activities." (Cekaite, 2012, p. 643). In this framework, we understand the "willingness to learn" as the setting within which the other elements of the liminal space take place. Hotifah et al. (2020) identified that the factors affecting willingness to learn, repeatedly found across studies, include "internal" factors of individual attitudes and personality, as well as "external" factors of family and school environment.

We explore in more detail the three processes that are a part of the liminal space:

- *Reflection*: This is the process of questioning, carefully examining and evaluating one's own assumptions. It requires the individual to make their implicit assumptions explicit in the first place. While reflection is a prerequisite for re-framing, it does not automatically lead up to it. The reflecting individuals can either arrive to the conclusion that their assumptions hold in sight of new information and experiences (and will be even more confident about them) or conclude that they need to be adjusted. In the latter case, reframing can take place (Schön, 1992).

> "Keep asking 'why' is key for obtaining interesting observations […]. Formulating problem statements is an exercise of making the implicit, explicit." (Winter school participant B, 2020)

- *Problem reframing and iteration:* This is the process of iteratively re-adjusting one's assumptions or perspective on a problem situation or topic. Reframing occurs when individuals conclude that their original mental model (i.e. assumptions and beliefs) has become inadequate for understanding a problem situation or topic. Individuals try to assimilate new information into existing knowledge structures. This process can be uncomfortable (letting go), joyful (relieve) or a mix of both. Reframing is a nonlinear process requiring time, repetition or several loops until a new frame emerges (Pearce and Ejderyan, 2019).

> "We are following a non-linear path, overall converging on an outcome but with individual, iterative phases/steps which diverge (opening up) and converge (zooming in)." (Winter school participant C, 2020)

- *Signal processing*: This is the means by which individuals try to make sense of the external 'signals' the individual is exposed to while they are in the liminal space and making the shift between the original and the adapted mental model. These signals can be, for instance, new information, indicators from other individuals that the individual is on the "right track". These signals encourage the individual to continue the search for clarity within the liminal space.

> "It is essential to test your ideas iteratively with different people to discover your blind spots or implicit assumptions that participants might or might not share" (Winter school participant D, 2020)

Phase 3: Forming insights. The third phase of our model is the formation of an insight—this is a moment of clarity and newfound understanding, which leads to a shift in an individual's mental model. This phase is often characterized by a strong positive feeling of accomplishment and concludes with the formulation of knowledge that is understood and shareable by the individual. The formation of an insight is comparable to a threshold concept. Insights, like threshold concepts, are concepts that, once understood, transform the perception of a given phenomenon or subject (Meyer and Land, 2005). Once an individual has formed an insight, they cannot go back to seeing the problem space from their old mental model and will make use of a new adapted mental model to think about a problem or situation.

> "…I got to see the land and understand the place from a geographical point-of-view and how that could impact on the mindset of the community. I also think that gives an insight into the current concerns that have come up for the community of Wislikofen […] This experience was

somewhat like an outer body experience." (Winter school participant E, 2020)

State 2: Adapted mental model. Once an insight has formed, individuals enter a new state of knowledge. With a formed insight, the individual is able to apply and adapt their new knowledge. In this phase participants have an adapted mental model of the problem space, that incorporates the insight(s) gained. Going forward, this adapted mental model will replace or enrich the previous original mental model to assess future problem situations that are relevant to the topics covered by the mental model.

Non-linearity of the IDP. The iterative analysis of the winter school participants' insight diaries revealed that insight discovery entails going through three dynamic phases, followed by the emergence of a new mental model. Our analysis reveals that these sub-processes of the liminal space, i.e., reflecting, reframing and signal processing, do not necessarily occur in a linear manner. Some diary entries described these sub-processes in a well-defined order, but others did not. Of the latter, we made three core observations: (1) multiple sub-processes can occur concurrently and might repeat themselves iteratively; (2) not all participants described all of the identified sub-processes of the liminal space explicitly in their diaries and/or different participants assigned more importance to one sub-process than to another; (3) the diaries suggest that not all participants necessarily arrived at an insight that led to a new, adapted mental model. Therefore, entering the liminal space alone does not guarantee the formulation of a new insight.

The following journal entries by two Winter School participants exemplifies these three observations (also visualized in the figures in Example A and B):

Example A:

"Having done the reading before coming to the Winter School I felt like I had a good grasp of what [the programme] and transdisciplinarity meant [original mental model]. However, after today's 'fish bowl' session [trigger], I felt I left feeling more confused and having more questions than answers [liminal space]. So I felt like I did not contribute as much as I would have liked to. For me, my whole career and the way I approach life I feel I have the 'Td spirit' but I want to consolidate this feeling into something more tangible in the days to come [willingness to learn]. I am happy that this is a safe environment to share ideas and questions for when I am ready [external context—collective norms, collective practices].

(Winter school participant F, 2020)

Example B:

"Slowly throughout the days, I began to think of myself as a researcher [adapted mental model] and not a passive student [original mental model]

The focus started to widen to include me as an active and important actor to be observed and cared for throughout the process [liminal space—reframing].

As such, I also have different levels of involvement in the process, and also different levels of interaction with other actors [liminal space—reflection]:

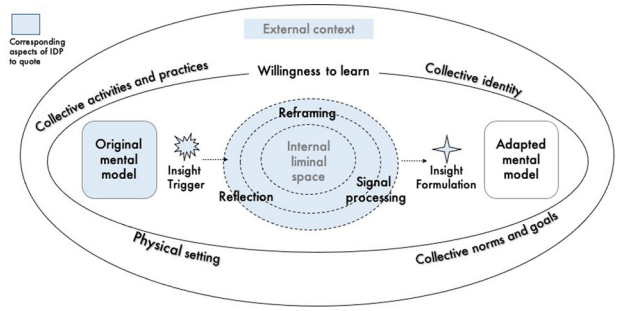

Fig. 2 Applying the insight discovery process for Example A.

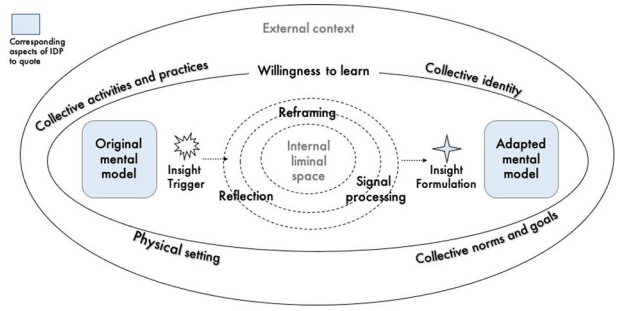

Fig. 3 Applying the insight discovery process for Example B.

sometimes the process requires a high intensity of engagement and sometimes more quiet times for me as a researcher to process the information and connect the dots [liminal space—signal processing].

I understood that the graph of varying degrees of involvement is not only a cold and rational representation of tools and stages [original mental model] but rather a flow of energy among people throughout a process [formed insight]."

(Winter school participant G, 2020)

Both examples display multiple stages and phases of the insight discovery process within a single journal entry. Noteworthy of these examples is that the recognition of the initial state of knowledge occurs only after reaching the formed insight. This demonstrates a non-linear process of learning. By going through the IDP and reaching a new state of knowledge, individuals are able to acknowledge how the original mental model could be adapted and enriched through interaction with others' perspectives and new information. This process requires reflection and assimilation before it can proceed further (Figs. 2 and 3).

Enabling conditions for insights discovery process (IDP). The IDP is dependent on both individual, internal factors as well the collective, external context. The *enabling conditions* for the IDP, then, stem from both these internal and external factors. The internal enabling condition is the willingness to learn. This condition creates the openness for reflection, reframing and signal processing. Without such a willingness, the act of exploring an uncertain and sometimes uncomfortable liminal space seems unlikely. When students are willing to learn new things, we assume that they are also more open to accepting and assimilating new insights. The question remains—what factors might affect this willingness to learn? In this paper, we posit that this willingness is only in part a function of *individual* desire and

circumstances, but rather also results from a set of external factors which make it more likely for an individual to cultivate this willingness. We define these as the external enabling conditions of the IDP.

These external enabling conditions can be broadly categorized in how an individual relates to: (1) the physical environment in which the learning is taking place; (2) the collective identity, collective norms and goals shared by those taking part in learning and teaching activities; (3) the specific types of activities and practices that are taking place and available tools to carry out the learning. The combination of the enabling conditions then creates a safe space that is important in the insight discovery process.

Various authors have shown that the physical setting of the learning environment has a significant effect on the ability of learners to foster critical thinking, social skills and creativity (Jindal-Snape et al., 2013; Lippman, 2010; Weinstein, 1979). The responsive approach in the design of learning environments, for example, recognizes the contribution of the physical setting and could contribute to "a culture of inquisitiveness" (Lippman, 2010; Altman, 1992). The physical setting of the TdLab Winter School, for example, was at a monastery-turned seminar hotel located in a small, rural village that serves as the centre of community life and activities. The participants shared rooms in pairs during their stay. Wislikofen is situated amongst farms and rolling hills, providing a possibility for students to spend time outdoors and to explore the landscape. In the evenings, students socialized in the former monastery cellar where local beer and specialities were available.

The setting served as a retreat from the normal routine of participants' usual academic life at a university. They were led on a tour of the village by local residents and sometimes even spent time at the local bar. The residents were invited for cake and coffee at the hotel as a part of the programme. This intimate setting enabled participants to form bonds with each other and with local residents.

Collective norms and goals are also a part of the enabling environment. These norms and goals are collective through the sense of purpose and mission shared by the individuals in the group. The idea that the individual is affected, and affects, the system in which one is a part of belongs to practice theory (Bourdieu, 1972; Giddens, 1984). Social phenomena are not only the result of individual intention alone, but rather also mediated by the collective structures and norms by which individuals are conditioned. This is in line with critical realism, which emphasizes the dialectical and dynamic interplay of agency and structure (Archer, 1995). It is this complex entanglement of the individual and the collective (and collective artefacts) that contributes to the social outcomes that we are able to observe. The social identity model of pro-environmental action (SIMPEA) (Fritsche et al., 2018) posits that individual actions are driven by identity, but that identity is determined collectively, through the individual linking to collective norms, goals and emotions. The IDP acknowledges the permeable boundary between the individual and the group such that the group context mediates insights reached by the individual. The TdLab Winter School sought to create a collective identity as a group of researchers and scholars more interested in listening than telling. The collective identity was that of facilitating a process in which we share with them transdisciplinary tools for stakeholder engagement that the participants are also learning about during the Winter School. The collective norms and goals included valuing listening over speaking, encouraging reflection of oneself and the situation, encouraging the questioning of one's own assumptions and firmly held beliefs and to the welcoming of uncertainty by staying flexible and adaptable to changing situations.

To encourage the willingness to learn, specific activities and practices were implemented, and were a part of the enabling conditions. The diversity of the participant group itself made it possible that all were confronted with foreign languages, cultures different views and unfamiliar topics. These participants, coming from all over the world, suddenly landed in a small Swiss village where they were exposed to its social, political and economic developments and related apprehensions and aspirations by its residents. With the help of Swiss participants and simultaneous translation, we encouraged participants, also those who did not speak German, to communicate and connect with those whom they would normally not be comfortable speaking. Additionally, the daily practice of journaling helped to create the norm of reflection as a part of growth and becoming more comfortable with being in the liminal space. Kligyte et al. (2019) proposed that these so-called third spaces can emerge when the enabling practices and conditions are present. "Such processes can be encouraged, tended to, and guided, but are usually spoilt if attempts are made to control them" (Hasan, 2014 in Kligyte et al., 2019, p. 15).

Other tools introduced to the participants, such as the use of rich pictures, systems thinking, joint problem framing and design thinking encouraged them to see stakeholder engagement as a means not only to draw out information from people in the community, but as a means of creating dialogue and understanding. All tools were focused on helping participants to get to the heart of complex problems, based on using a variety of mediums, rather than tools such as modelling or scenario analysis, that operates more on scientific data and knowledge rather than a bottom-up understanding of human interests. We made use of the methods and tools from the td-net toolbox (https://naturalsciences.ch/co-producing-knowledge-explained/methods/td-net_toolbox), an online resource for co-producing knowledge.

In creating the enabling conditions of the IDP from the physical setting, collective norms and goals and putting into place specific practices and activities, we are able to encourage learning processes by creating a safe space that allowed the participants to come out of their comfort zone (Fry and Thieme, 2021). That this, the importance of the safe space is not only supported by our own experience, but also in the literature: "To develop attitudes and values enabling them to address real-world sustainability issues, students need a "safe space" where they can experience the emotional learning edge that triggers transformative learning moments through disruptive learning" (Trechsel et al., 2021, p. 2).

The safe space is important when experiencing a disruption of what one is used to or comfortable with. There are strong emotions first of shock, uncertainty as well as denial (Förster et al., 2019). A safe space allows the students to share what they are really thinking and to be vulnerable, without the burden of judgement. This safe environment—an atmosphere of openness, cooperation, collaboration, creativity and mutual appreciation are important external enabling conditions which, combined with the willingness to learn, helps manoeuvre through the liminal space and helps to enter the phase were the individuals can formulate their insight. This is also in line with Pohl et al. (2021) and Boix Mansilla et al. (2016), who emphasize that integrating diverse perspectives include not only a cognitive dimension, but also its interplay with emotional (e.g. mutual respect) and a social dimensions (e.g. climate of conviviality).

Discussion

Why do we care about insights? What are the implications of the insight discovery process (IDP) for inter- and transdisciplinary research and learning? Our paper proposes three main implications for the concept of the IDP:

1. The IDP can be a key process for confronting social dilemmas.
2. The IDP is an important aspect of knowledge integration expertise for inter- and transdisciplinary collaboration.
3. The IDP can aid transformative learning.

Each of these implications are discussed in more detail below.

Insight discovery process for confronting societal dilemmas. The IDP has an important role in addressing sustainability and climate change challenges, particularly in mobilizing change through social innovation (Hoppe and de Vries, 2018) at the individual and community level. As mentioned at the opening of the paper, these problems can be referred to as "wicked" problems (Rittel and Webber, 1973). The problem is dependent on the perspective of the one experiencing the problem, meaning that there is little agreement on what the problem is. This means that the solution or the means by which to arrive at a solution is also open-ended (Rittel and Webber, 1973; Dörner and Funke, 2017; Alford and Head, 2017). The IDP can be of particular importance for these problems because it presents a process showing how different points of view can be integrated and accepted. With the IDP, we are able to see how we, as transdisciplinary researchers and practitioners, can create external conditions that foster the willingness to learn between stakeholders in a real-world problem. Integrating diverse perspectives through insights can enable, for example, transformation processes in the energy transition. For such a social challenge, communities have the complex task of being able to bridge the global challenges of climate change with diverse local needs and perspectives. For instance, some people might see renewable energy projects as a viable investment, but some may resist change as an immediate financial burden requiring difficult trade-offs in household spending. Energy technology and service providers may have specific interests and expert knowledge in either keeping or changing the current energy system for decarbonization. Diverse insights can sometimes pull initiatives apart but the IDP process can facilitate the creation of a new collective mental model by helping to find overlaps across different stakeholders. Currently, the research project Energy Citizens for Inclusive Decarbonization (ENCLUDE) (http://www.encludeproject.eu), an H2020 research project, has an application of the IDP to explore the potential for scaling up new energy citizenship initiatives while considering the internal and external context.

The insight discovery process and inter- and transdisciplinary knowledge integration. There are two means by which the capacity for IDP assists with knowledge integration for inter- and transdisciplinary collaboration. First, the mindset needed for the discovery of insights is similar to that needed for carrying out inter- and transdisciplinary knowledge integration. According to Augsburg (2014, p. 240), transdisciplinary researchers need to have "curiosity about, and willingness to learn from other[s]", to be able to "think in a complex, interlinked manner" and use "creative enquiry", the capacity to suspend "one's own point of view", and have the ability to "acknowledge the pain inherent in abandoning one's intellectual comfort zone". These requirements of having a curious and open mind, thinking critically and being persistent are what we also observed as needed for going through each phase of the IDP. Insight discovery processes are key to inter- and trans-disciplinary research (ITDR) as they help people leave a fixed frame of reference (i.e., their mental model, influenced by their disciplinary silos), and allow them to engage in new ways of thinking and create new knowledge (Godemann, 2008; Defila and Di Giulio, 2015; Pohl et al., 2021).

Second, the formulation of insights requires going beyond routine knowledge acquisition from within a single field, making it inherently an inter- and/or transdisciplinary process. In the process of sense making that is a part of arriving at insights, there is a requirement to bring together elements of one's understanding, which have diverse origins. This also requires stepping outside of academic thought itself. The integrative nature of insights is what contributes to the emergence of a bigger picture and allows a team or group to bridge diverse perspectives and knowledge fields. In these inter- and transdisciplinary processes there is an aim at creating something larger than just the sum of its parts, where an enquiry of separate parts leads to an emergent understanding of the whole. This is especially relevant for university students transitioning into the 'future' workforce, where some of the predicted skills for 2025 include: analytical thinking and innovation; complex problem solving; critical thinking and analysis; creativity, initiative and analysis; reasoning, problem solving and ideation (WEF, 2020).

Insight discovery process and the transformative learning theory. The IDP is a means for transformative learning. Mezirow (1996, 1997) developed a theory of transformative learning with the purpose of designing adult education. He describes the adult learning as a process where the "frame of reference" is changed, synonymous with the "mental model" in the IDP. Mezirow (1997) explains that for adults, these frames define their world, made up of concepts, values, beliefs and conditioned responses. He further argues that these frames can be transformed through critical reflection when actions dictated by this frame of reference become problematic or fail in some way. It is exactly this process that the insight discovery process (IDP) tries to uncover. Mezirow also refers to "reflective insights" (Mezirow, 1996, p. 163) and implies that these insights are the products of critical reflection. The concept of the liminal space within the IDP can be linked to the need of a "critical reflection" for transformation to occur in the transformative learning theory.

Both transformative learning and the IDP approach learning from what Jürgen Habermas (1981) refers to as the communicative mode of learning and engagement for problem solving. Communicative learning is collective, involving at least two people, and includes learning about the meaning of an interpretation or the justification of a belief. Communicative learning is aimed at not only learning the "what" of a situation, but also the purposes, values, beliefs and feelings which belong to a set of facts and not revealed by the facts alone. Transformation is enabled when we are able to change our frame of reference, or mental model, through critical reflection of our habits of mind and points of view. The concepts of the mental model, liminal space and problem (re-)framing all find parallels within the transformative learning theory (see also Fry and Thieme, 2019). Therefore, the IDP could be a means to understand how transformation occurs in learning.

The IDP has been built into an award-winning transdisciplinary curriculum ("integrated systems and design thinking") for transformative learning for Bachelors students in the Department of Environmental Systems Science at ETH Zurich. To date, it has been introduced to more than 1000 students in Switzerland.

Conclusion

Traditionally, institutions of higher education have been organized around providing students with the competences to succeed in individual disciplines rather than to have the capacity to solve problems in the real world. However, there is growing recognition that higher education should impart both skills needed for conducting high quality research, as well as for solving wicked

sustainability problems in our societies. In this article, we argued that insight discovery is a key competence for: (i) conducting inter- and transdisciplinary research; (ii) eliciting transformative learning; and (iii) addressing wicked problems and societal dilemmas. We proposed a non-linear, dynamic and interactive model to advance the understanding of insight processes with regard to these three key areas. We went beyond a classic laboratory setting and based our analysis of insight journal entries, created by winter school students in a group learning setting. This model for an insight discovery process consists of three different phases-—the trigger, liminal space and insight formation—culminating in a peak transitional experience leading to a new state of "knowledge". When undergoing these phases, it requires not only cognitive abilities (linking different concepts or ideas), but also affective abilities (dealing with uncertainty and ambiguity) as it requires individuals to leave their comfort zone. We showed that, despite being a very subjective experience, insight discovery processes do not take place in a vacuum and need to be understood in relation to their physical and/or group settings. Hence, insight discovery can be enabled or hindered through external factors. For instance, creating a safe environment to share new ideas, providing sufficient space to explore different points of views and encouraging people to go beyond their current mental model with the help of different tools and methods are conducive for an insight discovery process. These external factors can then facilitate leaving fixation and arriving at a new, adapted mental model.

We believe that by providing a clear IDP model and showing the integrative and transformative potential of insights, this article can support other transdisciplinary researchers and instructors in enabling insight discoveries in their own projects, programmes or university courses.

Data availability

The datasets generated and analysed during the current study are not publicly available due to the personal nature of the statements provided, but may be partially available from the corresponding author on reasonable request, with the consent of affected data subjects.

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Competing interests

The authors declare no competing interests.

Ethical approval

The study was an unplanned research project and therefore could not have fit into the ethical approval framework provided by the home institution(s) of the authors, all of which are created for planned research proposals. In addition, the format by which information was collected from research participants did not fit into the categories provided by the home institution(s) (e.g. in the form of an online journal, rather than survey (online), smartphone-based data collection, interviews/group discussions, physical exercises, or clinical trial abroad). Additionally, the usual ethical approval procedure could not be applied because no participants were recruited, but rather a part of a pre-existing educational group. The inclusion and exclusion criteria were therefore not set up for research purposes, but rather for learning purposes. However, we followed the principles embodied by the Declaration of Helsinki in protecting the individual and his or her right to self-determination and the right to make informed decisions, taking the subject's welfare over the interests of science and society. All personal data was anonymized and the data secured in a local institutional server. Only authors have access to this data. The data will be archived up until 2 years after the article is published.

Informed consent

As all participants of the research were a part of a pre-existing educational group, and not recruited for the purpose of research, we discussed the possibility of the unplanned research together to arrive at a consensus of allowing the use of anonymized online journal entries, when it became evident that this was a possibility. Informed consent was then received from all individuals involved and quoted in the article. The goal of the work was explained to all participants and they were supportive in the concept of the research article.

Additional information

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