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Developing a Functional Food Systems Literacy for Interdisciplinary Dynamic Learning Networks

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The impact of human activity on the planet cannot be understated. Food systems are at the centre of a tangled web of interactions affecting all life. They are a complex nexus that directly and indirectly affects, and is affected by, a diverse set of social, environmental and technological phenomena. The complexity and often intractability of these interactions have created a variety of food-related problems that people seek to address in a collaborative and interdisciplinary manner through the adoption of a holistic food systems perspective. However, operationalising a systemic approach to address food system challenges is not a guarantee of success or positive outcomes. This is largely due to the partiality inherent in taking a systems perspective, and the difficulty in communicating these different perspectives among stakeholders. A functional food systems literacy is therefore required to aid people in communicating and collaborating on food system problems within dynamic learning networks. The Interdisciplinary Food Systems Teaching and Learning (IFSTAL) programme has been operating since 2015 as a social learning system to develop a food systems pedagogy with a range of multi-sectoral partners. The findings in this paper arise out of iterative reflexive practice into our teaching approach and delivery methods by former and current staff. In order to foster integrative engagement on food system challenges, we propose and define a functional food systems literacy—a theoretical minimum that can aid diverse stakeholders to explore and intervene in food systems through more effective communication and collaboration. Derived from a reflective analysis of instruments and methods in delivering the IFSTAL programme, we provide a framework that disaggregates functional food systems literacy according to four knowledge types, and includes examples of skills and activities utilised in the IFSTAL programme to support learning in these different domains. We argue that claims to comprehensive food systems knowledge are unrealistic and therefore propose that a functional food systems literacy should focus on providing a means of navigating partial claims to knowledge and uncertainty as well as fostering effective collaboration. We believe that this will enhance the capabilities of stakeholders to work effectively within dynamic learning networks.

Keywords: food systems, food systems literacy, interdisciplinary teaching, interdisciplinary learning, dynamic learning networks

INTRODUCTION

As a basic human need, food is at the centre of many complex webs of interaction and activity, which affect all life on the planet (Rockström et al., 2020). These webs of food-focused activity can be described as "food systems," which the Food and Agricultural Organisation (FAO) considers to "encompass the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry or fisheries, and parts of the broader economic, societal and natural environments in which they are embedded" (FAO, 2018). These activities are often distilled down to four basic steps of (i) producing, (ii) processing, (iii) packaging and distributing; and (iv) retailing and consuming food; waste and disposal may also be considered (Ingram, 2011). These activities lead to a set of outcomes that include food and nutritional security, environmental sustainability, and socio-economic well-being. What is crucial is that these activities have variable and undesirable outcomes, an activity that may be "good" for food security, may also benefit other socioeconomic and/or environmental outcomes, or conversely it may be detrimental to them.

There are numerous representations of food systems depending on the observer and their individual framings that may change over time [e.g., GECAFS, 2005; Ingram, 2011, 2020; Stuckler and Nestle, 2012; Gustafson et al., 2014; Tendall et al., 2015; Parsons and Hawkes, 2018; Global Panel, 2020; SAM (Scientific Advice Mechanism), 2020; Kennedy et al., 2021]. The number of components, processes, and range of interactions between parts of a food system and other subsystems give rise to complex behaviours (Ingram, 2011; Tendall et al., 2015), but also make it difficult to analyse synergies and trade-offs (Ingram, 2011), communicate what a food system is, and even what a person means by the term. Difficulty in describing and explaining food systems is further compounded by trying to plan, coordinate and implement intervention strategies potentially across multiple scales and diverse stakeholder groupings (Ingram, 2011). Because a person can only ever see a partial representation of the system, and people have different skills, capabilities and interests, there is a tendency to work in silos, generating unintended consequences and missing genuine system-based solutions. So far, a siloed way of working and learning has led to a food system that is vulnerable and greatly impacted by extreme events, such as severe weather, earthquakes, and pandemics (Gaupp, 2020). The food system's size and reach mean that it has major impacts on the economy, society, politics, health and the environment (Lang et al., 2009). Profit is commonly a major driver at all levels of operation (Stuckler and Nestle, 2012; Sanderson Bellamy, 2018), but is often counteracted by new rules, norms and regulations or social movements and boycotts that aim to promote a healthier and more sustainable system. Nevertheless, ongoing systemic problems like food insecurity, public health, and climate change continue to worsen.

To link people in the food system and expand knowledge collectively in a more holistic manner, different ways of learning are needed to give people the tools and skills to tackle food system challenges. These needs have been clearly recognised and described by several groups of authors, such as Ericksen (2008), Ingram (2011), Ison and Straw (2020), Ingram (2020), Krathwohl (2002), and Valley et al. (2018). Scientists, researchers, policymakers, and citizens are seeking to address food system challenges in a collaborative and interdisciplinary manner through adopting a holistic food systems perspective (Tu et al., 2019). "Interdisciplinary learning" is different from "integrative learning". The latter entails generating a curriculum and working environment where students can integrate their learning and make connections across different contexts and time periods (Huber and Hutchings, 2004). Interdisciplinary learning, in contrast, is a way for learners to understand multiple sources of knowledge (e.g., from different disciplines and areas) and find a way to integrate them to generate understanding and new knowledge. Typical competences to be achieved are an ability to synthesise, an appreciation of diverse perspectives, and flexible, critical thinking. While several interdisciplinary learning programmes exist for topics such as health and water, food systems present a wider cross-sectoral challenge that cannot be covered by one discipline or institution alone. Institutional structures often have established knowledge silos (Ebel et al., 2020) with theoretical concepts and specialisms in distinct areas of the food system. There are further challenges for institutions to integrate experiential learning and workplace or sector knowledge into their programmes, which are known to provide relevant and meaningful learning opportunities (Parr and Trexler, 2011). The latter are essential in transdisciplinary learning, where knowledge from all areas of a system is integrated and linked to real-life challenges, and learners ensure that the knowledge produced is valuable to a wide range of actors within the system (Tàbara and Chabay, 2013).

Co-production of learning programmes with actors in the food system, and the appreciation of other types of knowledge beyond academic knowledge are emerging as two practical and ethical principles to achieve food system sustainability (Ison, 1990; Francis et al., 2013). However, operationalising a food systems approach to address food system challenges is not a guarantee of success or positive outcomes. This is largely due to the partiality inherent in taking a systems perspective, and the difficulty in communicating these different perspectives among stakeholders. Simply incorporating diverse stakeholder perspectives is not enough to plug knowledge gaps and studies need to go further than simply describing generic food systems' constituent parts and relationships as outlined in food systems frameworks such as GECAFS (2005) or SUSFANS (Gustafson et al., 2014). These gaps need to be bridged by ensuring that anybody working in the food system can be food systems literate, i.e., have a basic set of skills and knowledge that can facilitate effective interdisciplinary approaches. Such a food systems literacy needs to build on an innate systemic sensibility (Ison and Straw, 2020)—the ability to be aware of and engage in relational thinking. This is distinct from literacy as a technical competence, or food literacy that tends to focus on strengthening dietary resilience over time (Truman et al., 2017). A functional food systems literacy is required to aid people in communicating and collaborating on food system problems within dynamic learning networks. These are networks "formally or informally set up for the primary purpose of enabling any kind of learning to take place over the time for building capabilities, managing change [...]" and have the ability to adapt their learning based on changing needs (Romano and Secundo, 2009, p. 6). The learning targets are defined by the network, adaptation mechanisms exist, boundaries for participation are defined, and network structures enable participative learning (Romano and Secundo, 2009).

While everybody working in food systems should have opportunities to acquire a food systems literacy, the obvious starting point for food system education is the existing education system. Early knowledge acquisition benefits people throughout their careers (Allen and van der Velden, 2009). Increasingly, tertiary educators, particularly in the fields of sustainable agriculture, environmental sciences and health are calling for pedagogies that are interdisciplinary, co-creational, problem solving and skills-based, and include systems thinking approaches which aim to develop learners into competent change agents (Galt et al., 2013; Reed et al., 2017; Brekken et al., 2018; Carr et al., 2018; Klaassen, 2018; Valley et al., 2018; Ingram et al., 2020). Whilst there is no one framework for achieving this, sharing best practice facilitates learning across disciplines and institutions. To foster integrative and effective engagement on food system challenges we propose to define a functional food systems literacy—a theoretical minimum that can aid diverse stakeholders to explore and intervene in food systems through more effective communication, mutual understanding and collaboration.

We provide a framework that disaggregates functional food systems literacy according to four knowledge types (Krathwohl, 2002) and include examples of skills and activities that can be used to support learning in these different domains. While the proposed literacy has been developed specifically for food systems, its core elements can be customised to support stakeholder collaboration on other complex adaptive systems. With these goals in mind, this paper is structured as follows. The section A Framework for Food Systems Literacy—a Functional Minimum elaborates on our proposed framework for food systems literacy, setting out the four forms of knowledge on which the idea is based. The section Developing Food Systems Literacy—the Example of the IFSTAL Programme provides an example of this framework in action by using the example of the Interdisciplinary Food Systems Teaching and Learning (IFSTAL) programme, working with hundreds of postgraduate students from across seven different UK higher education institutions between 2015 and the present day. This section also covers the method followed to assess the evaluation of IFSTAL activities against the food systems literacy framework proposed. The section Discussion reflects and draws conclusions on the key learning points from our experience of running the IFSTAL programme in terms of the extent to which it has engaged with, and enhanced, different forms of knowledge about the food system.

A FRAMEWORK FOR FOOD SYSTEMS LITERACY—A FUNCTIONAL MINIMUM

Valley et al. (2018) observed that a food systems pedagogy should disrupt the usual ways of learning and acquiring knowledge, and question how knowledge is being generated, who holds it and how it is evaluated. Further, they stated that students should have a good awareness of their skills and different cultures of learning and knowing, be able to discuss the limitations of academic knowledge, and embrace and handle pluralism. These are also important cornerstones of transdisciplinarity, where multiple sources of knowledge and experience are used to co-produce new knowledge, usually focusing on challenges of the real world, and using collaborative processes that include actors from government, industry, NGOs, academia and the wider society. Because of the combination of different perspectives and integration of knowledge across actors and sectors, a high level of reflectiveness is also required.

In considering food systems, we are confronted with a vast domain of different knowledges, disciplines, facts, constituent parts, relationships, and competing perspectives and priorities (Cabrera et al., 2008). Food systems can therefore be confusing to navigate, especially when we consider that, as humans, we are not omniscient or omnipotent—there are limits to what we as individuals can know or do. It can be helpful to think of these limits in the following terms:

1. *Limited knowledge*—we cannot know the totality of the potential information of any given food system we choose to define (Ulrich, 1993).
2. *Limited cognition* (processing and bias)—of the information that we do know, we can only consider a limited range of information in our working memory (7 ± 2) (Miller, 1956), much of which is subject to bias and processing errors (Haselton et al., 2015).
3. *Limited agency* (ability to intervene)—depending on the individual or organisation, there are limited degrees of freedom with which to intervene in a system, and even

then the desired end result may still not be realised (Otto et al., 2020)[1].

These limitations exist whether we like or choose to engage with them or not. Each of the three limitations points to a need to collaborate and communicate well with others. If we have incomplete knowledge, we should engage with others who can help us to fill in the picture. If we are uncertain about our cognition, we need to check its congruity with others. If we are to overcome our individual limited agency we need to work well with others in the food system to effect change.

Given that our individual understanding of food systems can only ever be partial, when we try to communicate with other people about food systems, we find that we might not be referring to the same thing (Midgley, 2000). People may use the term "food system" in a variety of different ways:

- **1**—they refer to *the* food system, but what they really mean is the food system that appears to them - a composite of information derived from their personal and professional histories and worldview.
- **0**—they believe there to be no such thing as a truly knowable food system, so the term, as it is commonly used, is at best meaningless and, at worst, potentially misleading.
- ∞—they understand that there are as many different possible food systems as there are minds to perceive them, and perspectives or viewpoints to selectively present them.

While all three positions are potentially valid, if we are to use the food system term, we have to find a way to accommodate these differences in order to arrive at a shared understanding of what we are talking about or referring to. In systems thinking, this is referred to as the interrogation of boundary judgements through the process of boundary critique (Ulrich, 1996, p. 15; Helfgott, 2018, p. 855). Boundary judgements involve making explicit to all concerned the facts and values that are to be considered, and those to be left out of the system in question (*Ibid.*). It also involves recognising and declaring the positionality of all relevant stakeholders who are analysing and attempting to intervene in the system, or who will be affected by the intervention.

Building on the definition of systems literacy (Ison and Straw, 2020) as "the extent to which systems concepts, traditions, methods, and approaches are appreciated and understood by a practitioner", we define food systems literacy as the degree of competence that an individual has with respect to analysing, communicating about and intervening in food systems. This definition implies that there is a scale of literacy with a minimal set of criteria denoting a functional food systems literacy, or minimal level of competence, at one end and a high degree of capability or expertise at the other.

A food systems literacy is functional if it allows individuals to understand and engage in food system analysis and intervention activities with others. In order to do this, and foster collaboration, participants need to understand that different people see the food system differently and have their own ways of navigating this intersubjectivity. This understanding is particularly important for diffuse networks of food system actors to coordinate and cooperate with each other. The food systems literacy enables transdisciplinary work and collaboration across food systems to support food system change.

Given the limitations and partiality involved in thinking about food systems, a functional food systems literacy can help individuals to know what knowledge is essential to facilitate discourse and cooperation between different actors working on food systems issues. As people seek to collaborate with others on issues that they cannot solve at an individual or organisational level, we envisage the community of people working on food system issues as an informal dynamic learning network, which seeks to understand not only the nature of food system issues but novel ways of developing better food system outcomes.

Learning concerns processes involved in the acquisition, use and reflection of knowledge. Krathwohl (2002) describes four different categories of knowledge based on Bloom's Taxonomy: factual, conceptual, procedural, and metacognitive (**Table 1**).

The content and types of food systems knowledge that will be useful will vary depending on the individual, their personal and professional backgrounds, and the situation they find themselves in. A functional food systems literacy therefore must provide a framework that allows for effective integration of knowledge across disciplines and interaction between actors within the food system. To that end, we conceive of there being different knowledges and skills that when used together can help facilitate collaboration between stakeholders, while also allowing different perspectives to be surfaced, explored and incorporated into

TABLE 1 | Structure of the knowledge dimension of Bloom's revised taxonomy.

Knowledge type	Description	Knowledge subtypes
Factual	The basic elements that students must know to be acquainted with a discipline or solve problems in it	• Terminology • Specific details and elements
Conceptual	The interrelationships among the basic elements within a larger structure that enable them to function together	• Classifications and categories • Principles and generalisations • Theories, models and structures
Procedural	How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods	• Subject-specific skills and algorithms • Subject-specific techniques and methods • Criteria for determining when to use appropriate procedures
Metacognitive	Knowledge of cognition in general as well as awareness and knowledge of one's own cognition	• Strategic • Cognitive tasks, including appropriate contextual and conditional knowledge • Self-knowledge

Source: Krathwohl (2002).

[1]See also Ashby's Law of Requisite Variety: the degree of control that one has over a system is relative to the amount of information on it that you have (Ashby, 1958).

TABLE 2 | Overview of the proposed functional food systems literacy comprising four levels of knowledge.

Knowledge type	Functional food systems literacy	Purpose and rationale
Factual	• Food system definition • Components of food systems: ○ Actors and activities ○ Drivers and relationships ○ Outputs and impacts ○ Food environments • Overview of disciplines or professions involved	• Foundational knowledge to facilitate an ability to communicate across disciplinary boundaries • Food systems definition is important as infers more than just, for example, value chain • Knowledge of core components and relationships in a food system allows for basic understanding of food system configuration and dynamics • Knowledge of key disciplines attunes the thinker to different stakeholders/actors, alternative ways of viewing the system, and potential intervention pathways and strategies
Conceptual	• General overview of food system challenges/problems (e.g., biodiversity loss, food waste) • General overview of food system goals and values (e.g., nutritional security) • Underlying nature of food system challenges (e.g., emergence, lack of cooperation, time discounting, feedback, cost/benefit sharing)	• Allows stakeholders to diagnose and address challenges • Allows stakeholders to visualise and work toward positive outcomes • Allows stakeholders to understand the underlying patterns that govern or underlie food system issues—providing depth to analysis and intervention approaches
Procedural	• Interdisciplinary working • General communications skills • Understanding and reconciling differences in perspectives • Systems thinking: ○ Distinctions, systems, relationships, and perspectives (DSRP) framework ○ Boundary critique • Intervention approaches (e.g., theory of change, design thinking, stakeholder analysis, various systems methodologies)	• Ability to work with others in the food system who hold different professional and personal knowledge • Ability to communicate effectively and be understood • To help incorporate and address different partial understandings and prioritisations of food system issues • To structure thinking around systems so as to provide a means of creating and critiquing conceptual representations of food systems ○ DSRP is a simple framework that can be used to map system components, relationships, boundaries and perspectives ○ Boundary critique provides a means for understanding and interrogating physical and conceptual boundaries • Intervention approaches take how we see the system and allow us to design appropriate products or processes
Metacognitive	• Awareness of limits and partiality of thinking and cognition in self and others • Reflexivity	• Awareness of one's own thinking is central to understanding our limited partial conceptualisation of systems, and forms the basis for incorporating diverse perspectives into a more accurate amalgamation • Reflexivity is the process by which the individual iteratively reflects on the aspects of self and other in the construction of knowledge

systems analysis and the design of different interventions. **Table 2** presents our proposed key knowledge dimensions and contents that would facilitate this kind of stakeholder engagement and effective food systems learning.

Becoming food systems literate is a process that takes time and commitment in developing a suite of knowledge and skills that will allow effective working with others for a better understanding of food systems and how to intervene in them. Food systems literacy is not only concerned with gaining knowledge of the food system (i.e., the acquisition of facts), it is the acquisition of knowledge that will help to organise, investigate and critique food system facts and values. This is indicated in **Table 2** in which 'factual knowledge' is focused on definitions, and components of food systems as well as knowledge of different disciplines/professions involved in the food system. We focus on the knowledge that would help to organise, investigate and critique food system facts and values.

As well as gaining factual knowledge, there are many different systems thinking methodologies that we argue are useful in better understanding food systems (Checkland, 1981; Midgley, 2000; Kurtz and Snowden, 2003; Ison, 2017; Jackson, 2019). However, we have chosen to focus on two complementary approaches that can be used together to quickly generate systems insights (Cabrera, 2006). The Distinctions, Systems, Relationships and Perspectives (DSRP) framework is an attempt to simplify the diversity and proliferation of systems approaches into four key interconnected concepts that are core to systems thinking and thinking processes in general (Cabrera et al., 2008). The "distinctions" aspect of DSRP is closely linked to the boundary concept, and judgements on boundaries, or in other words, boundary critique is complementary to DSRP (Midgley, 2000). Taken together, DSRP and boundary critique provide a simplified means for better understanding how we as individuals, and others, view the system in question.

There are several implications of this food systems literacy framework for food systems pedagogy. Firstly, food systems literacy is focused on the minimum knowledge required for effective collaboration between different food system actors analysing and intervening in food system issues. In the context of pedagogy, it contains a normative premise that argues that student learning on food systems should have utility and foster their abilities to more skilfully and effectively analyse and intervene in food systems. Secondly, in order to support this outcome, educators should focus not just on food system facts and a variety of food system problems or challenges, such as food waste (factual (F) and conceptual (C) knowledge types), but the procedural (P) and metacognitive (M) knowledges necessary for the critical interrogation and manipulation of these data (See **Table 2**). These P and M knowledge types, such as reflective exercises, communication skills and systems thinking methods, take longer to develop than F and C knowledges, and should be integrated longitudinally throughout the curriculum so that students have multiple opportunities to learn and progressively develop these skills over time. Thirdly, if food system literacy is to be an intended learning outcome, and given that food systems education can never be truly complete, students would benefit from being explicitly taught the framework so that they have a roadmap with which to continue their individual food systems learning journeys themselves, independently, beyond the educational setting.

The "functional minimum" aspect of the food systems literacy allows for the framework to be applied in diverse contexts, while providing educators with the opportunity to elaborate on it as they see fit within their respective institutions. There are undoubtedly a variety of areas that could benefit from further elaboration. For example, there are differences between food systems as they present to different people around the globe with questions pertaining to social justice, environmental impact, access, and cost/benefit sharing among actors. For each context, the factual and conceptual knowledge relevant will be determined by the challenges presenting within the system in question; for example European countries focusing on the negative impacts of livestock food systems and sub-Saharan African countries concerned with rural livelihoods and food and nutrition security. The food systems literacy framework does not specify the totality of what should be taught, rather what is needed to promote effective collaboration between disparate food system actors. Issues such as power and social justice, although not mentioned explicitly, are present within the framework through the processes of understanding and reconciling different perspectives, boundary critique, and developing awareness of limits and partiality of thinking and cognition in self and others. Therefore, the food systems literacy framework provides a foundation for the types and categories of knowledge and skills required for food system actors to collaborate effectively together.

Utilising these four knowledge types effectively can enable us to better generate dynamic learning networks comprising multiple individuals and institutions that represent different parts and experiences found within the food system and develop capacities for collaboration reaching far beyond academic structures to wider food systems actors. In the next section, IFSTAL is used to show an example of food systems literacy in action.

DEVELOPING FOOD SYSTEMS LITERACY—THE EXAMPLE OF THE IFSTAL PROGRAMME

IFSTAL Overview

The IFSTAL programme provides a suitable case study with which to reflect on the application, staff and student experience and outcomes of operationalising a food systems literacy and formulate recommendations for other food system dynamic learning networks. The core principles of IFSTAL include: easy-to-learn independent, facilitated and peer-to-peer learning; interactive and active learning; and an enabling environment. IFSTAL is an extra-curricular, optional programme offered to students with an interest in food systems across five (previously seven) higher education institutions in the United Kingdom that cover different disciplines and areas of the food system and institutional cultures[2]. While inter-university research projects are not uncommon in higher education in the United Kingdom, inter-university teaching across programmes and disciplines are rare, and this makes IFSTAL unique. The programme has been running since 2015 with the aim to generate a dynamic learning community that allows students to gain skills that are needed to work effectively with others in food systems.

IFSTAL's approach to teaching recognises that the complex challenges facing the food system are crosscutting, requiring transdisciplinary approaches to unpack them, and more importantly, tackle them. IFSTAL encourages students to think beyond the methods and problem-understanding perspectives of their own disciplines, to consider real life challenges they might encounter in their research and workplaces (Ajates Gonzalez and Wells, 2016).

Being a voluntary programme for a diverse cohort composed of students at different levels of their postgraduate education, from a wide range of disciplines, and potentially joining at any time of the academic year, the content had to be carefully designed to allow flexibility and maintain participation. The programme offers students different levels of engagement through a diversity of channels: face-to-face events of varying lengths and formats to meet students' different learning styles, content preference and time availability. A blended learning model was considered appropriate, as it has been used previously to promote interdisciplinary teaching and learning within higher education contexts (Cooner, 2011).

IFSTAL includes a flipped classroom model based on online units combined with full-day interactive workshops, webinars, lectures, a network of workplace contacts, a summer school, an alumni network, and internship opportunities. Throughout the year-long programme, opportunities are created for students to work in groups of mixed disciplines and to apply theory to real-life examples often interacting with workplace representatives. Integration of multiple technologies in an interactive teaching and learning environment was promoted to support interdisciplinary learning. A detailed description of the IFSTAL programme, its approach and activities can be found in Reed et al. (2017) and Ingram et al. (2020).

[2]London City University, University of Oxford, University of Reading, University of Warwick, London School of Hygiene and Tropical Medicine (LSHTM), the School of Oriental and African Studies (SOAS) and the Royal Veterinary College (RVC). The University of Reading is now working with EIT Food to deliver food system education through the European Food Systems Education and Training (EFSET) programme to partners across Europe.

Scoring of IFSTAL Instruments

With the aim of determining which instruments were most effective at facilitating learning in the different knowledge types, using the proposed functional food systems literacy framework, we compiled a list of all IFSTAL instruments and scored them against the four levels of knowledge. To generate the list of IFSTAL instruments, all teaching and learning activities used in IFSTAL were collated from reports and project records and then categorised systematically as:

- synchronous or asynchronous
- online or face-to-face
- interactive or independent

For each teaching and learning instrument, a short description of purpose and examples were provided. The list was given to all current and past IFSTAL staff members who were asked to score each teaching instrument on how well it was able to deliver the four knowledge types. For each instrument, 14 scorers gave a score of what they perceived to have been achieved in practice using four categories (0—none; 1—very little; 2—some; 3—a lot). Further, they provided a reflection on the instruments to explain their scores. All scores were collated and the modes identified in order to examine the emerging patterns (**Table 3**). This enabled us to visualise which instruments were perceived to be the most suitable and impactful in delivering the specific type of knowledge intended. In addition, we conducted a narrative analysis on the open text which provided further explanation and reflection.

Scores and Reflections

The aggregated responses and mode of the scores show a consistency of opinion around the effectiveness of meeting all four types of knowledge across the IFSTAL teaching instruments (**Table 3**). In the following paragraphs, some critical patterns are described, reflections shared, caveats and areas for improvements explained. Quotes from the scorers are used to highlight pertinent arguments.

Three instruments emerged as scoring a 3 in all four types of knowledge, namely synchronous face-to-face interactive workshops [J]; synchronous face-to-face interactive project work [M] and synchronous face-to-face interactive offsite experiential learning [P]. These three instruments are experiential, whether onsite or offsite, and build on a foundation of shared factual knowledge taught or learnt earlier in the programme year. The structure of these instruments all involved the layering of knowledge, tools and methods; the opportunity to practise these and build skills; and reflection on the process in interdisciplinary groups. Workshops and group work were tightly planned in managed environments. Overall group size was ∼40 students, with each individual working group limited to 5 or 6 people to facilitate active collaboration between group members. Each group was purposefully created to maximise the diversity of individuals present who had a range of different personal, professional and disciplinary backgrounds. These arrangements allowed everyone to understand their position in the system, and how their respective contributions count toward collaborative problem solving:

> *[M]_R11[3]: Intense group working on a problem that has importance and which all group members are able to provide parts of the solution. Knowledge brought to the table combines disciplinary knowledge which is shared with the group but also shares knowledge of analytical methods which make collaborative problem solving manageable.*

This may have been less evident in the interactive offsite experiential learning (e.g., field trips or volunteering activities), but the reflective activity built into each of these instruments help to embed the metacognitive elements.

The acquisition of factual and conceptual knowledge scored highly in the reflections and it appears from the analysis that these types of knowledge are most successfully accessed through the application of certain teaching instruments which exhibit some bias toward traditional methods such as lectures. Four of the examples scored highly in factual and conceptual knowledge, but low in procedural and metacognitive knowledge. These are: Asynchronous online independent curated content [A]; synchronous face-to-face independent lecture [G]; synchronous online and face-to-face independent lecture [Q] and synchronous online interactive webinar [R]. The use of online units for basic one-way learning is effective as a primer for workshops, where participants can gain a foundational knowledge in the topic of the workshop, therefore being more prepared to access the practical and collaborative learning available. The online units help to give students a common basis upon which to build effective communication:

> *[A]_R11: Online units focus on introducing students to specific language and terminology, definitions and explanations feature high in the material, help[ing] in collaborative work later as shared meanings and understanding can help communication. The units explain key principles of systems thinking and encourage students to recognise that their knowledge is partial and can exist in a disciplinary vacuum. There is a strong steer in the material to encourage students to understand interrelationships in the food system. Asynchronous accessibility enables students to learn in their own time.*

Asynchronous methods support the attainment of higher levels of knowledge, as learning materials can be revisited, or used as part of a structured reflective activity. They also allow students to process learning in their own time and facilitate reflective activity.

Standalone lectures and webinars also involve speakers with specialist knowledge. In some cases, these instruments are coupled with others to bolster the other types of knowledge. For example, asynchronous online independent assessment tools can cover a broader range of knowledge, by having an application and reflective element to the quiz.

Improvements in developing approaches to support procedural and metacognitive knowledge could be achieved by more regularly prompting students to respond to specific questions, for example regarding their perspectives and positionality throughout the unit and encouraging reflection

[3]The letter refers to the instrument as listed in **Table 3** and the Rx to the respondent (R) and its number (1–15).

TABLE 3 | IFSTAL teaching instruments and their contribution to food systems literacy.

Ref	Instrument	The intent of the IFSTAL instruments to deliver learning and achieve type of knowledge—the focus is on the instrument, not the content (example)	Food systems literacy			
			Factual	Conceptual	Procedural	Metacognitive
A	Asynchronous online independent curated content	Knowledge transfer on core food systems related topics concerning food issues and how to analyse and intervene in them (portal units)	3	3	1	2
B	Asynchronous online independent assessment tools	Self-assessment of learning, promoting further reflection and consolidation of learning (portal unit quiz)	3	1 2	1 2	1
C	Asynchronous online independent resources	Independent visual and audio learning of mainly factual concepts; "on demand learning"; access and exposure to topics and perspectives different than those available on enrolled course, gaining wider knowledge on issues concerning food (portal lecture recordings, website)	3	2 3	1	1 2
D	Asynchronous online independent reflexive activity	Developing reflective and critical thinking practice; document personal learning; development of writing skills; career and professional development planning. Student survey feeds back student experience of the course offering possibilities for staff reflection and course adjustments, benefiting future learners (journey document, student survey)	0	0	1	3
E	Asynchronous online independent push communications	Regular communications to prompt action, raise awareness of events, links, roles and signposting for recordings of other asynchronous events. Opportunities for participants to contribute to content (newsletters, blogs)	2	1	0	0
F	Asynchronous online interactive forums, discussion groups	Opportunity to share perspectives, information and discuss topics, meet other participants, alumni and workplace individuals (portal forums, IFSTAL social media)	1 2	1	1	2
G	Synchronous face to face independent lecture	Traditional form of knowledge-sharing from academics with opportunities to enhance learning through asking questions, listening to responses, and peer discussion during the session and in breaks (Summer School lecture, symposium lecture)	3	3	2	2
H	Synchronous face to face independent external speaker	Traditional form of knowledge-sharing from experts with opportunities to enhance learning through asking questions and listening to responses, and peer discussion during the session and in breaks. Can be in lecture or roundtable format (public lecture, meet the workplace)	3	2	2 3	2 3
I	Synchronous face to face independent reflexive activity	Personal reflection on students' position in the food system and learnings from course activities (journey document, personality tests)	1 2	1	2	3
J	Synchronous face to face interactive workshop	Practical application of concepts, theories and methods from online units in collaborative group work with peers to foster skills development (away day workshops, summer school workshops)	3	3	3	3
K	Synchronous face to face interactive discussion	Discussion with course peers, external speakers and faculty on food systems related topics (symposium group discussions)	1	3	3	3
L	Synchronous face to face interactive tutorials	One-to-one tutorials with faculty offering student support on food systems related topics and student development (career coaching)	1	1	3	3
M	Synchronous face to face interactive project work	Interdisciplinary group work to implement and practice food systems analysis and intervention approaches to address real-world problems. Students also required to develop reflexive capacity through active reflection on team dynamics, the task they are addressing, and evaluation of the methods and approach they have chosen to use (summer school projects)	3	3	3	3
N	Synchronous face to face interactive networking	Introductions, team building and networking (social activities, alumni events)	0	1	1	2

(Continued)

TABLE 3 | Continued

Ref	Instrument	The intent of the IFSTAL instruments to deliver learning and achieve type of knowledge—the focus is on the instrument, not the content (example)	Food systems literacy			
			Factual	Conceptual	Procedural	Metacognitive
O	Synchronous face to face interactive reflexive activies	Reflections on use and outcomes of personality assessment tools, and professional development (personality instruments discussions)	0	0	0 / 3	3
P	Synchronous face to face interactive offsite experiential learning	Practice-orientated learning based on exposure to real-life activities and processes in food system businesses/NGOs/organisations/institutions with the opportunity to explore the workings of the system and thereby make a connection between concepts and knowledge, deepen learning and develop all four levels of knowledge (field trips, volunteering)	3	3	3	3
Q	Synchronous online and face to face independent lecture	Knowledge transfer on core food systems related topics, individual receiving of teaching content, exposure to different ways of thinking/cognitive structures/storeys/contexts (from speaker and audience), making connections with one's own knowledge, deepen learning, expand boundaries (launch events, public lecture)	3	3	2	1
R	Synchronous online interactive webinar	Knowledge transfer and/or application of knowledge on a particular topic with the opportunity for interaction between the audience and the presenter in the form of questions and discussions. Low barrier format to asking questions and making contributions, everybody can contribute given they have an internet connexion. Constructive discussions can take place in chat function that help with knowledge exchange and formulation with arguments (webinars)	3	3	1 / 2	2

The scores reflect to what degree the instruments were perceived to achieve the type of knowledge in practice: 0 (purple): none; 1 (yellow): very little; 2 (orange): some; 3 (teal): a lot.

and application of understanding. Also, coupling more formally with the quiz, setting expectations with respect to why the quiz is being performed, and using it as a learning tool rather than as a steppingstone. For lectures, whether synchronous or asynchronous, these could be improved by better use of interactive activities such as breakout rooms, or discussion in pairs. In essence, the focus is the necessary factual knowledge as part of a holistic programme, recognising that this is a minimum to be able to move onto the other types of knowledge.

In identifying what instruments were most effective in delivering procedural and metacognitive knowledge, three examples demonstrate the instruments which scored high for procedural and metacognitive knowledge but low for factual and conceptual knowledge. Examples of instruments used were: Synchronous face-to-face independent reflexive activity [I], Synchronous face-to-face interactive tutorials [L] and Synchronous face-to-face interactive reflexive activities [O]. These activities comprise very specific "built-in" reflective moments detailed in the learning journey which encourage students to apply and develop their ideas as they reflect on their learning. In addition, instruments and teaching points were utilised to weave in reflections on students' personal career paths, skills, and attributes and opportunities to discuss with and seek advice from professionals in the food sector.

A key challenge found in this reflective work is assessing metacognitive knowledge. Consensus amongst the respondents demonstrates that although metacognitive knowledge has high intent built into the learning activity, it is not always possible to determine the actual effectiveness with the mechanisms available. A key reason for this may be due to the activity being carried out privately and there being few opportunities for facilitators to determine the learning outcomes of these activities via, for example, observing participants collaborating or demonstrating their learning through presentations. Building more explicit and directed learning opportunities into these activities so that they focus not only on the action but also explicitly the intent, such as providing instruction on "how to reflect" may make this more effective. Moreover, this could potentially result in an increase in Factual and Conceptual knowledge as students are made more aware of the rationale and methods of these instruments and how they can be used and developed.

> *[O]_R3: 3. This learning method (??)(sic) is not targeting or is not suited for factual, conceptual or procedural learning. If directed well it can help the learner with his/her metacognitive understanding and abilities and therefore this is the area where I expect I would gain the most with this learning method*

Evaluating the qualitative reflective comments from respondents, several commented on the importance of having recursive activities that touch on themes regularly and reinforce key messages and principles multiple times throughout the course. Over time, different types of knowledge are gradually achieved, greatly helped by the interaction from multiple perspectives among students, which shapes and reshapes their thinking and changes their awareness. Throughout the course, there is an increasing realisation that there is a limit to one's own knowledge and the acquisition of further factual knowledge and that the networked approach to solutions is a way to dealing with individual knowledge boundaries:

> *[A]_R10: The basic language and concepts used - what is a system, wicked problems, how components interact, etc. were evidenced through increasing and continual use throughout the course, there was a gradual building of the knowledge that worked in sync and complemented by the interactive workshops.*

A further aspect evidenced in the analysis was the importance attributed to the overall delivery of the IFSTAL programme, the learning environment plays a vital role. This is difficult to observe in the scoring but came out strongly in the comments. Instruments such as Synchronous face-to-face interactive networking [N] and Asynchronous online independent push communications [E] scored relatively low. However, the use of these to create a community and sense of belonging is vitally important to then enable deeper learning via other instruments. This is further observed by adding all the elements of the summer school together [G]+[J]+[M]+[P].

> *[N]_R10. Whilst these were not so important for specific knowledge and skills (and score lower here), the value of developing, being aware of and appreciating the networks built through participation in the programme (and subsequent ideas sharing) was really valuable to interdisciplinary systems work and not to be underestimated (hard to capture with the grading here)*

In addition, the summer school, which is limited to 30 places and requires application based on completed course elements, provided the opportunity to instil a sense of community and ongoing commitment and attendance of the cohort.

> *[N]_R4: This type of opportunity was one of the unique benefits granted to IFSTAL students. IFSTAL facilitated the creation of contacts and networks within and across universities and disciplines.*

The learning environment created by the interdisciplinary team is an important element in facilitating, encouraging and modelling collaboration and group cohesion, despite their diverse academic backgrounds. In addition, by creating multiple types of learning environments which span formal, informal, social and individual learning, the participant is exposed to multiple layers of learning, each building on the other. This scaffolding of skills, knowledge and authentic collaborations and interactions results in more holistic learning and creates the social and mindset foundation of the cohort to go on to attain high levels of knowledge across the scale. In a classic educational structure, the educator is often set outside of social activities that form part of education. However, by dismantling these barriers and generating a learning space for all, more room is made for the social immersion required to achieve metacognitive knowledge.

Skills-based learning also requires practise (P) and students have the opportunity to do this by working on "food system challenges" provided by food sector professionals. Co-creating the curriculum with these actors means that the skills identified by consulting with workplace representatives have a real-life anchor and relevance that supports students' learning (Kember et al., 2008). This, in turn, increases interest in the programme among students, pushing up enrolment at the start of the programme and engagement during it. The use of food system challenges, which are co-created with workplace partners, are particularly powerful in enhancing procedural forms of knowledge. This is because students not only utilise facts and concepts, but must also devise their own ways of working as an interdisciplinary group before these can be applied.

DISCUSSION

In this paper we propose a functional food systems literacy that can achieve more effective collaboration in food systems and illustrate its operationalisation through the example of IFSTAL. The theoretical minimum proposed using four knowledge types can be interpreted as the base level of "common knowledge" that each food system change maker should be cognisant of. In addition to the factual and conceptual knowledge, which are most commonly associated with addressing food system problems, we have stressed the crucial roles of procedural and metacognitive forms of knowledge. Procedural knowledge is important given the complexities of the food system, the wide variety of actors involved, and the wide geographical areas covered. Recognition that there is no "right" way to address food system problems and gaining skills in communication and multi-participatory methods are shown to be valuable attributes in food systems literacy. Moreover, metacognition is essential to recognising that no particular actor can claim to represent the "truth" in tackling intractable food system-related problems and that "solutions" are, at best, generated from a milieu of partial perspectives, understandings and experiences. This might be difficult to understand and put into practice at first, especially for those students based in the positivist natural sciences. Nonetheless, it is important if progress toward finding common solutions between diverse actors is to be achieved.

Due to the holistic, interconnected, interdependent and emergent nature of challenges and issues in food systems, their relationships to other systems such as public health and the biosphere, and the fact that food is a basic need, it is important to develop a concomitant understanding that enables cooperation between different actors. Moreover, because individual institutions and disciplines are partial in their knowledge, they need to be connected to others to make use of collective knowledge and innovation potential. This is also true for educational institutions that cannot cover all aspects of food systems in their curricula. Thus, cross-institutional, connective programmes such as IFSTAL can offer an opportunity to go beyond what is possible at the institutional level and thus capitalise on shared resources and expertise (de Róiste et al., 2015). Further, reflexivity, curiosity, collaboration and empathy are important skills that IFSTAL has sought to cultivate in its food systems change makers. This has been achieved through the inter- and trans-disciplinary nature of the programme;

carefully designed activities (e.g., online basic concepts, mixed group work applying theory to "real world" problems, personal journey logs); and experiential learning (Kolb, 1984) as part of a "scaffolded" curriculum (Vygotsky, 1978). Further, there has been attentive facilitating, employing for example discrepant questioning (Rea-Ramirez et al., 2009) along with training in communication skills. These have been crucial to promote reflection of one's place as a food system actor; the limits of one's knowledge and worldview; understanding the multiple positions and perspectives that different actors in the food system come with; the array of different knowledges and facts there may be to grasp or, as a minimum, acknowledge and be aware of, and flexibility to tackle the complexities and deal with trade-offs and unintended consequences.

IFSTAL, with its external start-up funding and non-credit bearing set-up, has given us the opportunity to experiment with different instruments and gain important insights concerning what works and what does not when trying to enhance different forms of food system knowledge. We have learned that while IFSTAL's extra-curricular structure provides the flexibility needed to run a programme across very different institutions, it also generates a learning environment that is appealing and valuable to the students. Our experience has also taught us the importance of having a strong scaffolding concept that allows cumulative learning over time and the use of concepts to then drive application. We argue that a holistic approach built on sound pedagogy is needed to encapsulate and facilitate the learning of all the types of knowledge required. IFSTAL has shown that the full value of food systems literacy can only be realised by a comprehensive package of teaching and learning—a model that we have replicated successfully at a smaller scale in international 1-week training schools.

IFSTAL has also been informed by adult-learning theory or andragogy principles (Knowles, 1984) to be able to cater to its high number of mature and professional students. When designing activities, the use of the interdisciplinary character of the subject of study fostering multiple perspectives is a key lever to engage students and connect to their prior knowledge and professional experience (Lattuca, 2001). Examples include providing essential vs. recommended reading or activity, to enable students to delve deeper into the subjects more relevant to their interests, time and previous experience. This approach is closely linked to the careful design of the content to make sure it was accessible to students new to certain topics, while appealing enough to students more familiar with the subject at hand. Pedagogically speaking, IFSTAL enables students to become proactive actors in identifying and stretching their own zone of proximal development (Vygotsky, 1978; Kilgore, 1999).

While the individual instruments used in the IFSTAL programme are not new and are relatively common in educational practice, it is when they are utilised simultaneously that they become most effective in delivering a food systems literacy. For example, setting up online learning units can be useful for factual and conceptual knowledge, but will need to be expanded or complemented with other instruments to also cover procedural and metacognitive knowledge. Instruments are not the only aspects to consider here, however, as there are other factors that are also important. In IFSTAL, we use a range of good practises to support the programme, such as consulting regularly with a range of professionals across the sector, receiving letters of support from stakeholders, lining up internships and work-based learning experiences, and workplace workshops to ascertain skills gaps and relevance of the current teaching. These activities help us to generate a programme that is topical and of relevance to the food system workplace; that relevance, in turn, is important for student motivation and the real-life aspect of transdisciplinary learning (Kember et al., 2008). Further, we pay close attention to the calibre and career stage of speakers, striving for a mix of different levels of seniority so that students can make connections between different levels of operation in the workplace.

When we leave behind ideas of classroom, curriculum and hierarchy, and exchange, share, appreciate and create knowledge in dynamic learning networks that make use of collective knowledge, collective expertise, and collective vision, we are bound to make positive changes in our food systems. The food system needs adaptive learning networks that can be shaped and structured by participants according to the needs of the system, and the expertise of the people positioned within it. For this reason, the IFSTAL programme was co-created through consultation with multiple stakeholders including sector professionals and academics from different disciplinary areas. In theory, everybody can contribute to the shaping of such learning networks, but our work in IFSTAL has also shown that effective acquisition of the functional food systems literacy relies on a strong pedagogical approach, the establishment of which requires particular skills including the educational expertise often found in educational establishments, such as universities. These are, in turn, increasingly run with business-like structures where there is little room for extra-curricular activities like IFSTAL that do not earn large sums of money and are not well-suited structurally for credit-bearing programmes. Thus, food systems education faces the dilemma of not having suitable structures in academia to support programmes for food systems literacy and other stakeholders, such as NGOs and industry, not having education as their primary focus.

Ultimately, the individuals that enter the food systems education sphere are aiming to engage with the food system in some way, and the assumption is that this will be more than as a citizen or consumer, and may lead to a career in this complex system. Currently, there is a call for the food system to transform, moving away from the status quo (Webb et al., 2020). For transformation to transpire, it is commonly accepted that trade-offs and disruption will occur and that all actors of the food system will need to be involved, emphasising a collaborative approach and the skills and knowledge needed to achieve this (Kennedy et al., 2021). A functioning food systems literacy allows not only the acquisition of knowledge and reflection, but also the development of the skills and understanding necessary for holistic systemic thinking when addressing complex problems that demand the inclusion of many different perspectives and leadership to drive change. The presence of a functioning food systems literacy with the addition of a global definition of food system leadership allows the development of these skills for global sustainable systems change.

CONCLUSION

Food systems literacy with four key knowledge dimensions (factual, conceptual, procedural and metacognitive), provides the basis for a holistic learning framework that facilitates interdisciplinary and stakeholder engagement for effective food systems learning. It can equip students with the necessary knowledge and skills to participate and act in transformative ways in the food system, and contributes to food system pedagogies that share this goal.

The IFSTAL reflective study shows that it is possible to acquire all four knowledge types by way of instruments which provide experiential learning (synchronous face-to-face interactive workshops, synchronous face-to-face interactive project work and synchronous face-to-face interactive offsite experiential learning). However, their success in students acquiring these four knowledge types relies heavily on the scaffolding method which lays a foundation of shared factual knowledge taught or learnt earlier in the programme year.

We find that built-in and supportive reflective learning is a key component of successful metacognitive learning. Moreover, the learning environment and culture is vital in supporting students to develop skills in listening, collaboration and reflective learning. The mixed, cross-institutional team is able to facilitate learning from different perspectives and fosters an environment of knowledge sharing, where teaching staff can act as guides and provide opportunities for students to articulate and contribute their knowledge and experiences which aids active learning and collaboration.

Collaborating is essential to working on the betterment of food systems. We have reflected on what knowledge and skills are necessary for effective food system collaboration, and what delivery methods can best contribute to learning. Our findings suggest that while it is possible to learn about food systems as an individual, learning how to collaborate with others needs structure and facilitation and consideration of all types of knowledge.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

HP, AdeF, RW, RB, RC, and BH conceptualised the study and wrote the first draft. HP and AdeF gathered co-authors feedback and produced the revised manuscript. All authors completed the scoring and shared their reflections, gave input into the manuscript writing, and approved the final version for submission.

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